



Inertia Dynamometer Auto-Motor-Sports (AMS) Brake Performance Simulation

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This standard is used to assess the high speed fade performance of the foundation brakes during conditions that simulate the Auto-Motor-Sports (AMS) brake fade schedule.

1.2 Applicability. This standard is applicable to all high performance passenger car and light truck front and rear disc corners.

1.3 Remarks. This test determines the brake output and fluid displacement for a brake corner during a simulated AMS2 and AMS3 fade schedule. In addition, apparent friction, apparent piston travel, brake torque variation, holdoff pressure, tapered lining wear and torque hysteresis are evaluated.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW14974

GMW14986

GMW15142

3 Resources

3.1 Facilities.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.1.3 Facilities. Milford Proving Ground (MPG) Brake Component Development (BCD) inertia brake dynamometer or equivalent test facility shall be used.

3.2 Equipment.

3.2.1 An inertia brake dynamometer capable of performing torque control, pressure control, corrected pressure control, ramp, and modulated brake applies.

3.2.2 The following measurements shall be made and digitally recorded at 500 Hz:

3.2.2.1 Dynamometer speed (km/h).

3.2.2.2 Brake apply pressure (kPa).

3.2.2.3 Brake torque (Nm).

3.2.2.4 Brake rotor temperature (°C).

3.2.2.5 Fluid displacement (mm³).

3.3 Test Vehicle/Test Piece. Production representative brake corner hardware shall be used to produce the tailstock assembly.

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November 2014

Page 1 of 16



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3.4 Test Time.

Calendar time:	1 day
Parts preparation time:	2 h
Setup time:	2 h
Test time:	(6 to 8) h

3.5 Test Required Information. Contact test site for any required forms for testing submission. At a minimum, the vehicle program Gross Vehicle Mass (kg), % front mass distribution (%), Wheelbase (mm), Center of gravity height at GVM (mm), the static loaded radius at GVM (mm) and the caliper effective radius (mm) is required for calculation of inertia and apparent friction. (Reference GMW15142 for inertia calculation). In addition, vehicle specific cycle times for both the 100 km/h fade (AMS2) and the 80 % v_{max} (AMS3) test sections will be needed, along with maximum initial brake temperatures based on thermal modeling or actual vehicle data.

3.6 Personnel/Skills. One (1) technician trained for the operation of an inertia brake dynamometer and to perform the instructions described in paragraph 4 is required.

4 Procedure**4.1 Preparation.**

4.1.1 Embedded rotor thermocouple shall be installed per GMW14974.

4.1.2 The assembled corner Lateral Run Out (LRO) shall not exceed 50 μm . The corner LRO shall be measured on the inboard face of the rotor at a radius 10 mm inside of the rotor outer diameter using a dial indicator.

4.2 Conditions.

4.2.1 Environmental Conditions. Cooling air is provided to the brake. Cooling air temperature shall be between (+10 to +30) °C. Cooling air humidity control is not required.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.2.2.1 The dynamometer inertia is adjusted according to GMW15142 (GVM setting).

4.3 Instructions. The test should be performed as described in Table 1.

Table 1: Test Sequence and Instructions

Test Section Name	Initial Braking Speed (km/h)	Cooling Air Speed (km/h)	Number of Stops/ Snubs	Control and Level	Condition
Start-of-Test Brake Lining Measurements	Not applicable	Not applicable	Not applicable	Not applicable.	Record the pre-test brake lining thickness and mass. (GMW14986).
Pre-test Equipment Check					
- Ramp Applies	100	30	5	5000 kPa/s to 13 000 kPa or 1.0G maximum deceleration cutoff limit.	Initial brake temperature +90 °C.
- Modulated Applies	100	30	3	0.5 Hz sinusoidal or ramp apply and release at 6200 kPa/s maximum. If $\leq$ two modulations achieved, reduce the maximum pressure to generate two to three modulations.	Initial brake temperature +90 °C.

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November 2014

Page 2 of 16

Test Section Name	Initial Braking Speed (km/h)	Cooling Air Speed (km/h)	Number of Stops/ Snubs	Control and Level	Condition
Green					
- Cold Ramp Applies	100	30	3	5000 kPa/s to 13 000 kPa or 1.0G maximum deceleration cutoff limit.	Initial brake temperature $\leq +40$ °C.
- Warm Ramp Applies	100	30	5	5000 kPa/s to 13 000 kPa or 1.0G maximum deceleration cutoff limit.	Initial brake temperature $+90$ °C.
- Modulated Applies	100	30	3	0.5 Hz sinusoidal or ramp apply and release at 6200 kPa/s maximum. If $\leq$ two modulations achieved, reduce the maximum pressure to generate two to three modulations.	Initial brake temperature $+90$ °C.
Burnish	80	50	200	Corrected pressure control stop, 3500 kPa/s apply rate to a 0.31G deceleration rate.	Initial temperature $+100$ °C.
Cool Down	10	50	Not applicable	Allow the brake rotor to cool to $+50$ °C.	
Burnished					
- Cold Ramp Applies	100	30	3	5000 kPa/s to 13 000 kPa or 1.0G maximum deceleration cutoff limit.	Initial brake temperature $\leq +40$ °C.
- Warm Ramp Applies	100	30	5	5000 kPa/s to 13 000 kPa or 1.0G maximum deceleration cutoff limit.	Initial brake temperature $+90$ °C.
- Modulated Applies	100	30	3	0.5 Hz sinusoidal or ramp apply and release at 6200 kPa/s maximum. If $\leq$ two modulations achieved, reduce the maximum pressure to generate two to three modulations.	Initial brake temperature $+90$ °C.
Apparent Piston Travel with Pre-conditioning					
- Pre-conditioning	50	30	10	Pistons are retracted prior to pre-conditioning stops. Torque control stops are made at 3500 kPa/s apply rate to 0.20G average deceleration.	Initial brake temperature $+90$ °C.
- Apparent Piston Travel	100	30	2	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 1.0G deceleration cutoff limit (whichever occurs first).	Initial brake temperature $+90$ °C.

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November 2014

Page 3 of 16

Test Section Name	Initial Braking Speed (km/h)	Cooling Air Speed (km/h)	Number of Stops/ Snubs	Control and Level	Condition
100 km/h Fade (AMS2) Simulation	100	20	10	Constant torque stops are made at 7500 kPa/s apply rate, 1.0G deceleration.	Initial brake temperature $\leq +80\text{ }^{\circ}\text{C}$ (1 st stop) and use program specific data to determine the IBT for all other stops. Default is $\leq +550\text{ }^{\circ}\text{C}$ (all other stops) with a cycle time of $\geq 10\text{ s}$ (program specific - depends from engine acceleration)
Recommended practice is to run the AMS2 OR the AMS3 test sequence and then proceed to the Post AMS Fade sections. When specified, the AMS3 section may be run on the same hardware following completion of the Post AMS2 Fade Apparent Piston Travel with Pre-Conditioning section. If this is done, then a second sequence of Post AMS Fade Performance and Post AMS Fade Apparent Piston Travel with Pre-Conditioning should be run following the AMS3 simulation.					
80% $v_{\max}$ Fade (AMS3) Simulation – Heating Snubs	Snubs from 80 % $v_{\max}$ or from the Speed Class described in Appendix B. The final speed is 70 km/h.	20 % of initial braking speed	9	Constant torque stops are made at 7500 kPa/s apply rate, 0.5G deceleration.	Initial brake temperature $\leq +100\text{ }^{\circ}\text{C}$ (1 st stop) and use program specific data to determine the IBT for all other stops. Default is $\leq +600\text{ }^{\circ}\text{C}$ (all other stops) with a cycle time defined by target vehicle capability (assumes WOT acceleration from 70 km/h to speed class target plus braking time). See Appendix B for details on computing test speed and cycle time.
80% $v_{\max}$ Fade (AMS3) Simulation - Performance Stop	Stop from 80 % $v_{\max}$ or from the Speed Class described in Appendix B.	20 % of initial braking speed	1	Constant torque stops are made at 20 000 kPa/s apply rate, 1.0G deceleration with a maximum apply pressure of 16 000 kPa.	Apply is initiated immediately after the specified cycle time, from the initiation of the 9 th heating snub, has elapsed.
Post AMS Fade Performance					
- Ramp Applies	100	30	5	5000 kPa/s to 13 000 kPa or 1.0G maximum deceleration cutoff limit.	Initial brake temperature $+90\text{ }^{\circ}\text{C}$.
- Modulated Applies	100	30	3	0.5 Hz sinusoidal or ramp apply and release at 6200 kPa/s maximum. If $\leq$ two modulations achieved, reduce the maximum pressure to generate two to three modulations.	Initial brake temperature $+90\text{ }^{\circ}\text{C}$.
Post AMS Fade Apparent Piston Travel with Pre-conditioning					
- Pre-conditioning	50	30	10	Pistons are retracted prior to pre-conditioning stops. Torque control stops are made at 3500 kPa/s apply rate to 0.20G average deceleration.	For disc brakes, the caliper piston is physically retracted to create clearance between the piston and the inboard pad. Initial brake temperature $+90\text{ }^{\circ}\text{C}$.

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November 2014

Page 4 of 16

Test Section Name	Initial Braking Speed (km/h)	Cooling Air Speed (km/h)	Number of Stops/ Snubs	Control and Level	Condition
- Apparent Piston Travel	100	30	2	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 1.0G deceleration cutoff limit (whichever occurs first).	Initial brake temperature +90 °C.
Brake Lining Measurements	Not applicable	Not applicable	Not applicable	Not applicable.	Allow brake to cool to room temperature. Record the post test brake lining thickness and mass. (GMW14986).

5 Data

5.1 Calculations.

5.1.1 Digital Signal Processing Rate. All test data is processed at 200 Hz.

5.1.2 Digital Signal Zeroing. Brake pressure and torque channels are digitally zeroed based on 0.5 s of digitally recorded data prior to each brake apply.

5.2 Interpretation of Results.

5.2.1 Graphical Summaries.

5.2.1.1 Ramp Applies. Plot Apparent Friction (output) vs. Hydraulic Apply Pressure between 0 kPa and 12 000 kPa for each ramp apply. Plot green, burnished, and post AMS fade applies in the cold and warm conditions on the same graph. Also plot average apparent friction (output), Initial Brake Temperature (IBT), and maximum brake temperature vs. stop number for each brake apply. Example plots are displayed in Figures A1.

5.2.1.2 Burnish Schedule. Plot average apparent friction (output), IBT, and maximum brake temperature for every 10th brake apply during the burnish schedule. An example plot is displayed in Figure A2.

5.2.1.3 Apparent Piston Travel with Pre-conditioning. Plot the apparent piston travel vs. hydraulic pressure between 0 kPa and 12 000 kPa for each Apparent Piston Travel with Pre-conditioning ramp apply. Plot burnished warm, and post AMS fade warm ramp applies on the same graph. An example plot is displayed in Figure A3.

5.2.1.4 Hysteresis. Plot braking torque vs. apply pressure for the second cycle of each modulated apply. Plot green, burnished post 1st and 2nd fade applies on separate graphs. An example plot is displayed in Figure A4.

5.2.1.5 Apparent Friction. Plot Average Apparent Friction (output) for each of the 10 stops (AMS2), or nine (9) heating snubs and single performance stop (AMS3) in the AMS fade section. An example plot is displayed in Figure A1.

5.2.1.6 Apparent Piston Travel During the AMS Fade Sections. Plot the apparent piston travel vs. stop number, 1 to 10 for the AMS2, or 1 to 9 for the AMS3 heating snubs plus the AMS3 performance stop. Plot apparent piston travel at 500 kPa, 2500 kPa, 5000 kPa, and maximum pressure along with the maximum pressure values on a secondary axis. An example plot displayed in Figure A5.

5.2.1.7 Brake Torque Variation (BTV) During the AMS Fade Sections. Plot the overall peak-to-peak BTV (Nm), maximum peak-to-peak BTV (Nm) and the most significant BTV order vs. stop number, 1 to 10 for the AMS2 fade or 1 to 9 for the AMS3 heating snubs plus the AMS3 performance stop. An example plot is displayed in Figure A6.

5.2.2 Tabular Summaries.

5.2.2.1 Apparent Friction.

5.2.2.1.1 Ramp Applies. Determine the average apparent friction at 500-P_{ho}, 1000-P_{ho}, 5000-P_{ho}, and 12 000-P_{ho} kPa for all stops, excluding the initial stop, at each brake condition (green, burnished, and post AMS fade). Also determine the average apparent friction (output) between 500-P_{ho} and 12 000-P_{ho} kPa at each brake condition. Also determine the average within apply apparent friction (output) range and variation between 500-P_{ho} and 12 000-P_{ho} kPa at each brake condition. Also determine within condition. Example data are displayed in Appendix A, Table A1.

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November 2014

Page 5 of 16