



## Inertia Dynamometer Simulation of Race Track Fade Conditions

### 1 Scope

**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 fade performance of the foundation brakes during fade conditions encountered during testing on the race track. This test is also applicable to police vehicle testing.

**1.2 Foreword.** This test determines the change in brake output and fluid displacement for a brake corner during the fade schedule. In addition, apparent friction, apparent piston travel, brake torque variation, holdoff pressure, tapered lining wear and torque hysteresis are evaluated.

**1.3 Applicability.** All high performance passenger car and high performance light truck front and rear disc brake corners.

### 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** 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 (mm<sup>3</sup>).

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

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**3.4 Test Time.**

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

**3.5 Test Required Information.**

**3.5.1** For testing at MPG, a Test Information Sheet needs to be completed by the test requester and submitted to the test engineer. The form will be supplied by the test engineer. Contact other test sites for any required forms for testing.

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

**4 Procedure****4.1 Preparation.**

**4.1.1** Rotor thermocouple shall be installed per GMW14974.

**4.1.2** The assembled corner lateral run out (LRO) shall not exceed 50  $\mu$ m. 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 °C and +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 to the gross vehicle mass, maximum tire static loaded radius, and 80 % of vehicle energy transferred into the brakes. For front brakes, dynamic loading is set at 0.9G deceleration, and for rear brakes the dynamic loading is set at 0.6G deceleration.

**4.3 Instructions.** The test shall be performed as described in the Table 1.

| Test Section Name                                        | Braking Speed (km/h) | Cooling Speed (km/h) | Number of Stops/ Snubs | Control and Level                                                                                                                                                        | Condition                                                        |
|----------------------------------------------------------|----------------------|----------------------|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|
| <b>Start-of-Test Brake Lining Thickness Measurements</b> | N/A                  | N/A                  | N/A                    | N/A                                                                                                                                                                      | Record the post test brake lining thickness and mass. (GMW14986) |
| <b>Pre-Test Equipment Check</b>                          |                      |                      |                        |                                                                                                                                                                          |                                                                  |
| - ramp applies                                           | 100                  | 70                   | 5                      | 5000 kPa/s apply rate to 13 000 kPa or 1.1G maximum pressure, or a 1.1G deceleration limit (whichever occurs first)                                                      | 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                                 |
| <b>Green</b>                                             |                      |                      |                        |                                                                                                                                                                          |                                                                  |
| - cold ramp applies                                      | 100                  | 70                   | 3                      | 5000 kPa/s apply rate to 13 000 kPa or 1.1G maximum pressure, or a 1.1G deceleration limit (whichever occurs first)                                                      | Initial brake temperature $\leq$ +40 °C                          |

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| Test Section Name                                   | Braking Speed (km/h) | Cooling Speed (km/h) | Number of Stops/ Snubs | Control and Level                                                                                                                                                        | Condition                                                                                                                              |
|-----------------------------------------------------|----------------------|----------------------|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| - warm ramp applies                                 | 100                  | 70                   | 5                      | 5000 kPa/s apply rate to 13 000 kPa or 1.1G maximum pressure, or a 1.1G deceleration limit (whichever occurs first)                                                      | 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                                                                                                       |
| <b>Burnish</b>                                      | 80                   | 40                   | 200                    | Corrected pressure control stop, 3500 kPa/s apply rate to a 0.31G deceleration rate.                                                                                     | Initial brake temperature +100 °C                                                                                                      |
| <b>Cool down</b>                                    | 10                   | 70                   | N/A                    | Allow the brake rotor to cool to +50 °C                                                                                                                                  |                                                                                                                                        |
| <b>Burnished</b>                                    |                      |                      |                        |                                                                                                                                                                          |                                                                                                                                        |
| - cold ramp applies                                 | 100                  | 70                   | 3                      | 5000 kPa/s apply rate to 13 000 kPa or 1.1G maximum pressure, or a 1.1G deceleration limit (whichever occurs first)                                                      | Initial brake temperature $\leq$ +40 °C                                                                                                |
| - warm ramp applies                                 | 100                  | 70                   | 5                      | 5000 kPa/s apply rate to 13 000 kPa or 1.1G maximum pressure, or a 1.1G deceleration limit (whichever occurs first)                                                      | 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                                                                                                       |
| <b>Apparent Piston Travel with Pre-conditioning</b> |                      |                      |                        |                                                                                                                                                                          |                                                                                                                                        |
| - Pre-conditioning                                  | 50                   | 30                   | 10                     | 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 1.1G deceleration limit (whichever occurs first)                                     | Initial brake temperature +90 °C                                                                                                       |
| <b>1st High Performance Fade</b>                    | 160                  | 80 $\pm$ 20          | 10                     | Constant torque stops are made at 7500 kPa/s apply rate, 1.0G deceleration.                                                                                              | Initial brake temperature $\leq$ +100 °C (1 <sup>st</sup> stop) and $\leq$ +700 °C (all other stops) with a cycle time of $\geq$ 15 s. |
| <b>Post 1st High Performance Fade</b>               |                      |                      |                        |                                                                                                                                                                          |                                                                                                                                        |
| - ramp applies                                      | 100                  | 70                   | 5                      | 5000 kPa/s apply rate to 13 000 kPa or 1.1G maximum pressure, or a 1.1G deceleration limit (whichever occurs first)                                                      | 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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| Test Section Name                                      | Braking Speed (km/h) | Cooling Speed (km/h) | Number of Stops/ Snubs | Control and Level                                                                                                                                                   | Condition                                                                                                                                                   |
|--------------------------------------------------------|----------------------|----------------------|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Apparent Piston Travel with Pre-conditioning</b>    |                      |                      |                        |                                                                                                                                                                     |                                                                                                                                                             |
| - Pre-conditioning                                     | 50                   | 30                   | 10                     | 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.<br>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 1.1G deceleration limit (whichever occurs first)                                | Initial brake temperature +90 °C                                                                                                                            |
| <b>2<sup>nd</sup> High Performance Fade</b>            | 160                  | 80 ± 20              | 20                     | Constant torque stops are made at 7500 kPa/s apply rate, 1.0G deceleration.                                                                                         | Initial brake temperature ≤ +100 °C (1 <sup>st</sup> stop) and ≤ +700 °C (all other stops) with a cycle time of ≥ 15 s.                                     |
| <b>Post 2<sup>nd</sup> High Performance Fade</b>       |                      |                      |                        |                                                                                                                                                                     |                                                                                                                                                             |
| - ramp applies                                         | 100                  | 70                   | 5                      | 5000 kPa/s apply rate to 13 000 kPa or 1.1G maximum pressure, or a 1.1G deceleration limit (whichever occurs first)                                                 | 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 ≤ two modulations achieved, reduce the maximum pressure to generate two to three modulations. | Initial brake temperature +90 °C                                                                                                                            |
| <b>Apparent Piston Travel with Pre-conditioning</b>    |                      |                      |                        |                                                                                                                                                                     |                                                                                                                                                             |
| - Pre-conditioning                                     | 50                   | 30                   | 10                     | 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 1.1G deceleration limit (whichever occurs first)                                | Initial brake temperature +90 °C                                                                                                                            |
| <b>End-of-Test Brake Lining Thickness Measurements</b> |                      |                      |                        |                                                                                                                                                                     |                                                                                                                                                             |
|                                                        | N/A                  | N/A                  | N/A                    | N/A                                                                                                                                                                 | 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.

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## 5.2 Interpretation of Results.

### 5.2.1 Graphical Summaries.

**5.2.1.1 Ramp Applies.** Plot Apparent Friction (output) versus Hydraulic Apply Pressure between 0 and 12 000 kPa for each ramp apply. Plot green, burnished, and post 1<sup>st</sup> and 2<sup>nd</sup> fade applies in the cold and warm conditions on the same graph. See Figure A1 for example graph. Also plot average apparent friction (output), initial brake temperature (IBT), and maximum brake temperature versus stop number for each brake ramp apply. See Figure A2 for example graph.

**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. These data for the burnish shall be included in the graph from paragraph 5.2.1.1 as shown in Figure A2.

**5.2.1.3 Apparent Piston Travel with Pre-conditioning.** Plot the apparent piston travel versus hydraulic pressure between 0 and 12 000 kPa for each Apparent Piston Travel with Pre-conditioning ramp apply. Plot burnished warm, and post 1<sup>st</sup> and 2<sup>nd</sup> fade warm ramp applies on the same graph. See Figure A3 for example graph.

**5.2.1.4 Hysteresis.** Plot braking torque versus apply pressure for the second cycle of each modulated apply. Plot green, burnished post 1<sup>st</sup> and 2<sup>nd</sup> fade applies on separate graphs. See Figure A4 for example graph.

**5.2.1.5 Apparent Friction.** Plot Average Apparent Friction (output) for each of the 10 and 20 stops during the fade sections. See Figure A1 for example graph.

**5.2.1.6 Apparent Piston Travel During the Fade Sections.** Plot the apparent piston travel versus stop number, 1 to 10 for the first fade and 1 to 20 for the second fade. Plot apparent piston travel at 500 kPa, 2500 kPa, 5000 kPa, and maximum pressure along with the maximum pressure values on a secondary axis. See Figure A5 for example graph.

**5.2.1.7 Brake Torque Variation (BTV) During the Fade Sections.** Plot the overall peak-to-peak BTV (N-m), maximum peak-to-peak BTV (N-m) and the most significant BTV order versus stop number, 1 to 10 for the first fade and 1 to 20 for the second fade. See Figure A6 for example graph.

### 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 1st and 2nd 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 apparent friction (output) range and variation. Example data are displayed in Table A1.

**5.2.2.1.2 Burnish Average Apparent Friction Schedule.** Determine average apparent friction (output), within apply apparent friction (output) range, IBT, maximum brake temperature, and percent peak-to-peak BTV for every 10<sup>th</sup> stop. Report the mean average apparent friction (output), average within apply apparent friction (output) range, within condition average apparent friction (output) range, mean IBT, mean maximum brake temperature, mean Overall peak-to-peak percent BTV, and mean maximum peak-to-peak percent BTV. Example data are displayed in Table A2.

**5.2.2.1.3 Fade Average Apparent Friction Schedule.** Determine average apparent friction (output), within apply apparent friction (output) range, IBT, maximum brake temperature, and percent peak-to-peak Brake Torque Variation (BTV) for every stop. Report the mean average apparent friction (output), percent change in average apparent friction from the end of burnish average, average within apply apparent friction (output) range, within condition average apparent friction (output) range, mean IBT, mean maximum brake temperature, mean Overall peak-to-peak percent BTV, and mean maximum peak-to-peak percent BTV for each fade section. Also report, for the last stop of each fade section, the apparent friction as a percent of the apparent friction of the first stop of that section. Example data are displayed in Table A2.

**5.2.2.2 Apparent Piston Travel with Pre-conditioning.** Report average apparent piston travel at 500, 1000, 5000, and 12 000 kPa using each of the first and second ramp applies of Apparent Piston Travel with Pre-conditioning test in the burnished and post 1<sup>st</sup> and 2<sup>nd</sup> fade condition. Example data are displayed in Tables A3 thru A5.

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