18-GTRBR-05

MOTORCYCLE BRAKE SYSTEMS gtr

- TECHNICAL REPORT -

1. Introduction

During the 58th session of the Working Party on Brakes and Running Gear (GRRF), a formal proposal for a global technical regulation (gtr) concerning Motorcycle Brake Systems was presented, along with the accompanying "Statement of Technical Rationale and Justification". This Technical Report serves to provide additional detail regarding the technical rationale for the respective requirements within the proposed gtr.

2. General

The proposed gtr on Motorcycle Brake Systems consists of a compilation of the most stringent and relevant tests procedures and performance requirements from current standards and regulations. The informal group reviewed the existing requirements on various levels, including estimating the relative severity of the requirements as well as considering the original rationales and appropriateness of the tests to modern conditions and technologies.

As a result of the comparison process, the selected performance requirements within the gtr are mainly developed from the UN/ECE Regulation No. 78 (ECE), the United States Federal Motor Vehicle Safety Standard FMVSS 122 (FMVSS) and the Japanese Safety Standard JSS 12-61 (JSS).

The selected format for the gtr text is based on the *Alternative format for regulations with many different requirements and test procedures*, as described in TRANS/WP.29/883, and was chosen to facilitate quick reference and understanding of the requirements. While developing the gtr, the informal group endeavoured to clarify discrepancies in the referenced tests, to assure a better understanding and the consistency in the way the respective tests are conducted.

The gtr is comprised of several fundamental tests, each with their respective performance requirements. These tests are listed below, along with the national regulation on which they are based:

1. dry stop test with each brake control operated separately (ECE R78 / JSS 12-61)
2. dry stop test with all brake controls activated simultaneously (FMVSS 122)
3. high speed test (JSS 12-61)
4. wet brake test (ECE R78 / JSS 12-61)
5. heat fade test (ECE R78 / JSS 12-61)
6. parking brake test (ECE R78 / JSS 12-61)
7. ABS tests (ECE R78 / JSS 12-61)
8. partial failure test – split service brake systems (FMVSS 122)
9. servo failure test (New)

2.1 gtr Test Parameters

To maintain the integrity of the referenced test, the parameters selected for each performance test are almost entirely as specified in the respective national regulation on which the test was based. Although the national regulations share many similarities, there are several differences in the terminology and their definitions.

The informal group sought to streamline the gtr with the use of common terminology and definitions. Whenever possible, these were obtained from the document *Special Resolution No. 1 (S.R.1) concerning the common definitions of vehicle categories, masses and dimensions.* Alternately, terminology and definitions were adopted from recognized sources such as the International Organization for Standardization (ISO), the Society of Automotive Engineers (SAE) and others.

Terminology borrowed from S.R.1 includes "mass in running order" and "gross vehicle mass". Mass in running order is defined as the sum of the unladen vehicle mass and the driver's mass, which are further defined in S.R.1. Gross vehicle mass is the maximum mass of the fully laden vehicle as declared by the manufacturer.

Definitions for existing terminology were revised or updated where necessary, such as for antilock brake system (ABS), vehicle maximum speed (Vmax) and peak friction coefficient (PFC). New terminology was also introduced when required. One such example deals with defining the motorcycle test mass: In this case, the terminology "lightly-loaded vehicle" (FMVSS 122), "unladen vehicle" (ECE R78) and "unloaded" (JSS 12-61) essentially share the same meaning, which is the sum of the "mass in running order" and all of the test equipment, including outriggers, if so equipped. In an effort to streamline the gtr, the Contracting Parties agreed to the term "lightly-loaded vehicle mass", as this does not conflict with existing definitions in S.R.1, nor other recognized sources.

2.2 Measurement of Deceleration and Stopping Distance

The ECE and JSS test methods allow brake performance to be measured through the use of either deceleration or stopping distance, whereas the FMVSS evaluates performance through stopping distance only.

The ECE and JSS measure deceleration slightly differently. The ECE utilizes the mean fully developed deceleration (MFDD), which is the vehicle deceleration calculated between 10 and 80 percent of the vehicle initial speed. The JSS uses the vehicle mean saturated deceleration (MSD), which can be obtained several ways depending on the instrumentation employed. Both methods measure a steady state deceleration rate, by excluding the transient period during the initial stage of the brake application and the very end of the braking maneuver. Nevertheless, the different methods can provide slightly different results. In order to maintain consistency in the results, the MFDD was adopted to measure braking deceleration performance, where required.

The FMVSS stopping distance is based on an average deceleration rate for the entire stopping maneuver, from the moment a force is applied to the brake control to the moment the vehicle comes to a complete stop. The ECE and JSS stopping distance are based on the MFDD (or MSD) and also account for a system reaction time.

To maintain the integrity of the referenced test, the performance requirements are almost entirely as specified in the respective national regulation on which the test was based.

2.3 Corrected Measured Distance

Deceleration or stopping distance performance requirements are related to a specific initial test speed. While professional test riders can approach this initial test speed, it is unlikely that the test will be started at the exact speed specified.

A braking distance correction factor is specified in JSS 12-61 to compensate for the difference between the specified test speed and the actual speed where the brakes were applied. Although not specified in the regulations, the USA and Canada utilise the correction factor specified in SAE J299 – *Stopping Distance Test Procedure*. Each method was evaluated, including the distance correction factor for motorcycle brake testing found in ISO 8710:1995, *Motorcycles – Brakes and braking devices - tests and measurement methods*.

The SAE offers the most basic method for estimating the corrected distance, and as a result the method is applicable to a speed tolerance of ± 3.2 km/h (± 2 mph). The ISO and JSS methods are based on the same principles, but also take into consideration the system reaction time. These methods are applicable to a wider speed tolerance of ± 5 km/h. However, a small error in handling the system reaction time is apparent in the ISO equation, which results in higher than expected corrected values.

Based on this analysis, the informal group agreed that the correction factor equation within JSS 12-61 was the most appropriate for the gtr.

2.4 Test Surface – Peak Friction Coefficient

Peak Friction Coefficient (PFC) is a measure of the coefficient of friction of the test surface and is an important parameter for assessing brake performance of a vehicle. FMVSS 122 currently requires that the road tests be conducted on an 8-foot-wide level roadway with a skid number of 81. The road test surface conditions specified do not apply to the burnish procedure. For parking brake tests, the test surface is clean, dry, smooth Portland concrete cement. ECE R78 and JSS 12-61 do not specify the coefficient of friction for the test surface but describe the test surface as level, dry, and affording good adhesion. Test lane width is also specified as 2.5 m (8 feet).

ECE R78 and JSS 12-61 rely on a subjective description of the test surface coefficient of friction. Under the self-certification system currently used by Contracting Parties such as the United States and Canada, the test surface is defined, objectively, to reduce variability of the results when testing motorcycle brake systems for compliance to their national standard. Given that the test surface coefficient of friction affects the attainable braking performance limit of a vehicle, specifying a value in the gtr will prevent unreasonable variability in the test results, which may be due to test surface variability and not due to the motorcycle's actual braking ability.

The Contracting Parties agreed to define the test surface using PFC instead of skid number as currently specified in FMVSS 122. The PFC is a measure of tire-to-road surface friction based on the maximum deceleration of a rolling tire whereas skid number is a measure of

the tire-to-road surface friction based on a skidding tire. Therefore, PFC is a more relevant surface friction measurement for non-locked-wheel tests, as those included in this gtr. The Contracting Parties agreed that specifying a test surface with a nominal PFC 0.9 is an appropriate and objective value for the dry test surface for the motorcycle braking tests.

The United States Federal motor vehicle safety standards that currently use PFC specify that the road test surface must have a PFC of 0.9 when measured using American Society for Testing and Materials (ASTM) E1136 standard reference test tire, in accordance with ASTM Method E1337-90, at a speed of 40 mph without water delivery. However, since the ASTM test method is not widely used outside of North America and there is no common test method used in Europe or Japan, the Contracting Parties agreed to specify the PFC for the test surface but to leave it to the national regulation to determine the test method that should be used to measure the PFC.

2.5 Test Sequence

There is no specified test order in the ECE R78. Similarly, the JSS indicates that tests can be done in any order, with the exception that the fade test be conducted last. The FMVSS requires a specific test sequence, ending with the wet brake test.

There was general agreement that the fade test was most likely to affect the condition of the motorcycle brakes, which could affect brake performance in subsequent tests. For this reason, the FMVSS requires that a re-burnishing be conducted after the fade test, to refresh the brake components. In order to eliminate the need for re-burnishing, the informal group agreed that the fade test be the last of the motorcycle brake performance tests.

Unlike in the ECE R78 and JSS 12-61, the FMVSS requires that all tests be conducted in a specific sequence, for demonstrating conformity to the regulation. The purpose is to minimize the variability of test results through consistency in the condition of the brakes throughout the tests, and consistency in the way the brakes are evaluated. The informal group agreed to adopt a specific sequence in which the tests are conducted.

2.6 Brake Controls - Force Application Location

Controls for the application of the brakes can include hand and foot operated control levers.

The national standards and regulations have slight differences as to the amount of input force allowed by the test rider, and in the case of a hand operated control lever, there is also a discrepancy as to the location of application of the input force. One consistent element is the location and direction of application of the input force to the foot operated lever (i.e. pedal). The respective input forces are noted in the following table.

Brake Actuation Forces

Regulation	Pedal Force, F_P (N)	Lever Force, F_L (N)
FMVSS 122	$25 < F_P < 400$	$10 < F_L < 245$
ECE R78 / JSS 12-61	$F_P < 350$	$F_L < 200$

The specified amount of input force remains as per the respective national regulation on which the individual test is based. In an effort to minimize confusion, the respective figures are listed for each test within the gtr.

With respect to the location of the input force on the control lever, the ECE and JSS place the input force 50 mm from the end of the lever, while the FMVSS locates the input force 30 mm from the of end of the handle bar grip. On most models (but not all), the control lever typically extends slightly beyond the handle bar grip, such that the control forces are almost at the same location regardless of the method followed. Depending on the regulation, however, it is not entirely clear whether this measurement should be taken along the length of the control lever or parallel to the handle bar grip; or, how to measure with a curved or angled control lever. Some interpretation is required.

The informal group agreed that none of the three national regulations are clear enough with respect to measuring the test location of the input force on the control lever. In an effort to define a common practice, a revised description for the location of the input force on the control lever and its direction of application was drafted, based on the document ISO 8710:1995.

2.7 Brake Temperature Measurement

Test procedures typically require the measurement of the initial brake temperature. FMVSS 122 includes a specification for plug type thermocouples, including detailed schematics addressing its installation on disc or drum type brakes. Although the ECE R78 and JSS 12-61 also require brake temperature measurement, neither makes reference to specific measurement equipment or installation methods. In informal meetings, the International Motorcycle Manufacturers Association (IMMA) and the Japan Automobile Standards Internationalization Center (JASIC) requested that rubbing thermocouples should also be considered.

The plug type thermocouples used by the NHTSA and Transport Canada are installed in the brake friction material, 0.04 inches (1 mm) below the contact surface between the friction material and the disc or drum. Issues raised with this method include; the effects of different friction material composition (i.e. different heat transfer rates) on temperature readings, and the thermocouple installation that requires a modification of the actual brake component.

Rubbing thermocouples, also referenced as contact thermocouples, are in direct contact with the disc or drum surface, and thus do not require dismantling or modifying any of the brake components. The thermocouple is spring loaded to maintain good contact with the surface being measured. Although this type of thermocouple can provide a quicker response to temperature change, there are limitations. Being spring loaded, the thermocouple has self-heating characteristics while rubbing against the measured surface, up to 15°C at 50 km/h per ISP/PAS 12158:2002 *Road vehicles – Braking systems – Temperature measuring methods*. Also, such thermocouples cannot be used or cannot be

properly located on certain discs with ventilation characteristics (whether groves or cross-drilled holes).

After several discussions, including one with type approval experts from TUV SUD, the informal group accepted the plug type thermocouple for measuring brake temperature. Because of lack of experience with the use of rubbing thermocouples for measuring brake temperature in North America, the informal group agreed that this method would be listed in the gtr, with the qualification that Contracting Parties may specify which temperature measurement method would be accepted.

2.8 Burnishing

The burnish procedure serves as a conditioning of the foundation brake components to permit the braking system to achieve its full capability. Burnishing typically matches the friction components to one-another and results in more stable and repeatable stops during testing. FMVSS 122 includes a burnish procedure, whereas ECE R78 and JSS 12-61 do not include any burnish procedure. Under the ECE and the JSS regulations, the motorcycle is generally presented for type approval compliance testing in a burnished condition, using a procedure determined by the motorcycle manufacturer.

All Federal motor vehicle safety standards for brake systems (FMVSS 105, 121, 122, and 135) currently include a burnish procedure. The burnish procedure in FMVSS 122 requires 200 stops with both brakes applied, simultaneously, decelerating from a speed of 30 mph at 12 fps^2 with an initial brake temperature (IBT) between 55^{o}C and 65^{o}C (130^{o}F and 150^{o}F).

The Contracting Parties agreed to specify a burnish procedure in the proposed Motorcycle Brakes gtr, which may be performed by the manufacturer. The procedure is based on FMVSS 122 but also includes some aspects of procedures currently used by motorcycle manufacturers in preparation for ECE/ JSS type approval testing. For example, the initial speed proposed for the procedure has been changed to 50 km/h to round-off the metric equivalent, which is a slight increase from 30 mph (48 km/h) as required in FMVSS 122. Instead of making complete stops, the proposal also includes braking the motorcycle at the specified deceleration down to a speed between 5 km/h and 10 km/h, after which the motorcycle may be accelerated to the initial test speed for the next stop in the burnish procedure. The primary reason for not braking the motorcycle to a complete stop is to expedite the burnish procedure. The increased motorcycle kinetic energy resulting from the small initial speed increase of 2 km/h is likely to offset any reduction in kinetic energy from not braking the motorcycle to a complete stop.

The Contracting Parties agreed to propose burnishing the brakes separately since this would result in a more complete burnish for both front and rear brakes, as compared with the current FMVSS method of using both brakes simultaneously. Hence, the proposed gtr requires each brake to be burnished for 100 decelerations.

Finally, the Contracting Parties agreed to propose a change in the IBT from a range of 55^{o}C to 65^{o}C as specified in FMVSS 122 to an IBT less than or equal to 100^{o}C. The primary reasons for proposing a change in the IBT are to accommodate the higher operational temperatures of motorcycles equipped with disc brakes and to reduce cooling time between stops. In addition, the Contracting Parties agreed that a narrow IBT range is

important for good repeatability during the performance tests but not as critical for the burnish procedure.

In summary, the Contracting Parties agreed to include in the proposed gtr the following burnish procedure, which is primarily developed from the FMVSS 122 burnish procedure:

- Vehicle conditions. a) Vehicle load: lightly-loaded; b) Transmission position: In neutral;
- IBT: $\leq 100^{o}C$ ($212^{o}F$)
- Test speed
  - Initial speed: 50 km/h
  - Final speed: 5 to 10 km/h
- Deceleration
  - Front wheel braking only: 3.0-3.5 m/s^2
  - Rear wheel braking only: 1.5-2.0 m/s^2
  - Combined brake system or split service brake system: 3.5-4.0 m/s^2
- Number of decelerations: 100 for each brake control

After burnishing, if appropriate, the brakes are adjusted in accordance with the manufacturer's specifications.

3. Specific Performance Tests

3.1 Dry Stop Test – Single brake control activated

The purpose of a dry stop test is to ensure a minimum level of motorcycle braking performance on a dry road surface. Each of the major national motorcycle brake regulations, ECE R78, FMVSS 122, and JSS12-61, includes such a test in its requirements.

The ECE and the JSS test procedures and performance requirements are similar but the FMVSS test is quite different. The ECE/JSS regulations require that the motorcycle be evaluated in the laden condition with each brake control applied separately, at test speeds of 40 km/h or 60 km/h depending on the vehicle category.

The main FMVSS performance requirements are for tests in the lightly-loaded condition and all brake controls applied simultaneously. The FMVSS requires testing from 30 mph (48.3 km/h), 60 mph (96.6 km/h) and 80 mph (128.8 km/h). Consistent with being tested in the lightly-loaded condition and with both brakes applied together, the FMVSS deceleration requirements are higher than in the ECE/JSS. The FMVSS and the ECE/JSS tests are conducted with the engine disconnected, which means that only the foundation brake performance is measured and engine braking is not a factor.

The IMMA severity comparison study concluded that the ECE/JSS test was marginally more stringent whereas the NHTSA/TC report indicated that the FMVSS was marginally more stringent. However, neither study demonstrated a significant difference in severity between these national regulations.

The primary advantage of the ECE/JSS requirement is that each brake control is tested separately, which ensures that each independent brake system meets specific performance criteria. Although the FMVSS also requires that independent service brake systems be

evaluated separately, this test is conducted with the brakes in the pre-burnished condition, hence, requiring a lower level of performance. In the main FMVSS dry stop test with both brake controls applied simultaneously, the test rider has to judge how to proportion the amount of brake force to the front and rear brakes. This may give unrepeatable test results, or may allow the test rider to compensate for a "weak" brake. Therefore, the informal group decided to include the ECE test in the gtr.

In order to address the fact that the ECE dry stop test is at a lower speed than the FMVSS and that it specifies a separate test for each brake control, the informal group agreed to include an additional, FMVSS based, dry stop test in the gtr. The Dry Stop Test – All service brake controls activated, is a test at 100 km/h with the vehicle in the lightly-loaded condition, thus at an intermediate speed between this test and the High Speed test.

In summary, the Contracting Parties agreed to include in the proposed gtr the following Dry Stop Test – single brake control activated test parameters, which are developed from ECE R78:

- Applicability: all vehicle categories
- Vehicle conditions. a) Vehicle load: gross vehicle mass, but for vehicles with CBS, also tested in the lightly-loaded condition; b) Transmission position: engine disconnected;
- IBT: $\geq 55^{o}$C and $\leq 100^{o}$C
- Test speed:
  a) Category 3-1 & 3-2 vehicles: 40 km/h or 0.9 Vmax, whichever is lower
  b) Category 3-3, 3-4 & 3-5 vehicles: 60 km/h or 0.9 Vmax, whichever is lower
- Number of stops: maximum 6 stops
- Separate test for each brake control
- Brake application force: for hand lever $\leq$ 200 N; for foot pedal $\leq$ 350 N for 3-3 & 3-5, $\leq$ 500 N for 3-4.
- Performance Requirement: see table below

Category	STOPPING DISTANCE (S) (Where V is the specified test speed in km/h and S is the required stopping distance in metres)	**OR**	MFDD
Single front brakes only:			
3-1	$S \leq 0.1\ V + V^2/90$		$\geq 3.4 m/s^2$
3-2	$S \leq 0.1\ V + V^2/70$		$\geq 2.7 m/s^2$
3-3	$S \leq 0.1\ V + V^2/115$		$\geq 4.4 m/s^2$
3-4	$S \leq 0.1\ V + V^2/115$		$\geq 4.4 m/s^2$
3-5	$S \leq 0.1\ V + V^2/95$		$\geq 3.6 m/s^2$
Single rear brakes only			
3-1	$S \leq 0.1\ V + V^2/70$		$\geq 2.7\ m/s^2$
3-2	$S \leq 0.1\ V + V^2/70$		$\geq 2.7 m/s^2$
3-3	$S \leq 0.1\ V + V^2/75$		$\geq 2.9 m/s^2$
3-4	$S \leq 0.1\ V + V^2/75$		$\geq 2.9 m/s^2$
3-5	$S \leq 0.1\ V + V^2/95$		$\geq 3.6 m/s^2$
Vehicles with CBS or Split Service Brake Systems			
3-1 + 3-2	$S \leq 0.1\ V + V^2/115$		$\geq 4.4 m/s^2$
3-3	$S \leq 0.1\ V + V^2/132$		$\geq 5.1 m/s^2$
3-4	$S \leq 0.1\ V + V^2/130$		$\geq 5.0 m/s^2$

3-5	$S \leq 0.1\ V + V^2/140$		$\geq 5.4 m/s^2$
Vehicles with CBS – secondary brake only			
ALL	$S \leq 0.1\ V + V^2/65$		$\geq 2.5\ m/s^2$

3.2 Dry Stop Test – all service brake controls activated

The purpose of the dry stop test with all service brake controls activated is to evaluate the full braking performance of the motorcycle from a speed of 100 km/h with both front and rear brakes applied simultaneously.

The current requirements in FMVSS 122 include a stopping distance test from 60 mph (96 km/h) with all brake controls applied simultaneously and with the motorcycle in the lightly-loaded condition. The stopping distance requirement from this speed is 185 feet, which is equivalent to an average deceleration of 6.4 m/s^2 over the entire stop. The current requirements in ECE R78 and JSS12-61 do not include a performance test from such a speed.

The Contracting Parties agreed to include in the proposed gtr a requirement based on the FMVSS test noted above. These test parameters are relevant since they represent the typical operating condition of a motorcycle with a single rider traveling at highway speeds. In addition, testing in the lightly loaded condition with a full brake application helps to evaluate vehicle stability during braking. In the proposed gtr, this test would apply to Category 3-3, 3-4, and 3-5 vehicles, but not to Category 3-1 and 3-2 vehicles, which are vehicles with a maximum speed less than 50 km/h. Given this speed restriction, Category 3-1 and 3-2 vehicles will use a test speed based on 90% Vmax, or almost at the same exact speed as the 40 km/h test speed for the dry stop test – single brake control activated. As the level of stringency was deemed comparable for both dry stop tests, the Contracting Parties agreed that a dry stop test with all the service brake controls activated would be redundant for these vehicles in the proposed gtr.

The brake application force specified is less than or equal to 245 N for hand lever and less than or equal to 400 N for foot pedal. Since this proposed requirement is being adopted from FMVSS 122 with a slight increase in speed to 100 km/h from 96 km/h, the Contracting Parties agreed to retain the corresponding lever/pedal efforts to maintain the stringency of the original test. If this dry stop requirement were adopted with the lever efforts of the ECE and JSS Standards (200N/350N for the hand lever/foot pedal), it would represent an increase in stringency of the requirement since it would effectively be proposing that the current FMVSS requirements be met with lower application forces.

The correlation between stopping distance and mean fully developed deceleration (mfdd) was not considered when establishing the original FMVSS performance requirements. The stopping distance requirement from 100 km/h (185 feet) is equivalent to an average deceleration of 6.4 m/s^2 over the entire stop, whereas the equivalent mfdd is 7.6 m/s^2. Since the equivalent mfdd is considered unreasonably high and in keeping with the original requirements on which this test is based, the Contracting Parties agreed to maintain the performance requirement for this dry stop test in terms of stopping distance only.

In summary, the Contracting Parties agreed to include in the proposed gtr, the following parameters for the Dry Stop Test – All service brake controls activated, which are developed from the FMVSS 122:

- Applicability: Category 3-3, 3-4 and 3-5 vehicles
- Vehicle conditions. Vehicle load: lightly-loaded; b) Transmission position: In neutral
- IBT: $\geq 55^{o}C$ and $\leq 100^{o}C$
- Test speed: the lesser of 100 km/h or 0.9 of the vehicle's maximum speed (V_{max}), whichever is lower
- Number of stops: maximum 6 stops
- Brake application force: all service brake controls applied simultaneously with a force $\leq$ 245 N for hand lever; $\leq$ 400 N for foot pedal
- Performance Requirement: Stopping distance, $S \leq 0.1V + 0.0051V^2$

3.3 High Speed Test

The purpose of the high speed test is to evaluate the full braking performance of the motorcycle from a high speed and with both front and rear brakes applied simultaneously. Each of the major national motorcycle brake regulations, ECE R78, FMVSS 122, and JSS12-61, includes a high speed test in its requirements.

The ECE and the JSS tests are similar and are performed from a speed of 160 km/h or 0.8 of the vehicle's maximum speed (V_{max}), whichever is less. The ECE test requires that vehicle braking performance and behaviour be recorded, however, does not have specific performance requirements. The performance required by JSS includes achieving a mean fully developed deceleration (mfdd) of at least 5.8 m/s^2 or coming to a stop prior to the equivalent braking distance. The high speed effectiveness test in FMVSS 122 is conducted from a test speed that is based on the speed capability of the motorcycle but does not exceed 193.2 km/h (120 mph). When tested from this maximum speed of 120 mph, the required stopping distance performance in the FMVSS is 861 feet (262.5 meters), equivalent to an average deceleration of 5.5 m/s^2. Based on these figures, the FMVSS test appears to be more severe due to a higher test speed whereas the JSS 12-61 appears to be more stringent based on a deceleration requirement.

The test conditions for the FMVSS and the ECE/JSS high speed tests are quite similar, including the motorcycle test mass and the simultaneous application of both brakes. The main difference between test parameters, besides the difference in the vehicle test speeds, is that the FMVSS test is conducted with the engine disconnected (clutch disengaged), whereas the ECE/JSS test is conducted with the engine connected (clutch engaged). It is understood that with a connected engine, the subsequent engine braking can assist in the deceleration of the motorcycle. This effect is reduced to a minimum by placing the transmission in the highest gear during the braking manoeuvre. The benefit of having the engine connected is the effect of stabilizing the motorcycle while braking from such a high speed and simulating normal riding behavior.

Based on the Transport Canada Test Report "Review of Motorcycle Brake Standards", the Contracting Parties believe that 100 mph (160 km/h) or 0.8 Vmax is adequate for a high speed effectiveness test since the benefits of testing from higher speeds do not warrant the potential hazard to which the rider is exposed. The Contracting Parties agree that the test speed should be limited to 160 km/h to address test facility limitations and safety concerns.

The FMVSS and JSS performance requirements are very similar from a maximum speed of 160 km/h. The equivalent average deceleration in FMVSS 122 is 5.5 m/s^2 from 100 mph compared with the JSS 12-61 of 5.8 m/s^2 from 160 km/h. In actual testing, the performance differences for the high speed tests were too small to clearly identify one testing procedure as being more stringent than the other.

Finally, the Contracting Parties also agreed to require that the high speed test be conducted with the motorcycle transmission in gear, per JSS 12-61,which has the effect of enhancing vehicle stability during braking from test speeds of 160 km/h.

In summary, the Contracting Parties agreed to include in the proposed gtr the following parameters for the High Speed Test, which are developed from the JSS 12-61:

- Applicability: Category 3-3, 3-4 and 3-5 vehicles with V_{max} > 125 km/h
- Vehicle conditions. a) Vehicle load: lightly-loaded; b) Transmission position: In highest gear;
- IBT: $\geq 55^oC$ and $\leq 100^oC$
- Test speed: the lesser of 160 km/h or 0.8 of the vehicle's maximum speed (V_{max}) for a V_{max} > 125 km/h or < 200 km/h
- Number of stops: maximum 4 stops
- Brake application force: all service brake controls applied simultaneously with a force $\leq$ 200 N for hand lever; $\leq$ 350 N for foot pedal
- Performance Requirement: Stopping distance, $S \leq 0.1V + V^2/149$; or mfdd $\geq$ 5.8 m/s^2

3.4 Wet Brake Test

The purpose of the Wet Brake Test is to ensure a minimum level of braking performance when the motorcycle is ridden in heavy rain conditions. Each of the major national motorcycle brake regulations, ECE R78, FMVSS 122, and JSS12-61, includes a wet brake test but different philosophies are used.

The ECE and the JSS test procedures and performance requirements are similar but are different from the FMVSS test. The ECE regulation was developed 20 years ago in the United Kingdom in order to deal with problems in the field where the braking performance of motorcycles with exposed disc brakes was significantly reduced when ridden in heavy rain. This coincided with the large scale introduction of disc brakes on motorcycles. Therefore, in order to simulate heavy rain conditions, the ECE test requires a brake performance test with a wetted brake. This is achieved by spraying water directly onto the brakes during the test.

The ECE wet brake performance evaluation begins with a baseline test where each brake is tested separately and is required to decelerate a laden motorcycle at a specified rate, using the conditions of the Dry Stop Test – single brake control activated. For comparison, the same test is then repeated but with a constant spray of water to wet the brakes. The difference in performance is evaluated immediately after the application of the respective brake, to assure a minimum rise in deceleration performance with wet brakes. In addition, a drying brake can sometimes result in an excessively high pad friction leading to vehicle instability and wheel lock, therefore a check for this "over recovery" is also included.

As with the ECE/JSS, the FMVSS wet brake performance is evaluated by comparison of a baseline dry stop test with the performance after wetting. However, the philosophy is quite different, as it is based on brake performance recovery following the motorcycle crossing an area of standing water. As such, the wetting procedure consists of immersing the front and rear brakes in water, separately, for two minutes each. Performance is evaluated with all brakes applied simultaneously and the wet brake recovery performance is based on the fifth stop after having immersed the brakes. The motorcycle is also tested in the lightly loaded condition. Practical problems can occur when carrying out the brake immersion requirement, due to low exhaust systems and other mechanical system locations, which may affect the motorcycle engine/transmission.

The respective brake regulations address minimum performance requirement for wet brakes, albeit under different conditions. In terms of the overall performance requirements, the severity comparison studies by IMMA and the NHTSA/TC both concluded that the ECE/JSS performance requirements are more stringent. The Contracting Parties agreed that the ECE/JSS procedure akin to braking while riding in the rain is a more common operating condition than crossing an area covered with water.

Therefore, the Contracting Parties decided to propose a wet brake test based on the contents of the ECE/JSS test, and to make it applicable to all vehicle categories. The test procedure was slightly modified to confirm the performance of drum brakes that have ventilation or inspection holes, as this is a potential entry point for water spray. At present, the ECE/JSS procedure excludes drum brakes that are fully enclosed because water is prevented from reaching the braking surface.

In summary, the Contracting Parties agreed to include in the proposed gtr the following Wet Brake Test parameters which are developed from ECE R78/JSS 12-61:

Tests are applicable to all vehicle categories.
Baseline Test:
Based on Dry Stop Test – single brake control activated as follows:

- Vehicle conditions. a) Vehicle load: gross vehicle mass, but for vehicles with CBS, also tested lightly-loaded; b) Transmission position: engine disconnected;
- IBT: $\geq 55^{o}C$ and $\leq 100^{o}C$
- Test speed:
    a) Category 3-1 & 3-2 vehicles: the lesser of 40 km/h or 0.9 Vmax.
    b) Category 3-3, 3-4 & 3-5 vehicles: the lesser of 60 km/h or 0.9 Vmax
- Separate test for each brake control
- Brake application force: the force that results in a deceleration of 2.5 – 3.0 m/s^2
- Number of stops: 3 (The average brake control force of the 3 stops shall be used for the subsequent Wet Brake Stop)

Wet Brake Stop:

- The vehicle shall be ridden at the speed specified for the baseline test for 500m with water being sprayed on to the brake(s) at 15 litres/hr.
- The brake control shall then be applied using the force derived in the baseline test.
- Performance requirement:

a) The vehicle deceleration shall be ≥ 60% of the average deceleration recorded in the baseline test in the period 0.5 to 1.0 seconds after the brake control has been applied.
b) The vehicle deceleration shall be ≤ 120% of the average deceleration recorded in the baseline test for the complete stop.

3.5 Heat Fade Test

The heat fade test will assure that a minimum level of braking performance is maintained, after numerous consecutive brake applications. In terms of real world conditions, this could be akin to frequent braking while driving in a busy suburban area or on a downhill gradient. Each of the national regulations includes a test to evaluate the brake for heat fade and any change in brake performance.

As with the wet brake test, the ECE and JSS share the same test procedure and performance requirements. Each require that the brakes be tested separately, with the motorcycle loaded to its maximum mass capacity. The FMVSS test parameters are different in that all brakes are applied simultaneously and the motorcycle test mass is limited to 200 pounds (90.7 kg) above the unloaded motorcycle mass (i.e. the 200 pounds includes the mass of the test rider and test equipment).

Each test begins with a baseline test with an IBT between 55°C and 100°C, which provides the benchmark for performance comparison and evaluation against the heated brakes. This is followed by 10 consecutive fade stops with the purpose to build heat within the brakes. The similarities between national regulations end here. In the ECE/JSS, the final performance test occurs with one stop immediately following the 10 fade stops. The FMVSS requires an additional five recovery stops, and the performance in the fifth stop is compared to the baseline performance. The respective regulation test parameters include additional differences such as initial test speeds, brake lever and pedal control forces, deceleration rates, and the transmission gear selection (engine connected / disconnected).

Finally, to evaluate brake fade performance, the FMVSS procedure compares the brake pedal and lever actuation forces to maintain the same deceleration in the baseline test, whereas the ECE/JSS procedures compare deceleration (or stopping distance) for the same brake pedal and lever actuation forces as used in the baseline test.

Although the national regulations have distinct differences, they share the common goal of evaluating the effect of heat on braking performance. The stringency of the respective tests was evaluated separately by the IMMA and in a joint study by TC/NHTSA. The results from both studies indicated that the ECE/JSS fade test was more severe, thus provided the basis for the purposes of the gtr.

Minor adjustments were brought to the referenced national test procedure. In addition to narrowing the range for the initial brake temperature, the text was revised to use the average brake control force from the baseline test, calculated from the measured values between 80 percent and 10 percent of the specified vehicle test speed.

The proposed gtr fade test is applicable to category 3-3, 3-4 and 3-5 vehicles, as is presently the case in the ECE, JSS and FMVSS. Only Canada's national regulation requires a fade test for vehicles with an engine size less than 50cc and a top speed less than

50 km/h (i.e. category 3-1 and 3-2 vehicles). However, none of the participants in the informal group could substantiate the need to include the fade test for those vehicle categories. There was no negative experience reported due to the absence of a fade test for these smaller motorcycles, and therefore it was agreed that such motorcycles would not require the heat fade test.

In summary, the Contracting Parties agreed to include in the proposed gtr the following Heat Fade test parameters, which are taken from the ECE and JSS:

Tests are applicable to Category 3-3, 3-4 and 3-5 vehicles.
Baseline Test:

- Vehicle conditions. a) Vehicle load: gross vehicle mass; b) Transmission position: engine disconnected;
- IBT: $\geq 55^{o}C$ and $\leq 100^{o}C$
- Test speed: 60 km/h
- Number of stops: 1
- Separate test for each brake control
- Brake application force: for hand lever $\leq$ 200 N; for foot pedal $\leq$ 350 N for category 3-3 & 3-5, $\leq$ 500 N for category 3-4.
- Performance Requirement: Same as for Dry Test – single brake control activated.

Heating Procedure:

- Vehicle conditions:
  a) Vehicle load: gross vehicle mass;
  b) Transmission position:
    i) From the test speed to 50% test speed: connected, with the highest gear selected.
    ii) From 50% test speed to standstill: disconnected
- IBT: $\geq 55^{o}C$ and $\leq 100^{o}C$ for first stop only.
- Test speed:
  a) Front brake(s): the lesser of 100 km/h or 0.7 V max.
  b) Rear brake(s): the lesser of 80 km/h or 0.7 V max.
  c) CBS: the lesser of 100 km/h or 0.7 V max.
- Number of stops: 10
  a) The first stop to achieve an average deceleration of 3.0 – 3.5 m/s^2
  b) The remaining 9 stops with the average brake control force utilized in the first stop.
  c) Interval between stops: 1000 m
- Separate test for each brake control

Hot Brake Stop:
This stop must be done within 1 minute of completing the Heating Procedure. Same conditions as for the baseline stop with the following exceptions:

- Brake application force: Average brake control force $\leq$ baseline average brake control force
- Performance Requirement:
  a) If based on MFDD, $\geq$ 60% of MFDD in the baseline test.
  b) If based on stopping distance, $S_2 \leq 1.67\ S_1 - 0.67 \times 0.1V$
  Where:

S_1 = corrected stopping distance in baseline test (metres)
S_2 = corrected stopping distance in hot brake stop (metres)
V = specified test speed (km/h)

3.6 Parking Brake Test

The purpose of the parking brake requirement in the motorcycle brake gtr is to ensure that 3-wheeled motorcycles can remain stationary without rolling away when parked on an incline.

FMVSS 122 requires that the parking brake system be capable of holding the motorcycle stationary for 5 minutes when tested in the lightly-loaded condition on a 30% grade, in the forward and reverse directions. In addition, FMVSS 122 requires that the parking brake be of a friction type with solely mechanical means to retain engagement. The parking brake requirement in ECE R78 and JSS 12-61 are equivalent, and require that the brake must be capable of holding the motorcycle stationary on an 18% grade in the laden condition (i.e., the maximum weight limit specified by the manufacturer), in the forward and reverse directions. No time limit is specified in either the ECE or JSS regulation.

The Contracting Parties agreed to use the ECE/JSS parking brake test as a basis for the proposed motorcycle brake gtr, even though the level of stringency appears to be similar to that in the FMVSS, given the ECE's laden condition on an 18% grade versus the FMVSS' lightly loaded condition on a 30% grade. The Contracting Parties agreed that the laden condition is the worse case loading condition and test facilities around the world are more likely to have an 18% grade than a 30% grade available for testing.

The proposed gtr includes a requirement that the motorcycle remain stationary for 5 minutes, which was adopted from the FMVSS. In addition, the Contracting Parties agreed that the proposed gtr retain the common requirement that the parking brake be designed to retain engagement solely by mechanical means but not include the FMVSS requirement that the parking brake be of a friction type. This removes a design restriction and allows a manufacturer to use any parking brake design that retains engagement by mechanical means.

In summary, the Contracting Parties agreed to include in the proposed gtr the following parking brake requirement, which is developed from the ECE R78 parking brake requirement:

- Applicability: 3-wheeled motorcycles or 2-wheeled motorcycles with a sidecar
- Vehicle conditions. a) Vehicle load: Gross vehicle mass; b) Transmission position: In neutral; c) Forward and reverse directions
- Test surface grade: 18 percent
- IBT: $\leq 100^{o}$C
- Brake application force: Hand control force $\leq$ 400 N; Foot control force $\leq$ 500 N
- Performance Requirement: When tested in each direction on the grade, the vehicle must remain stationary for 5 minutes

3.7 ABS Performance

The purpose of the antilock brake system (ABS) requirements is to assess the stability and stopping distance performance of the motorcycle with the ABS activating. The proposed gtr does not require that a motorcycle be equipped with ABS but establishes minimum performance requirements for motorcycles so equipped.

ECE R78 and JSS 12-61 include ABS performance requirements but do not require ABS. The performance requirements include: 1) ABS adhesion utilization (efficiency) requirement, which is only in ECE R78, with braking on high adhesion and low adhesion surfaces; 2) high-adhesion surface to low-adhesion surface transition stop; 3) low-adhesion surface to high-adhesion surface transition stop; 4) wheel lock tests on high adhesion and low adhesion surfaces; and 5) ABS failed systems test. FMVSS No. 122 does not include any additional performance requirements for a motorcycle equipped with ABS nor does it include any failed system requirement for ABS.

The Contracting Parties reviewed each of the ABS performance tests and their corresponding requirements to assess their appropriateness for the proposed motorcycle brake gtr.

The adhesion utilization test is required by the ECE standard only, and compares the performance of the front and rear ABS brakes, separately, to the maximum braking performance of the front and rear brakes, separately, with the ABS disabled. It is evaluated on two road surfaces, a high-adhesion surface and a low-adhesion surface, and the required performance (ABS efficiency) must be 70 percent or higher. After considerable deliberation, the Contracting Parties agreed to exclude the adhesion utilization test from the proposed gtr because of the difficulties in performing the test and achieving repeatable and objective results. As an alternative, the Contracting Parties agreed to include a stopping performance ABS test on the high-adhesion surface to ensure a specified level of performance compared with the dry stop test. This ensures that when the ABS activates, a balance is maintained between stopping performance and vehicle stability during braking. No test was included for ABS stopping performance on a low-adhesion surface since there is no corresponding wet stop test for comparison.

For the other ABS tests, the Contracting Parties agreed to adopt, with some minor revisions or clarifications, the requirements as stated in the ECE and JSS regulations. For example, in the low-adhesion to high-adhesion surface tests, if water is used to obtain the necessary PFC on the low-adhesion surface, then the high-adhesion surface must also be wetted for the test. This will ensure consistent PFC values of the test surfaces and prevent the effect of a drying tire from changing the surface adhesion characteristics as the motorcycle crosses surfaces. Also, to ensure that the ABS is activated during the test, the hand lever and foot pedal efforts are specified at maximum levels. There are a few areas in the ECE and JSS standards where the requirements were revised to make them more objective in the proposed gtr.

In summary, the Contracting Parties agreed to include in the proposed gtr the following performance tests for 2-wheel vehicles of Category 3-1 and 3-3 which are equipped with ABS, developed from ECE R78 and JSS 12-61:

- Stops on a high adhesion surface
- Stops on a low adhesion surface
- Wheel lock checks on high and low adhesion surfaces

- High-adhesion to low-adhesion surface transition test
- Low-adhesion to high-adhesion surface transition test
- Stops with a failed ABS

Stops on a high-adhesion surface

- Vehicle conditions. a) Vehicle load: lightly-loaded; b) Transmission position: In neutral
- IBT: $\geq 55^{o}C$ and $\leq 100^{o}C$
- Test speed: 60 km/h or 0.9 V_{max}, whichever is lower
- Maximum number of stops: 6
- Brake application force: Separate test for each brake control with a force = 200 N for hand lever; = 350 N for foot pedal
- Performance Requirement: 1) 70% of mfdd, or 1.3 times the stopping distance specified in the test for dry stop-single brake control activated; 2) Vehicle must stay within the 2.5-meter lane

Stops on a low-adhesion surface

- Vehicle conditions. a) Vehicle load: lightly-loaded; b) Transmission position: In neutral
- IBT: $\geq 55^{o}C$ and $\leq 100^{o}C$
- Test speed: 60 km/h or 0.9 V_{max}, whichever is lower
- Maximum number of stops: 6
- Brake application force: Separate test for each brake control with a force = 200 N for hand lever; = 350 N for foot pedal
- Performance Requirement: Vehicle must stay within the 2.5-meter lane

Wheel lock checks on high and low adhesion surfaces

- Vehicle conditions. a) Vehicle load: lightly-loaded; b) Transmission position: In neutral
- IBT: $\geq 55^{o}C$ and $\leq 100^{o}C$
- Initial test speed: 80 km/h or 0.8 V_{max}, whichever is lower
- Final test speed: When the speed reaches 20 km/h below the initial test
- Maximum number of stops: 3
- Brake application force: Test #1) Separate test for each brake control with a force = 200 N for hand lever; = 350 N for foot pedal; Test #2) all service brake controls applied simultaneously with a force = 200 N for hand lever; = 350 N for foot pedal
- Brake application rate: Specified brake force must be achieved in 0.2 – 0.5 seconds
- Performance Requirement: There must be no wheel lock

High-adhesion to low-adhesion surface transition test

- Vehicle conditions. a) Vehicle load: lightly-loaded; b) Transmission position: In neutral
- IBT: $\geq 55^{o}C$ and $\leq 100^{o}C$
- Test speed: 50 km/h or 0.5 V_{max}, whichever is lower, at the point where the vehicle passes from the high-adhesion surface to the low-adhesion surface
- Maximum number of stops: 3
- Brake application force: Test #1) Separate test for each brake control with a force = 200 N for hand lever; = 350 N for foot pedal; Test #2) all service brake controls applied simultaneously with a force = 200 N for hand lever; = 350 N for foot pedal

- Performance Requirement: 1) There must be no wheel lock; 2) Vehicle must stay within the 2.5-meter lane

Low-adhesion to high-adhesion surface transition test

- Vehicle conditions. a) Vehicle load: lightly-loaded; b) Transmission position: In neutral
- IBT: $\geq 55^{o}C$ and $\leq 100^{o}C$
- Test speed: 50 km/h or 0.5 V_{max}, whichever is lower, at the point where the vehicle passes from the low-adhesion surface to the high-adhesion surface
- Test surface: if water is used to obtain the required PFC on the low-adhesion surface, the high-adhesion surface must also be wetted, and must possess the required PFC in that condition.
- Maximum number of stops: 3
- Brake application force: Test #1) Separate test for each brake control with a force = 200 N for hand lever; = 350 N for foot pedal; Test #2) all service brake controls applied simultaneously with a force = 200 N for hand lever; = 350 N for foot pedal
- Performance Requirement: 1) There must be no wheel lock; 2) Vehicle must stay within the 2.5-meter lane; 3) vehicle deceleration must increase after transition onto the high-adhesion surface

Stops with a failed ABS

- Disable the ABS
- Vehicle conditions. a) Vehicle load: gross vehicle mass; b) Transmission position: In neutral
- IBT: $\geq 55^{o}C$ and $\leq 100^{o}C$
- Test speed:
  a) Category 3-1 vehicles: 40 km/h or 0.9 Vmax, whichever is lower
  b) Category 3-3 vehicles: 60 km/h or 0.9 Vmax, whichever is lower
- Maximum number of stops: 6
- Brake application force: Separate test for each brake control with a force $\leq$ 250 N for hand lever; $\leq$ 400 N for foot pedal
- Performance requirement for each brake:
  a) Category 3-1 vehicles: Stop Distance, $S \leq 0.1V + V^2/70$; or mfdd ≥ 2.7 m/s^2
  b) Category 3-3 vehicles: Stop Distance, $S \leq 0.1V + V^2/75$; or mfdd ≥ 2.9 m/s^2

3.8 Partial Failure Test – Split service brake system

The split service brake system is based on the passenger car braking system and its use on motorcycles is unique to vehicles in Canada and the United States. The purpose of this test is to assure that, in the event of a pressure component leakage failure in one of the hydraulic subsystems, a minimum level of braking performance is still available in the remaining hydraulic subsystem to allow the rider to bring the motorcycle to a stop.

Of the three national regulations, only the FMVSS 122 addresses a failure test for motorcycles equipped with a split service brake system. The test requirements are not applicable to Category 3-1 and 3-2 vehicles. The Contracting Parties agreed that the performance requirements contained therein were sufficient for the purposes of this gtr.

In summary, the proposed test to address a split service system partial failure includes the following parameters, taken from the FMVSS 122:

- Applicability: Category 3-3, 3-4 & 3-5
- Vehicle conditions. a) Vehicle load: lightly-loaded; b) Transmission position: In neutral;
- IBT: $\geq 55^{o}C$ and $\leq 100^{o}C$
- Test speed: 50 km/h and 100 km/h or 0.8 of the vehicle's maximum speed (V_{max})
- Number of stops: maximum 6 for each test speed
- Brake application force: all service brake controls applied simultaneously with a force $\leq$ 245 N for hand lever; $\leq$ 400 N for foot pedal
- Performance Requirement: Stopping distance, $S \leq 0.1V + V^2/85$; or mfdd ≥ 3.3 m/s^2

3.9 Servo Failure Test

An outline including all of the proposed test procedures for the gtr was presented during the 57th GRRF, for the purposes of soliciting initial comments. One such comment was the absence of and request for a servo failure test. None of the referenced motorcycle brake regulations or standards include such a requirement, most likely because the application of servo systems on motorcycles is relatively new.

It is recognized that some motorcycles are presently equipped with servo brake systems, and that the use of such systems could expand in the future. In the event of a servo failure, existing standards are limited to motor vehicles where this technology has been in use for many years, such as on passenger cars. At present, however, there is no known performance requirement in the event of the failure of a servo brake system on a motorcycle.

The informal group therefore proposes a test to assure that, in the event of a servo failure, a minimum level of braking performance is still available to allow the rider to bring the motorcycle to a stop. The test is not required if the motorcycle is equipped with another separate service brake system.

In summary, the proposed test is based on the Dry Stop test – single brake control activated (Section 4.3 in the gtr) with the performance requirement being that of the secondary brake for vehicles with CBS.

The Contracting Parties agreed to include in the proposed gtr the following parameters for the Servo Failure test:

- Applicability: all vehicles except if equipped with another separate service brake system
- Vehicle conditions.
    a) Vehicle load: gross vehicle mass; for vehicle fitted with CBS, also lightly-loaded
    b) Transmission position: engine disconnected.
    c) Servo disabled
- IBT: $\geq 55^{o}C$ and $\leq 100^{o}C$
- Test speed:
    a) Category 3-1 & 3-2 vehicles: 40 km/h or 0.9 Vmax, whichever is the lower

b) Category 3-3, 3-4 & 3-5 vehicles: 60 km/h or 0.9 Vmax, whichever is the lower

- Number of stops: maximum 6 stops
- Separate test for each brake control
- Brake application force: for hand lever $\leq$ 200 N; for foot pedal $\leq$ 350 N for 3-3 & 3-5, $\leq$ 500 N for 3-4.
- Performance Requirement: Stopping distance, $S \leq 0.1V + V^2/65$; or mfdd $\geq$ 2.5 m/s^2