2 One acceptable means for demonstrating compliance with CS 25.107(d) and 25.107(e)(1)(iv) with respect to the capability for a safe lift-off and fly-away from the geometry limited condition is to show that at the lowest thrust-to-weight ratio for the all-engines-operating condition:

2.1 During the speed range from 96 to 100% of the actual lift-off speed, the aft under-surface of the aeroplane should be in contact with the runway. Because of the dynamic nature of the test, it is recognised that contact will probably not be maintained during this entire speed range, and some judgement is necessary. It has been found acceptable for contact to exist approximately 50% of the time that the aeroplane is in this speed range.

2.2 Beyond the point of lift-off to a height of 11m (35 ft), the aeroplane's pitch attitude should not decrease below that at the point of lift-off, nor should the speed increase more than 10%.

2.3 The horizontal distance from the start of the take-off to a height of 11 m (35 ft) should not be greater than 105% of the distance determined in accordance with CS 25.113(a)(2) without the 115% factor.

AMC 25.107(e)(3) Take-off speeds

ED Decision 2003/2/RM

In showing compliance with CS 25.107(e)(3) –

a. Rotation at a speed of V_R-9,3 km/h (5 kt) should be carried out using, up to the point of lift-off, the same rotation technique, in terms of control input, as that used in establishing the one-engine-inoperative distance of CS 25.113(a)(1);

b. The engine failure speed used in the V_R-9,3 km/h (5 kt) demonstration should be the same as that used in the comparative take-off rotating at V_R;

c. The tests should be carried out both at the lowest practical weight (such that V_R-9,3 km/h (5 kt) is not less than V_{MCG}) and at a weight approaching take-off climb limiting conditions;

d. The tail or tail skid should not contact the runway.

AMC No. 1 to CS 25.107(e)(4) Take-off speeds

ED Decision 2003/2/RM

Reasonably expected variations in service from established take-off procedures should be evaluated in respect of out-of-trim conditions during certification flight test programmes. For example, normal take-off should be made with the longitudinal control trimmed to its most adverse position within the allowable take-off trim band.

AMC No. 2 to CS 25.107(e)(4) Take-off speeds

ED Decision 2003/2/RM

1 CS 25.107(e)(4) states that there must be no marked increase in the scheduled take-off distance when reasonably expected service variations, such as over-rotation, are encountered. This can be interpreted as requiring take-off tests with all engines operating with an abuse on rotation speed.

2 The expression 'marked increase' in the take-off distance is defined as any amount in excess of 1% of the scheduled take-off distance. Thus the abuse test should not result in a field length more than 101% of the scheduled field length.

3 For the early rotation abuse condition with all engines operating and at a weight as near as practicable to the maximum sea-level take-off weight, it should be shown by test that when the aeroplane is rotated rapidly at a speed which is 7% or 19 km/h (10 kt), whichever is lesser, below the scheduled V_R speed, no 'marked increase' in the scheduled field length would result.

CS 25.109 Accelerate-stop distance

ED Decision 2016/010/R

(See AMC 25.109)

(a) (See AMC 25.109(a) and (b).) The accelerate-stop distance on a dry runway is the greater of the following distances:

(1) The sum of the distances necessary to –

(i) Accelerate the aeroplane from a standing start with all engines operating to V_{EF} for take-off from a dry runway;

(ii) Allow the aeroplane to accelerate from V_{EF} to the highest speed reached during the rejected take-off, assuming the critical engine fails at V_{EF} and the pilot takes the first action to reject the take-off at the V_1 for take-off from a dry runway; and

(iii) Come to a full stop on a dry runway from the speed reached as prescribed in sub-paragraph (a)(1)(ii) of this paragraph; plus

(iv) A distance equivalent to 2 seconds at the V_1 for take-off from a dry runway.

(2) The sum of the distances necessary to –

(i) Accelerate the aeroplane from a standing start with all engines operating to the highest speed reached during the rejected take-off, assuming the pilot takes the first action to reject the take-off at the V_1 for take-off from a dry runway; and

(ii) With all engines still operating, come to a full stop on a dry runway from the speed reached as prescribed in sub-paragraph (a)(2)(i) of this paragraph; plus

(iii) A distance equivalent to 2 seconds at the V_1 for take-off from a dry runway.

(b) (See AMC 25.109(a) and (b).) The accelerate-stop distance on a wet runway is the greater of the following distances:

(1) The accelerate-stop distance on a dry runway determined in accordance with sub-paragraph (a) of this paragraph; or

(2) The accelerate-stop distance determined in accordance with sub-paragraph (a) of this paragraph, except that the runway is wet and the corresponding wet runway values of V_{EF} and V_1 are used. In determining the wet runway accelerate-stop distance, the stopping force from the wheel brakes may never exceed:

(i) The wheel brakes stopping force determined in meeting the requirements of CS 25.101(i) and sub-paragraph (a) of this paragraph; and

(ii) The force resulting from the wet runway braking coefficient of friction determined in accordance with subparagraphs (c) or (d) of this paragraph, as applicable, taking into account the distribution of the normal load between braked and unbraked wheels at the most adverse centre of gravity position approved for take-off.

(c) The wet runway braking coefficient of friction for a smooth wet runway is defined as a curve of friction coefficient versus ground speed and must be computed as follows:

(1) The maximum tyre-to-ground wet runway braking coefficient of friction is defined as (see Figure 1):

Tyre Pressure (psi)	Maximum Braking Coefficient (tyre-to-ground)
50	$\mu_{t/gMAX} = -0{\cdot}0350\left(\frac{V}{100}\right)^3 + 0{\cdot}306\left(\frac{V}{100}\right)^2 - 0{\cdot}851\left(\frac{V}{100}\right) + 0{\cdot}883$
100	$\mu_{t/gMAX} = -0{\cdot}0437\left(\frac{V}{100}\right)^3 + 0{\cdot}320\left(\frac{V}{100}\right)^2 - 0{\cdot}805\left(\frac{V}{100}\right) + 0{\cdot}804$
200	$\mu_{t/gMAX} = -0{\cdot}0331\left(\frac{V}{100}\right)^3 + 0{\cdot}252\left(\frac{V}{100}\right)^2 - 0{\cdot}658\left(\frac{V}{100}\right) + 0{\cdot}692$
300	$\mu_{t/gMAX} = -0{\cdot}0401\left(\frac{V}{100}\right)^3 + 0{\cdot}263\left(\frac{V}{100}\right)^2 - 0{\cdot}611\left(\frac{V}{100}\right) + 0{\cdot}614$

Figure 1

where:

Tyre Pressure = maximum aeroplane operating tyre pressure (psi)

$\mu_{t/gMAX}$ = maximum tyre-to-ground braking coefficient

V = aeroplane true ground speed (knots); and

Linear interpolation may be used for tyre pressures other than those listed.

(2) (See AMC 25.109(c)(2) The maximum tyre-to-ground wet runway braking coefficient of friction must be adjusted to take into account the efficiency of the anti-skid system on a wet runway. Anti-skid system operation must be demonstrated by flight testing on a smooth wet runway and its efficiency must be determined. Unless a specific anti-skid system efficiency is determined from a quantitative analysis of the flight testing on a smooth wet runway, the maximum tyre-to-ground wet runway braking coefficient of friction determined in sub-paragraph (c)(1) of this paragraph must be multiplied by the efficiency value associated with the type of anti-skid system installed on the aeroplane:

Type of anti-skid system	Efficiency value
On-off	0·30
Quasi-modulating	0·50
Fully modulating	0·80

(d) At the option of the applicant, a higher wet runway braking coefficient of friction may be used for runway surfaces that have been grooved or treated with a porous friction course material. For grooved and porous friction course runways,

(1) 70% of the dry runway braking coefficient of friction used to determine the dry runway accelerate-stop distance; or

(2) (See AMC 25.109(d)(2).) The wet runway braking coefficient of friction defined in sub-paragraph (c) of this paragraph, except that a specific anti-skid efficiency, if determined, is appropriate for a grooved or porous friction course wet runway and the maximum tyre-to-ground wet runway braking coefficient of friction is defined as (see Figure 2):

Tyre Pressure (psi)	Maximum Braking Coefficient (tyre-to-ground)
50	$\mu_{t/gMAX} = 0{\cdot}147\left(\frac{V}{100}\right)^5 - 1{\cdot}05\left(\frac{V}{100}\right)^4 + 2{\cdot}673\left(\frac{V}{100}\right)^3 - 2{\cdot}683\left(\frac{V}{100}\right)^2 + 0{\cdot}403\left(\frac{V}{100}\right) + 0{\cdot}859$
100	$\mu_{t/gMAX} = 0{\cdot}1106\left(\frac{V}{100}\right)^5 - 0{\cdot}813\left(\frac{V}{100}\right)^4 + 2{\cdot}13\left(\frac{V}{100}\right)^3 - 2{\cdot}20\left(\frac{V}{100}\right)^2 + 0{\cdot}317\left(\frac{V}{100}\right) + 0{\cdot}807$
200	$\mu_{t/gMAX} = 0{\cdot}0498\left(\frac{V}{100}\right)^5 - 0{\cdot}398\left(\frac{V}{100}\right)^4 + 1{\cdot}14\left(\frac{V}{100}\right)^3 - 1{\cdot}285\left(\frac{V}{100}\right)^2 + 0{\cdot}140\left(\frac{V}{100}\right) + 0.701$
300	$\mu_{t/gMAX} = 0{\cdot}0314\left(\frac{V}{100}\right)^5 - 0{\cdot}247\left(\frac{V}{100}\right)^4 + 0{\cdot}703\left(\frac{V}{100}\right)^3 - 0{\cdot}779\left(\frac{V}{100}\right)^2 - 0{\cdot}00954\left(\frac{V}{100}\right) + 0{\cdot}614$

Figure 2

where:

Tyre Pressure = maximum aeroplane operating tyre pressure (psi)

$\mu_{t/gMAX}$ = maximum tyre-to-ground braking coefficient

V = aeroplane true ground speed (knots); and Linear interpolation may be used for tyre pressures other than those listed.

(e) Except as provided in sub-paragraph (f)(1) of this paragraph, means other than wheel brakes may be used to determine the accelerate-stop distance if that means –

(1) Is safe and reliable;

(2) Is used so that consistent results can be expected under normal operating conditions; and

(3) Is such that exceptional skill is not required to control the aeroplane.

(f) The effects of available reverse thrust –

(1) Must not be included as an additional means of deceleration when determining the accelerate-stop distance on a dry runway; and

(2) May be included as an additional means of deceleration using recommended reverse thrust procedures when determining the accelerate-stop distance on a wet runway, provided the requirements of sub-paragraph (e) of this paragraph are met. (See AMC 25.109(f).)

(g) The landing gear must remain extended throughout the accelerate-stop distance.

(h) If the accelerate-stop distance includes a stopway with surface characteristics substantially different from those of the runway, the take-off data must include operational correction factors for the accelerate-stop distance. The correction factors must account for the particular surface characteristics of the stopway and the variations in these characteristics with seasonal weather conditions (such as temperature, rain, snow and ice) within the established operational limits.

(i) A flight test demonstration of the maximum brake kinetic energy accelerate-stop distance must be conducted with not more than 10% of the allowable brake wear range remaining on each of the aeroplane wheel brakes.

[Amdt 25/18]

AMC 25.109(a) and (b) Accelerate-stop distance

ED Decision 2003/2/RM

Propeller pitch position. For the one-engine-inoperative accelerate-stop distance, the critical engine's propeller should be in the position it would normally assume when an engine fails and the power levers are closed. For dry runway one-engine-inoperative accelerate-stop distances, the high drag ground idle position of the operating engines' propellers (defined by a pitch setting that results in not less than zero total thrust, i.e. propeller plus jet thrust, at zero airspeed) may be used provided adequate directional control is available on a wet runway and the related operational procedures comply with CS 25.109(f) and (h). Wet runway controllability may either be demonstrated by using the guidance available in AMC 25.109(f) at the appropriate power level, or adequate control can be assumed to be available at ground idle power if reverse thrust credit is approved for determining the wet runway accelerate-stop distances. For the all-engines-operating accelerate-stop distances on a dry runway, the high drag ground idle propeller position may be used for all engines (subject to CS 25.109(f) and (h)). For criteria relating to reverse thrust credit for wet runway accelerate-stop distances, see AMC 25.109(f).

AMC 25.109(c)(2) Accelerate-stop distance: anti-skid system efficiency

ED Decision 2003/2/RM

CS 25.109(c)(2) identifies 3 categories of anti-skid system and provides for either the use of a default efficiency value appropriate to the type of system or the determination of a specific efficiency value. Paragraph 1 of this AMC gives a description of the operating characteristics of each category to enable the classification of a particular system to be determined. Paragraph 2 gives an acceptable means of compliance with the requirement for flight testing and use of default efficiency values in accordance with CS 25.109(c)(2). These values are appropriate where the tuning of the anti-skid system is largely qualitative and without detailed quantitative analysis of system performance. Where detailed data recording and analysis is used to optimise system tuning, an efficiency value somewhat higher than the default value might be obtained and determined. Typically, a value of 40% might be achieved with an On/Off system. The quasi-modulating category covers a broad range of systems with varying performance levels. The best quasi-modulating systems might achieve an efficiency up to approximately 80%. Fully modulating systems have been tuned to efficiencies greater than 80% and up to a maximum of approximately 92%, which is considered to be the maximum efficiency on a wet runway normally achievable with fully modulating digital anti-skid systems. Paragraph 3 gives an acceptable means of compliance with CS 25.109(c)(2) where the applicant elects to determine a specific efficiency value.

In Paragraph 4 of this AMC, guidance is given on the use of 2 alternative methods for calculating antiskid system efficiency from the recorded data. One method is based on the variation of brake torque throughout the stop, while the other is based on wheel speed slip ratio. Finally, Paragraph 5 gives guidance on accounting for the distribution of the normal load between braked and unbraked wheels.

1 *Classification of anti-skid system types*

1.1 For the purposes of determining the default anti-skid efficiency value under CS 25.109(c)(2), anti-skid systems have been grouped into three broad classifications; on/off, quasi-modulating and fully modulating. These classifications represent evolving levels of technology and performance capabilities on both dry and wet runways.

1.2 On/off systems are the simplest of the three types of anti-skid systems. For these systems, fully metered brake pressure (as commanded by the pilot) is applied until wheel locking is sensed. Brake pressure is then released to allow the wheel to spin back up. When the system senses that the wheel is accelerating back to synchronous speed (i.e. ground speed), full metered pressure is again applied. The cycle of full pressure application/complete pressure release is repeated throughout the stop (or until the wheel ceases to skid with brake pressure applied).

1.3 Quasi-modulating systems attempt to continuously regulate brake pressure as a function of wheel speed. Typically, brake pressure is released when the wheel deceleration rate exceeds a preselected value. Brake pressure is re-applied at a lower level after a length of time appropriate to the depth of skid. Brake pressure is then gradually increased until another incipient skid condition is sensed. In general, the corrective actions taken by these systems to exit the skid condition are based on a pre-programmed sequence rather than the wheel speed time history.

1.4 Fully modulating systems are a further refinement of the quasi-modulating systems. The major difference between these two types of anti-skid systems is in the implementation of the skid control logic. During a skid, corrective action is based on the sensed wheel speed signal, rather than a preprogrammed response. Specifically, the amount of pressure reduction or reapplication is based on the rate at which the wheel is going into or recovering from a skid. Also, higher fidelity transducers and upgraded control systems are used, which respond more quickly.

1.5 In addition to examining the control system differences noted above, a time history of the response characteristics of the anti-skid system during a wet runway stop should be used to help identify the type of anti-skid system. Comparing the response characteristics from wet and dry runway stops can also be helpful.

Figure 1 shows an example of the response characteristics of a typical on-off system on both wet and dry runways. In general, the on-off system exhibits a cyclic behaviour of brake pressure application until a skid is sensed, followed by the complete release of brake pressure to allow the wheel to spin back up. Full metered pressure (as commanded by the pilot) is then re-applied, starting the cycle over again. The wheel speed trace exhibits deep and frequent skids (the troughs in the wheel speed trace), and the average wheel speed is significantly less than the synchronous speed (which is represented by the flat topped portions of the wheel speed trace). Note that the skids are deeper and more frequent on a wet runway than on a dry runway. For the particular example shown in Figure 1, the brake becomes torque-limited toward the end of the dry runway stop and is unable to generate enough torque to cause further skidding.

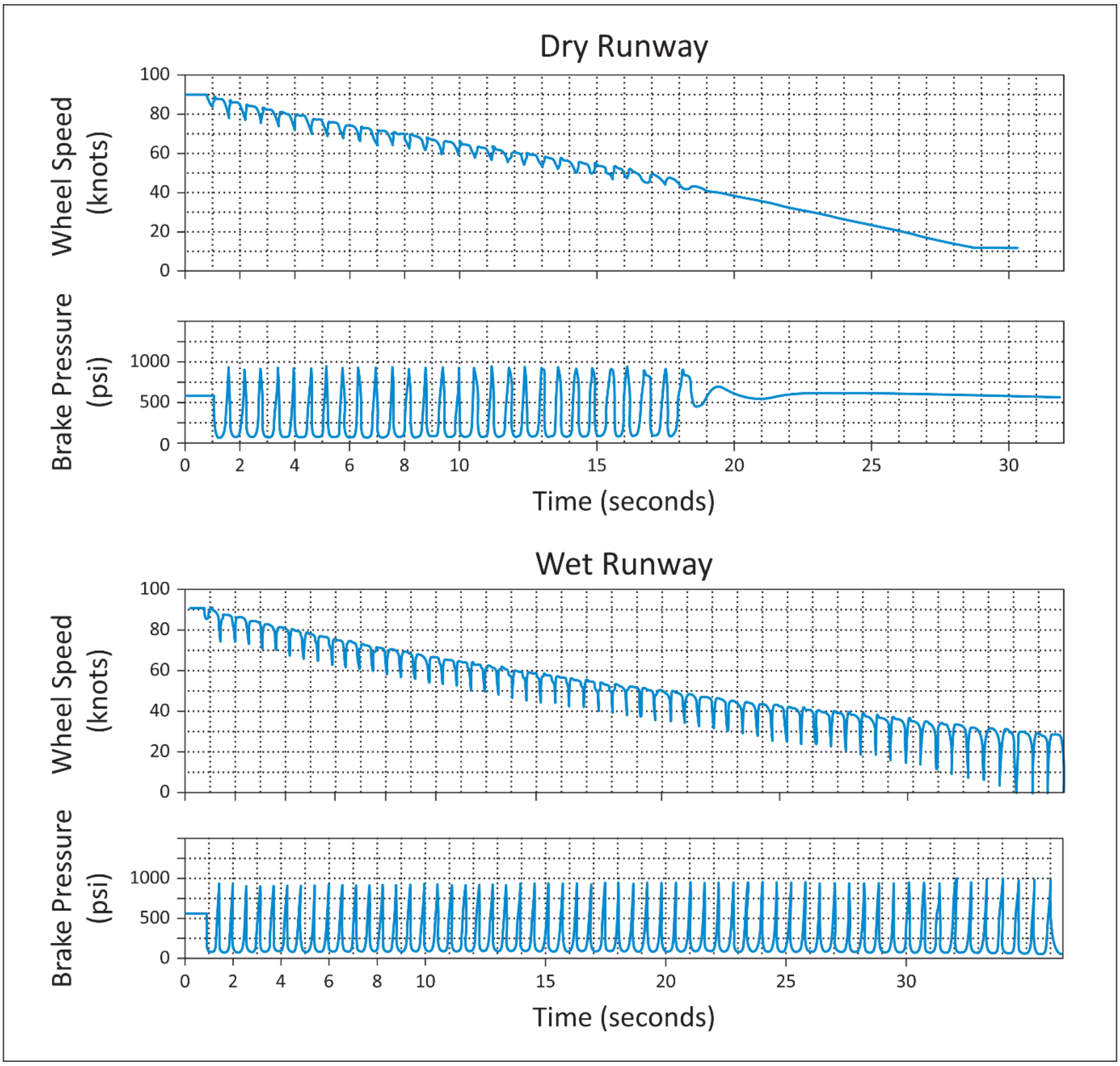

FIGURE 1. ANTI-SKID SYSTEM RESPONSE CHARACTERISTICS On-Off System

The effectiveness of quasi-modulating systems can vary significantly depending on the slipperiness of the runway and the design of the particular control system. On dry runways, these systems typically perform very well; however, on wet runways their performance is highly dependent on the design and tuning of the particular system. An example of the response characteristics of one such system is shown in Figure 2. On both dry and wet runways, brake pressure is released to the extent necessary to control skidding. As the wheel returns to the synchronous speed, brake pressure is quickly increased to a pre-determined level and then gradually ramped up to the full metered brake pressure. On a dry runway, this type of response reduces the depth and frequency of skidding compared to an on-off system. However, on a wet runway, skidding occurs at a pressure below that at which the gradual ramping of brake pressure occurs. As a result, on wet runways the particular system shown in Figure 2 operates very similarly to an on-off system.

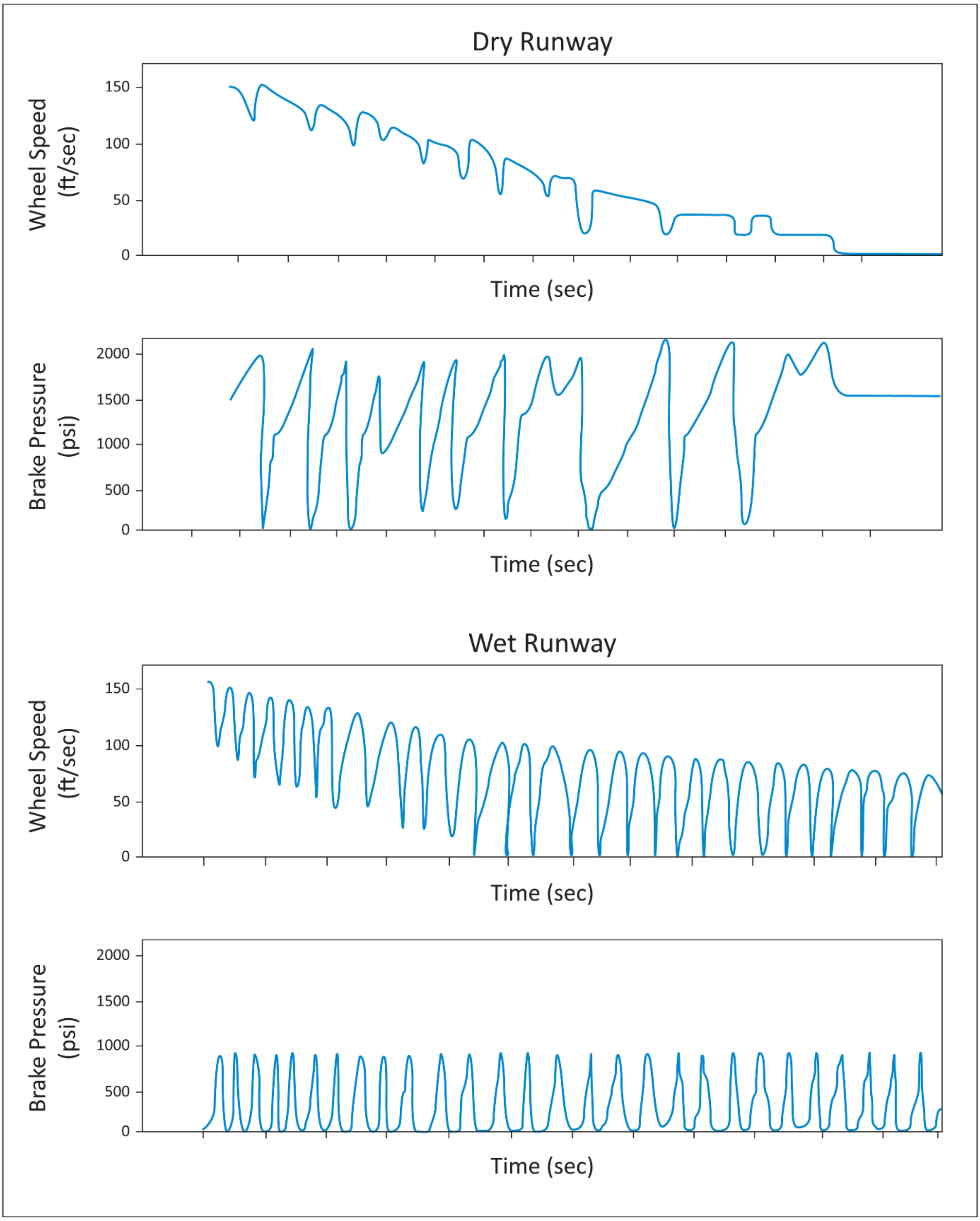

FIGURE 2. ANTI-SKID SYSTEM RESPONSE CHARACTERISTICS Quasi-Modulating System

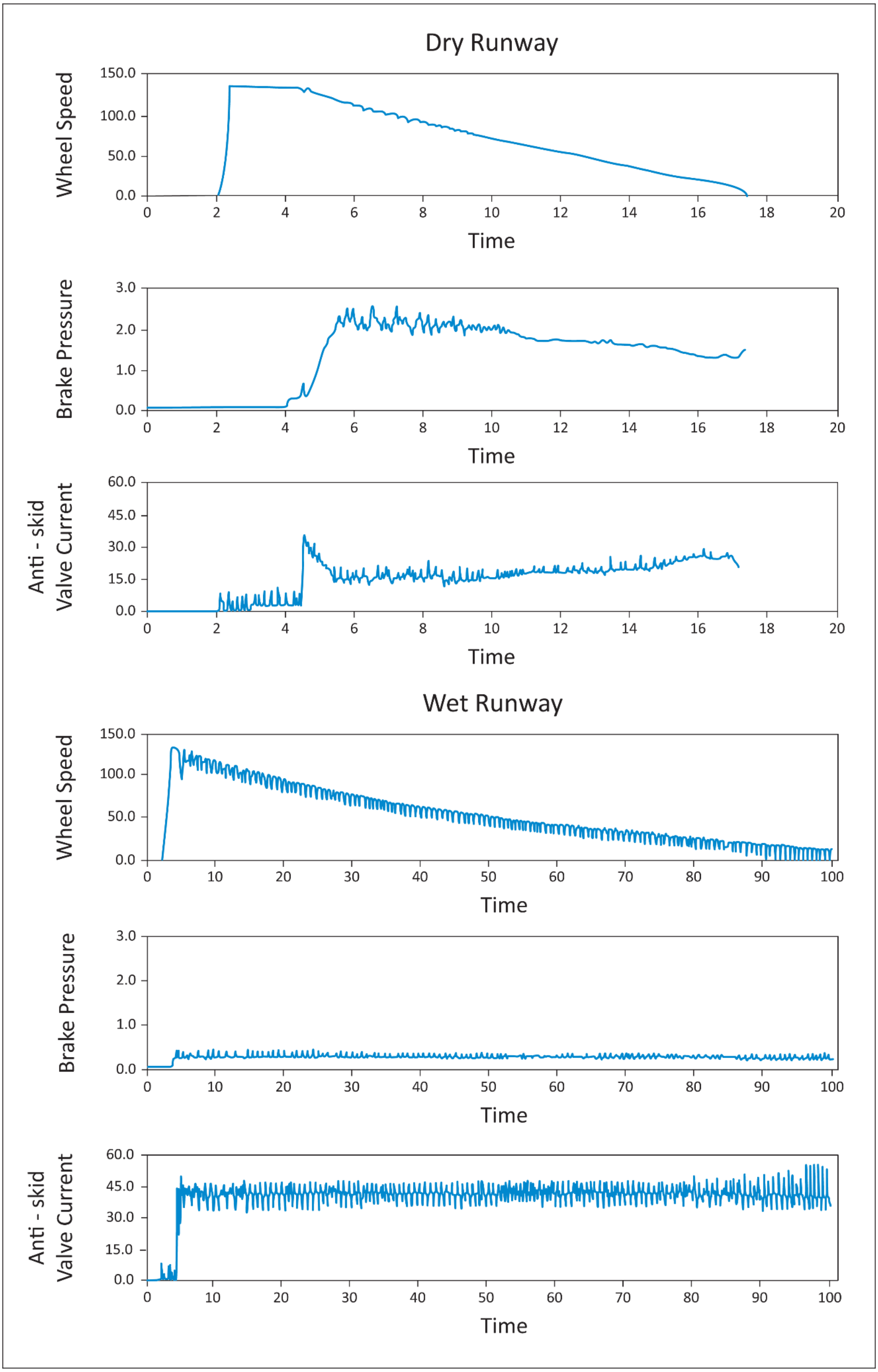
Dry Runway
Wheel Speed
150.0
100.0
50.0
0.0
0 2 4 6 8 10 12 14 16 18 20
Time
Brake Pressure
3.0
2.0
1.0
0.0
0 2 4 6 8 10 12 14 16 18 20
Time
Anti - skid
Valve Current
60.0
45.0
30.0
15.0
0.0
0 2 4 6 8 10 12 14 16 18 20
Time
Wet Runway
Wheel Speed
150.0
100.0
50.0
0.0
0 10 20 30 40 50 60 70 80 90 100
Time
Brake Pressure
3.0
2.0
1.0
0.0
0 10 20 30 40 50 60 70 80 90 100
Time
Anti - skid
Valve Current
60.0
45.0
30.0
15.0
0.0
0 10 20 30 40 50 60 70 80 90 100
Time

FIGURE 3. ANTI-SKID SYSTEM RESPONSE CHARACTERISTICS Fully Modulating System

When properly tuned, fully modulating systems are characterised by much smaller variations in brake pressure around a fairly high average value. These systems can respond quickly to developing skids and are capable of modulating brake pressure to reduce the frequency and depth of skidding. As a result, the average wheel speed remains much closer to the synchronous wheel speed. Figure 3 illustrates an example of the response characteristics of a fully modulating system on dry and wet runways.

2 *Demonstration of anti-skid system operation when using the anti-skid efficiency values specified in CS 25.109(c)(2)*

2.1 If the applicant elects to use one of the anti-skid efficiency values specified in CS 25.109(c)(2), a limited amount of flight testing must still be conducted to verify that the anti-skid system operates in a manner consistent with the type of anti-skid system declared by the applicant. This testing should also demonstrate that the anti-skid system has been properly tuned for operation on wet runways.

2.2 A minimum of one complete stop, or equivalent segmented stops, should be conducted on a smooth (i.e. not grooved or porous friction course) wet runway at an appropriate speed and energy to cover the critical operating mode of the anti-skid system. Since the objective of the test is to observe the operation (i.e. cycling) of the anti-skid system, this test will normally be conducted at an energy well below the maximum brake energy condition.

2.3 The section of the runway used for braking should be well soaked (i.e. not just damp), but not flooded. The runway test section should be wet enough to result in a number of cycles of anti-skid activity, but should not cause hydroplaning.

2.4 Before taxy and with cold tyres, the tyre pressure should be set to the highest value appropriate to the take-off weight for which approval is being sought.

2.5 The tyres and brakes should not be new, but need not be in the fully worn condition. They should be in a condition considered representative of typical in-service operations.

2.6 Sufficient data should be obtained to determine whether the system operates in a manner consistent with the type of anti-skid system declared by the applicant, provide evidence that full brake pressure is being applied upstream of the anti-skid valve during the flight test demonstration, determine whether the anti-skid valve is performing as intended and show that the anti-skid system has been properly tuned for a wet runway.

Typically, the following parameters should be plotted versus time:

(i) The speed of a representative number of wheels.

(ii) The hydraulic pressure at each brake (i.e. the hydraulic pressure downstream of the anti-skid valve, or the electrical input to each anti-skid valve).

(iii) The hydraulic pressure at each brake metering valve (i.e. upstream of the anti-skid valve).

2.7 A qualitative assessment of the anti-skid system response and aeroplane controllability should be made by the test pilot(s). In particular, pilot observations should confirm that:

(i) Anti-skid releases are neither excessively deep nor prolonged;

(ii) The gear is free of unusual dynamics; and