INTERNATIONAL STANDARD

**ISO 3324-2**

Third edition
2013-07-01

# Aircraft tyres and rims —

## Part 2:
## Test methods for tyres

*Pneumatiques et jantes pour aéronefs —*

*Partie 2: Méthodes d'essai des pneumatiques*



Reference number
ISO 3324-2:2013(E)

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# Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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The committee responsible for this document is ISO/TC 31, *Tyres, rims and valves*, Subcommittee SC 8, *Aircraft tyres and rims*.

This third edition cancels and replaces the second edition (ISO 3324-2:1998), which has been technically revised.

ISO 3324 consists of the following parts, under the general title *Aircraft tyres and rims:*

— *Part 1: Specifications*

— *Part 2: Test methods for tyres*



# Aircraft tyres and rims —

# Part 2:
# Test methods for tyres

## 1 Scope

This part of ISO 3324 specifies test methods for new and retreaded aircraft tyres in the following categories:

a) low-speed tyres: for ground speeds up to and including 104 kn (120 mile/h);

b) high-speed tyres: for ground speeds above 104 kn (120 mile/h).

NOTE 1 kn = 1,852 km/h = 1,1508 mile/h.



## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4223-1, *Definitions of some terms used in the tyre industry — Part 1: Pneumatic tyres*

## 3 Terms and definitions

For the purposes of this document, the definitions given in ISO 4223-1 apply.

## 4 Symbols

$L_0$ tyre load at start of take-off (greater than or equal to the rated load), in pounds

$L'_0$ tyre load at start of take-off for the operational load curve, in pounds

$L_1$ test tyre load at rotation, in pounds

$L'_1$ operational tyre load at rotation, in pounds

$L_2$ tyre load at lift-off, in pounds

$S_0$ speed at start of take-off, in miles per hour

$S_1$ speed at rotation, in miles per hour

$S_2$ tyre speed at lift-off, in miles per hour (greater than or equal to the rated speed)

$T_0$ time at start of take-off, in seconds

$T_1$ time at constant test load, in seconds

$T_2$ time to rotation, in seconds

$T_3$ time to lift-off, in seconds

# 5 Tyre preparation/break-in

## 5.1 Tyre conditioning

Before break-in of the tyre, it shall be conditioned by mounting on its design rim and inflating it to the rated inflation pressure. It shall be allowed to remain in this condition for 12 h at an ambient temperature between 16 °C and 37,8 °C.

## 5.2 Tyre inflation and ambient temperature

After the tyre has been stretched for 12 h on the design rim as indicated in 5.1, the tyre pressure shall be adjusted to the rated pneumatic inflation pressure and checked with a gauge which has been calibrated to within one percent. All tests shall be carried out at ambient temperatures between 16 °C and 37,8 °C.

## 5.3 Break-in procedure: static

This method of tyre break-in is to prepare the test tyre by inflating it to rated inflation pressure and loading the tyre under direct vertical load against a hard flat unyielding surface until the tyre deflection measures 50 % of the section height. The load is then removed. This break-in is to be carried out at two locations equally spaced around the tyre, with the centreline of the contact patch being located at 180° intervals around the circumference of the tyre.

## 5.4 Break-in procedure: dynamic or alternate static testing

This method of tyre break-in is to prepare the test tyre by inflating it to rated inflation pressure corrected for flywheel curvature, then performing five rated load take-off cycles with a load-speed-time curve representative of the applicable aircraft.

# 6 Static tests

## 6.1 Burst pressure (pressure proof test)

Mount the tyre on a test wheel of adequate strength, and inflate it hydraulically at a slow rate to the minimum specified burst pressure.

Maintain the tyre at this pressure for 3 s without failure.

Continue inflating the tyre at a slow rate until burst.

Burst pressure tests of tubeless tyres may be conducted with an inner tube fitted.

## 6.2 Bead seating pressure

Determine the bead seating pressure by the following method:

The contact area of the wheel is cleaned to expose the metal surface.

Three pieces of shim copper or steel, 120° from each other, are fixed to one tyre bead. The shims are held in place with light gauge non-conducting adhesive tape (see Figure 1). The tape insulates the shims from the top of the rim flange.

This procedure calls for the use of a battery, fitted with two leads, one of which is a fixed lead containing a lamp or ohmmeter; the other lead is used as the probe lead to make contact with the three shims in turn.

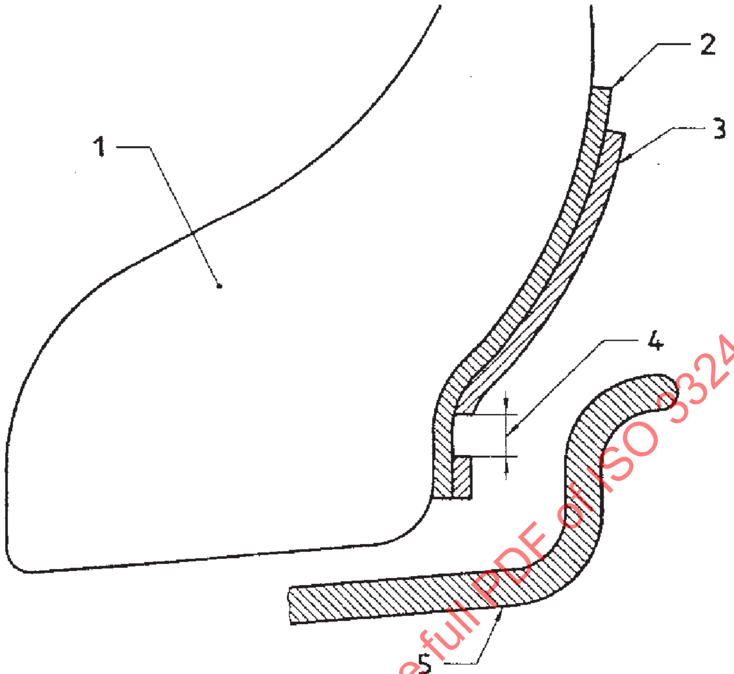
The tyre is inflated in increments, and after each increment, the probe lead is placed on the shims in turn. When the lamp lights or the ohmmeter reading is zero, at all three shim locations, the bead is considered to be fully seated on the wheel at the recorded inflation pressure, and that pressure is considered to be the bead seating pressure.



Other procedures may be used if these are recognized and approved by the certification or airworthiness authority.

In all procedures, the test shall be conducted without the use of lubricant on the tyre bead or rim.




**Key**

1 tyre bead

2 steel or copper shims 0,05 mm (0,002 in)

3 non-conducting adhesive tape, thin gauge

4 gap in tape

5 wheel

**Figure 1 — Bead seating pressure: electrical method**



## 6.3 Air retention: tubeless tyres

After an initial 12 h minimum stabilization period at rated inflation pressure, the tyre shall be capable of retaining pressure with a loss of pressure not exceeding 5 % in 24 h. Ambient temperature shall be measured at the start and finish of the test to ensure that the pressure change was not caused by an ambient temperature change.

## 6.4 Tyre dimensions

Mount the tyre on the specified rim, inflate it to its maximum rated inflation pressure and allow it to stand for a minimum of 12 h at normal room temperature. After this lapse of time, readjust the inflation to the original value.

Following the pressure adjustment, measure and record the following tyre dimensions:

— overall diameter;

— overall width;

— shoulder diameter;

— shoulder width.

When a tyre does not have a readily identifiable shoulder point, measure the shoulder width at the maximum specified shoulder diameter and measure the shoulder diameter at the maximum specified shoulder width.

## 6.5 Load-deflection curves

### 6.5.1 Tyre mounting

Mount the tyre and inflate as specified in 6.4

Install the tyre and wheel in the testing machine. Make every attempt to remove all the looseness (freeplay) between the wheel, axle, bushings, etc., so that an accurate zero point can be determined.

### 6.5.2 Vertical load deflection curves

**6.5.2.1** To obtain the zero load and deflection point, move the tyre until it barely touches the flat plate. Do not pre-load.

Vertical load deflection curves shall be obtained on the inflated tyre by applying a vertical load and measuring the corresponding deflection between the wheel flange and the unyielding flat surface against which the tyre acts. The load shall be applied beginning from the point of contact of the tyre with the flat surface until the tyre bottoms, with continuous recording of load and corresponding deflection. The load shall then be reduced until its value reaches zero once more, again continuously monitoring load and corresponding deflection. The total load deflection loop or curve shall be presented as indicative of the vertical load deflection characteristics of the tyre. The tyre pressure should be recorded throughout the test.

This test shall be carried out at two locations around the tyre, each separated by 180°. Each vertical load deflection test shall be performed at the location which is opposite from the location of the last loading, in order to minimize the effect of a flat spot.

The time rate of the tyre deflection shall be not more than 50,8 mm/min.

**6.5.2.2 Method for determining bottoming point**

**6.5.2.2.1** The tyre bottoming point is when the tyre has fully deflected its sidewall and is beginning to compress the lower sidewall structure. This is recognized by a noticeable change in the slope of the load deflection curve occurring at a high load and deflection. The bottoming point is the load and deflection at that point.

**6.5.2.2.2** For the purposes of approximating the bottoming load for a given tyre with a given inflation pressure, the bottoming load shall be considered as that load at which the rate of loading (kg/25 mm) is 2,2 times the average rate of loading between 28 % and 48 % radial deflection.

**6.5.2.2.3** The bottoming load is determined as follows (see Figure 2):

a) Conduct the load deflection test in the usual manner, obtaining sufficient data to plot a representative curve for the inflation pressure required. (This should be carried slightly beyond the slope change described in 6.5.2.2.2.)

b) Plot the load deflection curve.

c) Calculate the inverse slope (kg/25 mm) between 28 % and 48 % deflection.

   EXAMPLE 9 000 kg/36 mm = 6 250 kg/25 mm.

d) Construct a straight line (A-A) having a slope (kg/25 mm) equal to 2,2 times that calculated in c).

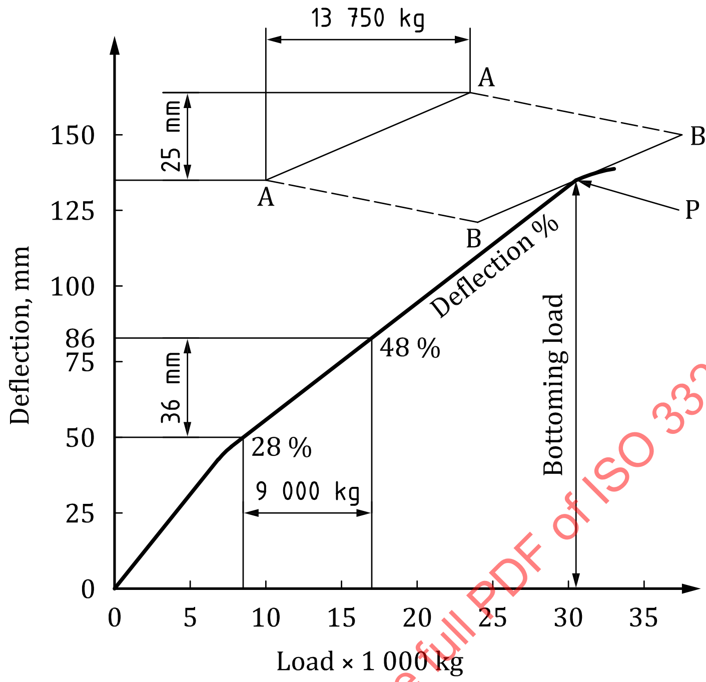
   EXAMPLE 2,2 × 6 250 = 13 750 kg/25 mm.



e) Draw line B-B parallel to A-A and tangent to the load deflection curve in the bottoming area.

f) The bottoming load will be considered that which occurs at the point of the tangency P (approximately 30 500 kg in the example given above).




NOTE Values given for illustrative purposes (see 6.5.2.2.3).

**Figure 2 — Determination of bottoming load**

### 6.5.3 Lateral load deflection curves

**6.5.3.1** The lateral deflection of the tyre is defined as the relative lateral displacement between the wheel flange at a point immediately above the centreline of the contact patch and the loading plate, parallel to the loading plate surface.

**6.5.3.2** The surface of the plate which is in contact with the tyre shall be covered with a material designed to prevent tyre slippage. Lateral load deflection curves shall be obtained by first loading the inflated tyre to the rated deflection under rated load conditions, followed by lateral displacement of the tyre yoke or the flat surface against which the tyre rests in a direction perpendicular to the wheel plane. The lateral displacement may be obtained either by displacement of the yoke or of the flat surface or both.

**6.5.3.3** Lateral load deflection curves shall be obtained by increasing the lateral load from zero to 30 % of the rated vertical load, then by decreasing this lateral force to zero and increasing it in the opposite direction to 30 % of the rated vertical load, and finally returning to 30 % of the rated vertical load, completing the loop. The load, pressure and lateral deflection shall be continuously recorded. This lateral hysteresis loop shall be obtained at a deflection rate not more than 50,8 mm/min.

**6.5.3.4** During this process of lateral deflection the vertical load of the tyre will change somewhat, unless appropriate correction is made. This shall be monitored and adjusted to a constant value equal to the rated load during the conduct of the test.

**6.5.3.5** The vertical sinkage of the tyre accompanying this vertical load adjustment shall be measured and recorded using the same vertical deflection measuring techniques as in 6.5.2. It shall be presented as a plot of vertical sinkage vs. lateral force with the accompanying vertical load and inflation pressure clearly stated.



**6.5.3.6** These lateral load deflection curves shall be obtained at two points around the periphery of the tyre, separated by 180°, and representing the centreline of the contact patch under loaded conditions. All curves shall be performed as indicative of the tyre lateral force deflection characteristics.

### 6.5.4 Fore-aft load deflection curves

**6.5.4.1** Fore-aft deflection is defined as the deflection between the wheel flange at the point immediately above the centre of the contact patch, and the motion of the flat loading surface.

**6.5.4.2** The surface of the plate in contact with the tyre shall be covered with a material designed to prevent tyre slippage. The tyre should be inflated to rated pressure with vertical loading equal to the rated load. The wheel should be restrained from rotating and marked in relationship to the tyre to indicate any tyre/wheel slippage. The fore-aft displacement may be obtained either by displacement of the yoke, or of the loading plate or both.

During the loading processes the wheel must be securely locked to prevent rotation so that no flat spots occur on the force vs. deflecting curve. Any wheel slippages should be noted.

**6.5.4.3** Fore-aft load deflection curves shall be obtained by increasing the fore-aft load from zero to 15 % of the rated vertical load, then by decreasing this fore-aft force to zero and increasing it in the opposite direction to 15 % of the rated vertical load and finally returning to 15 % of the rated vertical load, completing the loop. The load, pressure, and fore-aft deflection shall be continuously recorded. The total fore and aft hysteresis loop shall represent the fore-aft deflection characteristics of the tyre. Two such loops will be obtained, one each at two positions located 180° apart around the circumference of the tyre. The rate of loading during the fore-aft process shall not be more than 50,8 mm/min.

**6.5.4.4** During the process of fore-aft loading, vertical loads also tend to change somewhat. These shall be monitored and adjusted to a constant value equal to the rated load during the conduct of the test.

**6.5.4.5** The vertical sinkage of the tyre accompanying this vertical load adjustment shall be measured and recorded using the same vertical deflection measuring techniques as in 6.5.2. It shall be presented as a plot of vertical sinkage vs. fore-aft force with the accompanying vertical load and inflation pressure clearly stated.



# 7 Dynamometer tests

## 7.1 General

### 7.1.1 Test procedure

Tyres shall be tested by means of one of the following test procedures:

— low speed tyres shall be tested either in accordance with 7.3 or in accordance with 7.4;

— high-speed tyres shall be tested in accordance with 7.4 or in accordance with 7.6.

### 7.1.2 Test temperature and cycle interval

The temperature of the gas contained in the tyre or of the casing measured at the hottest point of the tyre shall not be lower than 41 °C at the start of 90 % of the cycles. For the remaining cycles, the contained gas or casing temperature shall not be lower than 27 °C at the start of each cycle. Rolling the tyre on the dynamometer is acceptable to obtain the minimum starting temperature.

## 7.2 Pressure correction

The test inflation pressure shall be the pressure needed to provide the same loaded radius on the flywheel as was obtained on a flat surface at the rated tire load and inflation pressure.

## 7.3 Dynamometer test procedure: low-speed tyres for which no load/speed/time/distance data are specified

### 7.3.1 Dynamometer characteristics

The tyres shall be tested on a dynamometer having a stored kinetic energy, $E_k$, in joules, at a flywheel peripheral speed of 104 kn (120 mile/h) computed as follows:

$$E_k = 485LR$$

where LR is the rated tyre load for the ply rating, in kilograms.

### 7.3.2 Tyre load

Throughout all test cycles, the tyre shall be loaded against the flywheel at a load equal to or greater than its rated tyre load (LR).

### 7.3.3 Test speeds

The tyre shall satisfactorily withstand 200 landing cycles on a variable mass dynamometer flywheel, without any detectable signs of deterioration, other than normal tread/surface abrasion. If the exact number of flywheel plates cannot be used to obtain the calculated kinetic energy value, a greater number of plates shall be selected and the dynamometer speed adjusted to obtain the required kinetic energy. The total number of dynamometer landings shall be divided into two equal parts having the speed ranges described below.

a) In the first series of 100 cycles, the tyre shall be loaded ("landed") against the flywheel at 78 kn (90 mile/h) and the tyre unloaded ("unlanded") at zero speed. The speed at "landing" shall be decreased as necessary (see 7.3.4) to ensure that 56 % of the calculated kinetic energy is absorbed by the tyre during each cycle.

b) In the second series of 100 cycles, the tyre shall be loaded ("landed") against the flywheel at 104 kn (120 mile/h) and the tyre unloaded ("unlanded") at 78 kn (90 mile/h). The speed of "unlanding" shall be increased as necessary (see 7.3.4) to ensure that 44 % of the calculated kinetic energy is absorbed by the tyre during each cycle.

All speeds shall be expressed in knots.

### 7.3.4 Flywheel kinetic energy

If the correct number of flywheel plates cannot be used to obtain the computed kinetic energy value (see 7.3.1), a greater number of plates shall be selected and the dynamometer test cycle speed adjusted to obtain the required kinetic energy for each series of test cycles. If this results in landing speeds of less than 70 kn (80 mile/h), the following shall apply:

— landing speed shall be determined by adding 28 % of the test $E_k$ to the flywheel $E_k$ at 55,6 kn (64 mile/h);

— unlanding speed shall then be determined by subtracting 28 % of the test $E_k$ from the flywheel $E_k$ at 55,6 kn (64 mile/h).

## 7.4 Dynamometer test procedure: low- and high-speed tyres

### 7.4.1 Test specimen

A single test specimen shall be used for a qualification test. The tyre shall withstand the following cycles without detectable signs of deterioration, other than normal expected tread surface abrasion, except when the overload take-off condition is run last (see 7.4.9).



### 7.4.2 Dynamometer cycle requirements

All aircraft tyres shall satisfactorily withstand 61 dynamometer cycles. The dynamometer cycles shall consist of 50 take-off cycles and eight taxi cycles, two taxi cycles at 1,2 times the rated load, and one overload take-off cycle starting at 1,5 times the rated load. The sequence of running the dynamometer cycles is optional. If the overload take-off is not run last, the tyre shall not show detectable signs of deterioration, other than normal tread/surface abrasion, after this test.

### 7.4.3 Take-off cycles

The 50 take-off cycles shall realistically simulate tyre performance during runway operations for the most critical combination of take-off weight and speed, and aircraft centre-of-gravity position. Consideration shall be given to increased speeds resulting from elevated airport operations and high ambient temperatures. The load-speed-time (LST) data shall be compiled by the airframe manufacturer in compliance with the applicable airworthiness authority requirements. Refer to Figures 3, 4 and 5 for graphic representations of the test.

Starting at zero speed, the tyre shall be loaded against the dynamometer flywheel. The test cycles shall simulate one of the curves in Figures 3, 4 and 5.

— Figure 3 defines a test cycle that is applicable to any aircraft tyre with a speed rating of 104 kn (120 mile/h) to 139 kn (160 mile/h).

— Figure 4 defines a test cycle that is applicable to any aircraft tyre with a speed rating greater than 139 kn (160 mile/h).

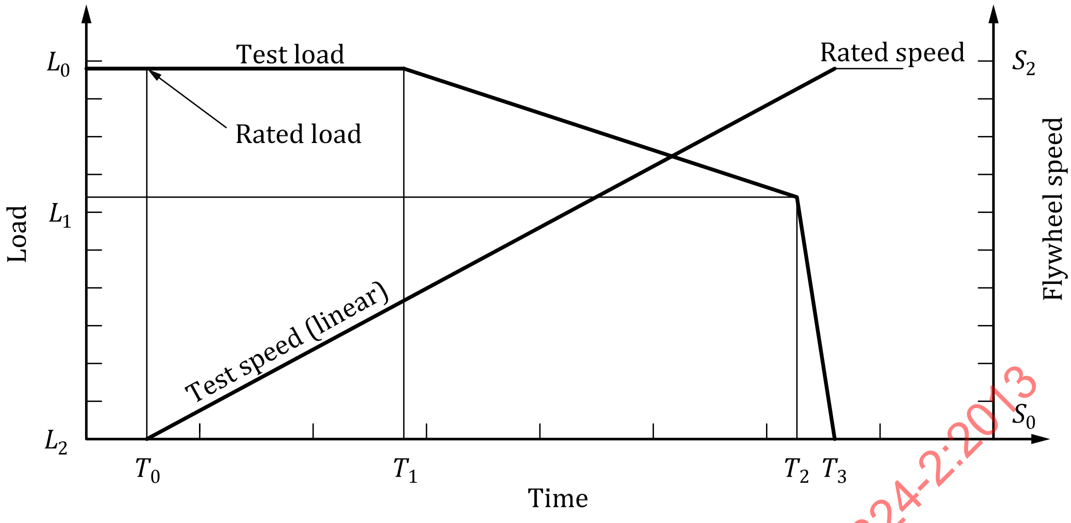
— Figure 5 defines a test cycle that is applicable for any speed rating.

### 7.4.4 Test load

The load at the start of the test shall be no less than the rated load of the tyre. The test loads shall conform to Figures 3, 4 or 5. Figures 3 and 4 define a test cycle that is generally applicable to any aircraft. If Figure 5 is used to define the test cycle, the loads shall be selected based on the most critical take-off conditions established by the applicant based on the data obtained from the airframe manufacturer. At any speed throughout the test cycle, the ratio of the test load to the airframe manufacturer's LST curve shall be the same as or greater than at the start of the test.



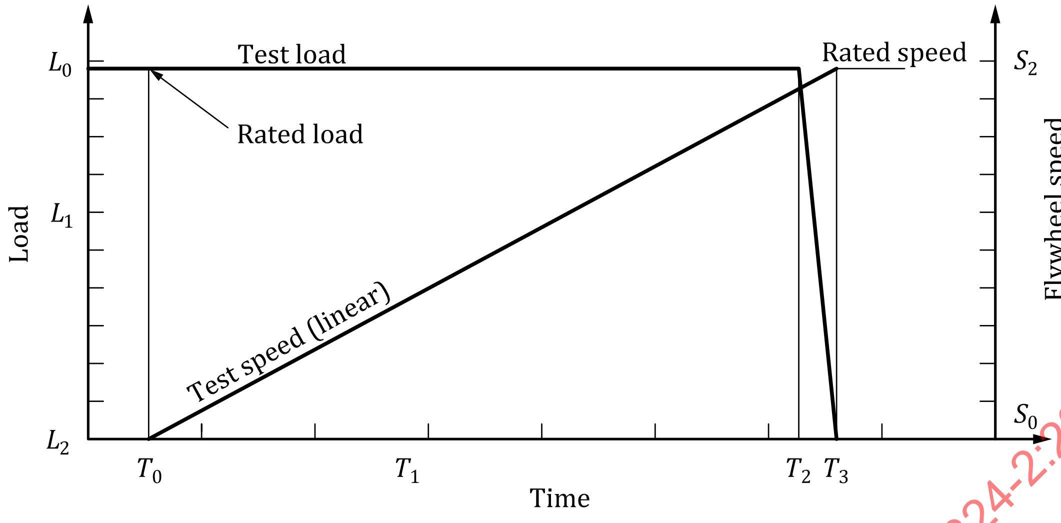



**Key**

| | | | |
|---|---|---|---|
| $L_1$ | 0,65 $L_0$ | $S_0$ | zero speed |
| $L_2$ | zero load | Roll distance | 1 981 m |
| $T_0$ | start time | $T_3$ - $T_2$ | 3 s max |
| $T_1$ | 20 s | | |

NOTE Test load at $L_0$ shall be equal to or greater than rated load of tyre. Test speed at $S_2$ shall be equal to or greater than rated speed of tyre.

**Figure 3 — Graphic representation of a universal load-speed-time test cycle — 104 kn (120 mile/h) to 139 kn (160 mile/h)**

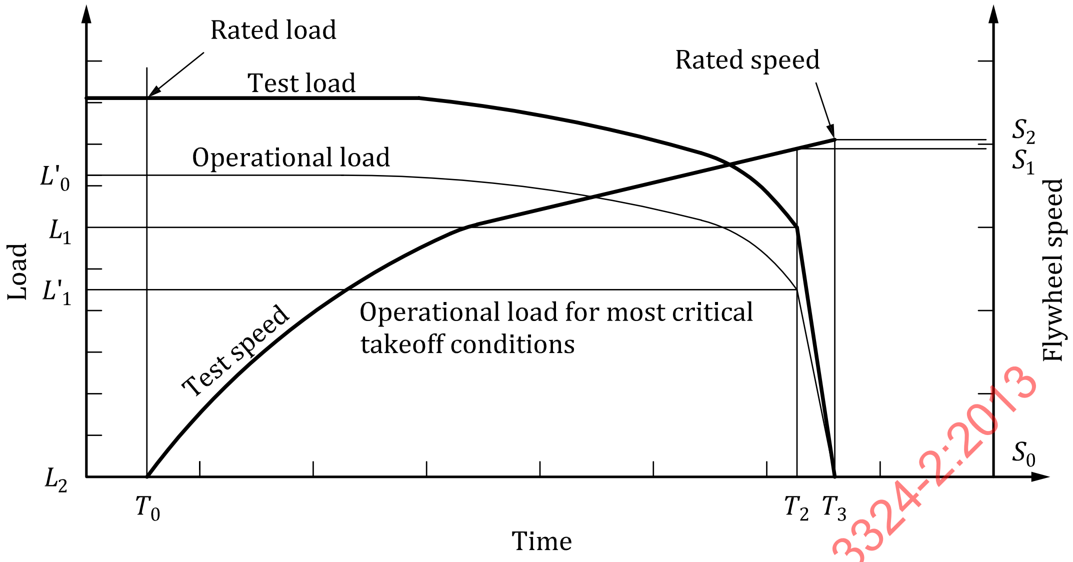



**Key**

| | |
|---|---|
| $T_0$ | start time |
| $L_2$ | zero load |
| $S_0$ | zero speed |
| Roll distance | 3 505 m |
| $T_3$ - $T_2$ | 3 s max |

NOTE Test load at $L_0$ shall be equal to or greater than rated load of tyre. Test speed at $S_2$ shall be equal to or greater than rated speed of tyre.

**Figure 4 — Graphic representation of a universal load-speed-time test cycle — above 139 kn (160 mile/h)**




**Key**

$T_0$ start time

$L_1$ tyre load at rotation

$L_2$ zero load

$T_2$ time at rotation

$T_3$ time at end of cycle

$S_0$ zero speed

$S_1$ speed at rotation

$L'_1$ tyre load

$L'_0$ tyre load at start of take-off for operational load curve

NOTE 1 Test load at $L_0$ shall be equal to or greater than rated load of tyre. Test speed at $S_2$ shall be equal to or greater than rated speed of tyre.

NOTE 2 Test load at any speed shall be equal to or greater than operational load. Test Load ≥ $L'_1$ x ($L_0$ / $L'_0$). Roll distance is determined for each application.

**Figure 5 — Graphic representation of a rational load-speed-time test cycle**



### 7.4.5 Test inflation pressure

The test inflation pressure shall be that which is necessary to provide the same loaded radius on the flywheel as was obtained on a flat surface at the rated load and inflation pressure of the tyre. Both determinations shall be made at the same ambient temperature. An adjustment in test inflation pressure may not be made to compensate for changes created by temperature variations during the test.

### 7.4.6 Test temperatures and cycle interval

The temperature of the gas contained in the tyre or of the casing measured at the hottest point of the tyre shall not be lower than 41°C at the start of the overload take-off and at the start of at least 45 of the 50 take-off cycles, and 49°C at the start of at least nine of the ten taxi cycles. For the remaining cycles, the contained gas or casing temperature shall not be lower than 27°C at the start of each cycle. Rolling the tyre on the dynamometer flywheel is acceptable to obtain the minimum starting temperature.

### 7.4.7 Dynamometer take-off cycle speeds

The dynamometer test speeds for corresponding maximum aircraft take-off speeds are those given in Table 2.

### 7.4.8 Taxi cycles

The tyre shall withstand 10 taxi cycles on a dynamometer under the test conditions given in Table 1.

**Table 1 — Taxi cycle test conditions**

| Number of taxis | Minimum tyre load | Minimum speed | Minimum roll distance m | |
|---|---|---|---|---|
| | kg | kn | Tyre speed rating | |
| | | | 104 kn (120 mile/h) to 139 kn (160 mile/h) | > 139 kn (160 mile/h) |
| 8 | rated load | 35 | 7 620 | 10 668 |
| 2 | 1,2 × rated load | 35 | 7 620 | 10 668 |

### 7.4.9 Overload take-off cycle

The overload take-off cycle shall duplicate the test described in 7.4.3 except that the test load shall be increased by a factor of 1,5 throughout. The tyre tread is not required to be in good condition after completion of this test cycle if it is run last. If the overload take-off cycle is not run last, it shall withstand the cycle without detectable signs of deterioration, other than normal tread/surface abrasion.

### 7.4.10 Diffusion test

Upon completion of the 61 test cycles, the tyre shall be capable of retaining inflation pressure for 24 h with the loss of pressure not exceeding 10 % of the initial test pressure. Ambient temperature should be measured at the start and finish of this test to ensure that the pressure change was not caused by an ambient temperature change.

### 7.4.11 Tyre/wheel slippage

No slippage of the tyre on the rim is allowed in the first five cycles. Slippage of the tyre on the rim during the subsequent cycles shall not damage the tube valve of tube type tyres, or the gas seal of the tyre bead of tubeless tyres.

## 7.5 Dynamometer test speeds

The applicable dynamometer test speeds for corresponding maximum operational ground speeds shall be as given in Table 2.

**Table 2 — Dynamometer test speeds**

| Maximum operational ground speed of aircraft kn (mile/h) | | Dynamometer test speed kn (mile/h) |
|---|---|---|
| above | to | |
| 0 | 104 (120) | 104 (120) |
| 104 (120) | 139 (160) | 139 (160) |
| 139 (160) | 165 (190) | 165 (190) |
| 165 (190) | 182 (210) | 182 (210) |
| 182 (210) | 195 (225) | 195 (225) |
| 195 (225) | 204 (235) | 204 (235) |
| 204 (235) | 213 (245) | 213 (245) |
| 213 (245) | | Consult the aircraft manufacturer |