



JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS D 1012 : 2005

(JSAE/JSA)

Automobiles—Rate of fuel consumption test methods

ICS 43.060.40

Reference number : JIS D 1012 : 2005 (E)

PROTECTED BY COPYRIGHT

Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee, as the result of proposal for revision of Japanese Industrial Standard submitted by Society of Automotive Engineers of Japan, Inc. (JSAE)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently **JIS D 1012 : 1997** is replaced with this Standard.

Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have technical properties. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have the said technical properties.

Date of Establishment: 1954-05-22

Date of Revision: 2005-03-20

Date of Public Notice in Official Gazette: 2005-03-22

Investigated by: Japanese Industrial Standards Committee

Standards Board

Technical Committee on Road Vehicles

JIS D 1012:2005, First English edition published in 2005-12

Translated and published by: Japanese Standards Association
4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440 JAPAN

In the event of any doubts arising as to the contents,
the original JIS is to be the final authority.

© JSA 2005

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from the publisher.

Printed in Japan

PROTECTED BY COPYRIGHT

Contents

	Page
1 General	1
1.1 Scope	1
1.2 Normative references	1
1.3 Definitions	2
2 Running resistance measuring method	3
2.1 Tolerance of required measuring accuracy.....	3
2.2 On-road measurement of running resistance	3
2.3 Measuring running resistance by bench method	14
3 Setting running resistance on the chassis dynamometer	17
3.1 Tolerance of required measuring accuracy.....	17
3.2 Test preparations	17
3.3 Setting the load	18
3.4 Records of running resistance measurement and load setting.....	22
4 Fuel consumption test method	22
4.1 Test preparations	22
4.2 Method for connecting test automobile with fuel consumption rate measuring equipment	23
4.3 Test method.....	24
4.4 Calculation of rate of fuel consumption.....	29
Annex 1 (informative) Method of on-road fuel consumption test	34
Annex 2 (informative) Measuring running resistance by vehicle-mounted wind direction and wind velocity meter method.....	39
Annex 3 (informative) Equations for direct regression method	41
Annex 4 (informative) Correction of rolling resistance measured by a chassis dynamometer	43
Annex 5 (normative) Calculating running resistance in chassis dynamometer tests.....	48
Annex 6 (normative) Adjustment of load set to a chassis dynamometer	50

Annex 7 (informative)	Conversion of target running resistance by the wheel torque method to that of the coasting method	52
Annex 8 (informative)	Guidance for installation of a fuel flow meter	53
Annex 9 (normative)	Simple calculation methods of numerical ratios of hydrogen atoms and carbon atoms and of oxygen atoms and carbon atoms in gasoline and gas oils	54
Annex 10 (informative)	Calculation method of fuel consumption used in USA and Europe	56
Annex 11 (informative)	Driving method for 10 · 15 mode running uniquely used in Japan	58

Automobiles—Rate of fuel consumption test methods

1 General

1.1 Scope This Japanese Industrial Standard specifies test methods for fuel consumption rate (hereafter referred to as “fuel consumption”) of automobiles with a vehicle mass of not more than 3 500 kg measured on a chassis dynamometer. See Annex 1 (informative) for test methods for on-road fuel consumption. However, this Standard is not applicable to two-wheeled vehicles.

1.2 Normative references The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

- JIS D 0102 *Road vehicles—Dimensions, masses, weights and performances—Vocabulary*
- JIS D 1030 *Automobiles—Analytical procedure for measurement of carbon monoxide, carbon dioxide, total hydrocarbons and oxides of nitrogen in exhaust gas*
- JIS K 2202 *Motor gasoline*
- JIS K 2204 *Diesel fuel*
- JIS K 2240 *Liquefied petroleum gases*
- JIS K 2249 *Crude petroleum and petroleum products—Determination of density and petroleum measurement tables based on a reference temperature (15 °C)*
- JIS K 2254 *Petroleum products—Determination of distillation characteristics*
- JIS K 2255 *Petroleum products—Gasoline—Determination of lead content*
- JIS K 2258 *Crude oil and petroleum products—Determination of vapour pressure—Reid method*
- JIS K 2261 *Petroleum products—Motor gasoline and aviation fuels—Determination of existent gum—Jet evaporation method*
- JIS K 2265 *Crude oil and petroleum products—Determination of flash point*
- JIS K 2280 *Petroleum products—Fuels—Determination of octane number, cetane number and calculation of cetane index*
- JIS K 2283 *Crude petroleum and petroleum products—Determination of kinematic viscosity and calculation of viscosity index from kinematic viscosity*
- JIS K 2536 *Liquid petroleum products—Testing method of components*
- JIS K 2541 *Crude oil and petroleum products—Determination of sulfur content*

1.3 Definitions The definitions of principal terms used in this Standard are in accordance with **JIS D 0102** and the following items:

- a) **running resistance** running resistance obtained by the coasting method or the bench method including frictional losses except for the engine
- b) **running load torque** resistance torque at running measured by a wheel torque meter mounted on the driving wheel including driving system loss downstream from the torque meter
- c) **running resistance** generic term for the types of resistance specified in a) and b) above
- d) **air resistance** resistance received in the air while a vehicle is advancing. Corresponds to the quadratic term of the vehicle when the running resistance is expressed by the quadratic equation of the vehicle speed.
- e) **rolling resistance** Resistance generated by the driving system and turning of the axle and type. Corresponds to the primary term and constant term of the vehicle speed when the running resistance is expressed by the quadratic equation of the vehicle speed.
- f) **reference vehicle speed** vehicle speed used to verify repeatability of the set running resistance by a chassis dynamometer
- g) **measurement point speed** Vehicle speed for measurement of running resistance. This should preferably be identical to the reference vehicle speed.
- h) **standard atmospheric conditions** standard conditions for conversion of running resistance which shall be as follows:
 - 1) **Air temperature** $T_0 = 20\text{ }^{\circ}\text{C}$
 - 2) **Atmospheric pressure** $P_0 = 100\text{ kPa}$
 - 3) **Atmospheric density** $\rho_0 = 1.189\text{ kg/m}^3$
 - 4) **Wind velocity** 0 m/s (Calm state)
- i) **atmosphere measuring station** a device to measure wind direction and wind velocity provided at the side of the test road at a point where most representative wind direction and wind velocity are observed during testing
- j) **force converted to roller surface** torque measured by a chassis dynamometer divided by the roller radius and converted to a force in the tangential direction of the roller surface
- k) **chassis dynamometer set load** running resistance exerted to a chassis dynamometer
- l) **regression running resistance** running resistance calculated by an equation obtained by quadratic regression by the least square method using running resistance data at more than one measuring point
- m) **coefficient setting chassis dynamometer** a chassis dynamometer set by coefficients of functions expressing running resistance

- n) **multipoint setting chassis dynamometer** a chassis dynamometer which sets running resistance by measuring running resistance at more than one vehicle speed point

2 Running resistance measuring method

2.1 Tolerance of required measuring accuracy Tolerance of measuring accuracy during tests is as follows: Equipment used for measuring each test item shall be maintained and calibrated based on the handling guidance specified by the manufacturer of the equipment concerned.

- a) **Vehicle speed:** $\pm 0.5 \text{ km/h}$ or $\pm 1 \%$, whichever is greater
- b) **Time:** $\pm 20 \text{ ms}$ or $\pm 0.1 \%$, whichever is greater
- c) **Wheel torque:** $\pm 3 \text{ N} \cdot \text{m}$ or $\pm 0.5 \%$, whichever is greater
- d) **Wind velocity:** $\pm 0.3 \text{ m/s}$
- e) **Wind direction:** $\pm 3^\circ$
- f) **Air temperature:** $\pm 1^\circ \text{C}$
- g) **Atmospheric pressure:** $\pm 0.3 \text{ kPa}$
- h) **Vehicle mass:** $\pm 10 \text{ kg}$
- i) **Tyre air pressure:** $\pm 5 \text{ kPa}$
- j) **Product of air drag coefficient and frontal projected area (SC_d):** $\pm 2 \%$
- k) **Roller speed of chassis dynamometer:** $\pm 0.5 \text{ km/h}$ or $\pm 1 \%$, whichever is greater
- l) **Force converted to chassis dynamometer roller surface:** $\pm 10 \text{ N}$ or $\pm 0.1 \%$ of full scale whichever is greater

2.2 On-road measurement of running resistance

2.2.1 Road test requirements

2.2.1.1 Atmospheric conditions during tests

2.2.1.1.1 Wind velocity The average wind velocity measured at the atmosphere measuring station shall be not more than 5 m/s and the beam wind component shall be not more than 3 m/s .

2.2.1.1.2 Air temperature To be in the range of 1°C to 35°C .

2.2.1.2 Test road conditions The test road shall be straight, the surface shall be flat, dry and paved, and the road surface roughness shall be representative of ordinary roads. The gradient of the road shall be $\pm 1 \%$ in the advancing direction and the gradient at two arbitrary points each 3 m apart shall be $\pm 0.5 \%$ with regard to the gradient in the advancing direction. Further, the gradient in the lateral direction shall be not more than 1.5% .

2.2.2 Test preparations

2.2.2.1 Preparing the vehicle

2.2.2.1.1 Vehicle condition A running-in shall be performed on the vehicle and tyres in advance of testing and according to the test objective. Tyre tread depth shall be not less than 50 % of that required for new tyres. The test vehicle shall be in the normal state specified by the manufacturer, unless otherwise required. This includes proper adjustment of tyre air pressure, wheel alignment, vehicle height, lubrication of the driving system and wheel bearings, and braking force. The engine hood, windows, air conditioning system, and headlight covers shall be closed during the test. The vehicle mass shall include the operator and measuring equipment and be adjusted to the state appropriate for test purposes.

2.2.2.1.2 Adjustment of tyre air pressure The tyre air pressure shall be adjusted to the specified pressure when there is a temperature difference within 5 °C between the adjustment site and the test road. When the temperature difference exceeds 5 °C, the following procedures shall be taken:

- a) The tyre air pressure shall be set approximately 10 % higher than the specified air pressure and the tyres soaked for 4 h or over.
- b) Immediately before the test, the tyre air pressure shall be reduced to the specified level at the place of soaking. Air pressure shall then be added according to the following equation, which is based on the air temperatures at the adjustment site and on the test road.

$$P_t = 0.8 \times (T_{\text{soak}} - T_{\text{amb}})$$

where, P_t : addition of tyre air pressure (kPa)

T_{soak} : air temperature at the place where the vehicle is stored and the air pressure adjusted (°C)

T_{amb} : air temperature on test road (°C)

2.2.2.1.3 Mounting of measuring equipment All measuring equipment, especially that mounted on the vehicle exterior, shall be mounted so that the effect on vehicle movement may be minimized.

2.2.2.1.4 Vehicle warm-up Prior to the test, an appropriate warm-up run shall be performed at a vehicle speed not more than the highest reference speed. Normally, the vehicle shall be run at a standard speed (60 km/h for a 10·15 mode test) for approximately 30 min.

2.2.3 Measuring running resistance by coasting The multipoint regression method and direct regression method are used to obtain equations for running resistance by coasting.

Information : Alternatively, running resistance is corrected through simultaneous mathematical processing of vehicle speed data at coasting and relative wind direction and wind velocity data measured with wind vehicle-mounted direction and wind velocity meters. This is specified in Annex 2 (informative).

2.2.3.1 Multipoint regression method

2.2.3.1.1 Selection of vehicle speed at measuring points Vehicle speed at a minimum of four running resistance measuring points shall be selected in order to obtain a running resistance curve in the form of a function of the vehicle speed. The selected maximum and minimum vehicle speeds shall include all reference vehicle speeds for verification of running resistance obtained on a chassis dynamometer. Measuring points for vehicle speed shall be in increments of 10 km/h with the minimum being 20 km/h.

2.2.3.1.2 Coasting of vehicle Following a warm-up run, the vehicle shall be operated as necessary for 1 min at the fastest measurement point speed. The vehicle speed shall then be increased to 5 km/h faster than the measurement start vehicle speed ($V_j + \Delta V$) and coasting shall begin immediately. The time elapsed between ($V_j + \Delta V$) and ($V_j - \Delta V$) shall be measured corresponding to each measurement point speed V_j . Although, basically, ΔV shall be 5 km/h, 10 km/h may be used with V_j more than 60 km/h. During coasting, the transmission gear shall be in the NEUTRAL position and the engine in the idling state. For vehicles equipped with a manual transmission, the clutch shall be kept engaged. The steering wheel shall be manipulated as little as possible and the brake pedal shall not be pressed. The coasting test shall be repeated in a reciprocating manner, assuring that vehicle speed at coasting start and vehicle condition are unchanged. While it is preferable that the coasting test be performed uninterrupted from the maximum to the minimum measuring points, the test may be divided if necessary. However, in this event, care shall be taken to assure that there is minimal change in the vehicle state at the point of division.

2.2.3.1.3 Verifying test accuracy The test shall be performed not less than three times in a reciprocating manner and be repeated until test accuracy p meets the following criterion:

$$p = \frac{ts}{\sqrt{n}} \times \frac{100}{\Delta T_j} \leq 3$$

where, p : accuracy of test (%)

n : number of repetitions of the measurement pair

ΔT_j : average coasting time at vehicle speed V_j which is obtained by the following equation:

$$\Delta T_j = \frac{1}{n} \sum_{i=1}^n \Delta T_{ji}$$

where, ΔT_{ji} denotes the harmonic average of the coasting time pair j at vehicle speed V_j at measuring point i and is given by the following equation:

$$\Delta T_{ji} = \frac{2}{1/\Delta T_{jai} + 1/\Delta T_{jbi}}$$

where, ΔT_{jai} and ΔT_{jbi} denote time (s) for coasting i in each reciprocating direction at vehicle speed V_j

s : standard deviation given by the following equation:

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (\Delta T_{ji} - \Delta T_j)^2}$$

t : coefficient given in table 1

Table 1 t and $t/\sqrt{n}$ for number of repetitions n of the measurement pair

n	t	$t/\sqrt{n}$
3	4.3	2.48
4	3.2	1.60
5	2.8	1.25
6	2.6	1.06
7	2.5	0.94
8	2.4	0.85
9	2.3	0.77
10	2.3	0.73
11	2.2	0.66
12	2.2	0.64
13	2.2	0.61
14	2.2	0.59
15	2.2	0.57

2.2.3.1.4 Determination of running resistance Running resistance at vehicle speed V_j is given by the following equation:

$$F_j = -\frac{1}{3.6} \times (m + m_r) \times \frac{2 \times \Delta V}{\Delta T_j}$$

where, F_j : running resistance (N)

m : vehicle mass during testing (kg)

m_r : inertia mass corresponding to the rotating part of the vehicle driving system (kg)

This is normally considered to be 3 % of empty vehicle mass.

ΔV : half of the vehicle speed divided for measurement of coasting time (km/h)

Running resistance is expressed by the following quadratic equation using the data pair (V_j, F_j) at each measuring point:

$$F = f_0 + f_1 V + f_2 V^2$$

where, F : running resistance (N)

f_0 : constant term of running resistance (N)

f_1 : coefficient of the primary term of V of running resistance [N/(km/h)]

f_1 may be 0 if $f_1 V$ is less than 3 % of F at each measurement point speed. In this case, coefficients f_0 and f_2 shall be recalculated.

f_2 : coefficient of the quadratic term V of running resistance [N/(km/h)²]

V : vehicle speed (km/h)

2.2.3.2 Direct regression method Regression is performed collectively using all the vehicle data for lapse of time from start to completion of measurement. Equations of the running resistance curve are obtained according to the following procedures:

Vehicle speed is expressed by the following function of $\tan$ by the least square method:

$$V = A \tan(B_t + C) + D$$

Running resistance curve is obtained by the following equation:

$$F = f_0 + f_1 V + f_2 V^2$$

$$f_0 = -\frac{1}{3.6} \times (m + m_r) \times \left(\frac{B}{A}\right) \times (A^2 + D^2)$$

$$f_1 = \frac{1}{3.6} \times (m + m_r) \times \frac{2 \times BD}{A}$$

$$f_2 = -\frac{1}{3.6} \times (m + m_r) \times \frac{B}{A}$$

Information : The reasons f_0 , f_1 and f_2 are expressed by A , B and D in the above equations are given in Annex 3 (informative).

2.2.4 Measuring running resistance by wheel torque meter

2.2.4.1 Mounting of measuring equipment The wheel torque meter shall be mounted to the driving wheel of the vehicle. Zero adjustment and span adjustment of the wheel torque meter shall be performed immediately before running the resistance test.

2.2.4.2 Selection of measurement point speed To be in compliance with 2.2.3.1.1.

2.2.4.3 Test During testing, the vehicle speed and running load torque of each wheel shall be measured after the vehicle speed at each measuring point is stabilized. Measurement shall be continued for not less than five seconds. Data sampling shall preferably be at a frequency of not less than 4 Hz. Vehicle speed tolerance with regard to the average vehicle speed during testing shall be in accordance with table 2.

Table 2 Vehicle speed tolerance

Measuring time s	Vehicle speed tolerance km/h
5 or over to and excl. 10	±0.2
10 or over to and excl. 15	±0.4
15 or over to and excl. 20	±0.6
20 or over to and excl. 25	±0.8
25 or over to and excl. 30	±1.0
30 or over	±1.2

2.2.4.4 Calculating average vehicle speed and average running load torque

Average vehicle speed and average running load torque are obtained by the following equations:

$$V_{jm} = \frac{1}{k} \sum_{i=1}^k V_{ji}$$

$$C_{jm} = \frac{1}{k} \sum_{i=1}^k C_{ji} - C_{js}$$

where, V_{jm} : average vehicle speed at measuring point j (km/h)

k : number of data sets

V_{ji} : i vehicle speed at measuring point j vehicle speed (km/h)

C_{jm} : j average running load torque (N · m)

C_{ji} : i reciprocation average running load torque at measuring point j vehicle speed (N · m)

C_{js} : correction term for vehicle speed drift. Although C_{js} shall be ± 5 % of the average running load torque, this may be neglected when α_j is ± 0.005 m/s². C_{js} is expressed by the following equation:

$$C_{js} = (m + m_r)\alpha_j r_j$$

where, m : vehicle mass during testing (kg)

m_r : inertia mass equivalent to rotating parts (kg)

This is normally considered to be 3 % of empty vehicle mass.

r_j : j radius of tyre (m)

This is obtained by the following equation:

$$r_j = \frac{1}{3.6} \times \frac{V_{jm}}{2\pi N}$$

where, N : rotational frequency of driving wheel (s⁻¹)

α_j : average acceleration (m/s²). This is obtained by the following equation:

$$\alpha_j = \frac{1}{3.6} \times \frac{k \sum_{i=1}^k t_i V_{ji} - \sum_{i=1}^k t_i \sum_{i=1}^k V_{ji}}{k \sum_{i=1}^k t_i^2 - \left(\sum_{i=1}^k t_i \right)^2}$$

where, t_i : i data measurement time (s)

2.2.4.5 Verification of test accuracy The test shall be performed not less than three times in each reciprocating direction and be repeated until test accuracy p meets with the following criterion:

$$p = \frac{ts}{\sqrt{k}} \times \frac{100}{\bar{C}_j} \leq 3$$

where, p : test accuracy (%)

k : number of data sets.

$\bar{C}_j$: average running load torque at vehicle speed V_j .

This is obtained by the following equation:

$$\bar{C}_j = \frac{1}{k} \sum_{i=1}^k C_{jm,i}$$

where, $C_{jm,i}$ denotes i average running load torque in each reciprocating direction at vehicle speed V_j . This is obtained by the following equation:

$$C_{jm,i} = \frac{1}{2} \times (C_{jma,i} + C_{jmb,i})$$

where, $C_{jma,i}$ and $C_{jmb,i}$ denote i running load torque in each reciprocating direction at vehicle speed V_j (N·m)

s : standard deviation given by the following equation:

$$s = \sqrt{\frac{1}{k-1} \sum_{i=1}^k (C_{jm,i} - \bar{C}_j)^2}$$

t : coefficient given by replacing n in table 1 in **2.2.3.1.3** by k

2.2.4.6 Accuracy verification of measured average vehicle speed The difference between average reciprocation vehicle speed $V_{jm,i}$ for each of k repetitions and average vehicle speed $\bar{V}_j$ for all k repetitions shall be ± 2 km/h. $\bar{V}_j$ and $V_{jm,i}$ are obtained by the following equations:

$$\bar{V}_j = \frac{1}{k} \sum_{i=1}^k V_{jm,i}$$

$$V_{jm,i} = \frac{1}{2} (V_{jma,i} + V_{jmb,i})$$

where, $\bar{V}_j$: average vehicle speed measured k repetitions (km/h)
 $V_{jma,i}, V_{jmb,i}$: average vehicle speed in each reciprocating direction
 i at vehicle speed V_j (km/h)

2.2.4.7 Determination of running resistance Running resistance shall be expressed by a quadratic regression equation of vehicle speed for each reciprocating running.

$$C_a = c_{0a} + c_{1a}V + c_{2a}V^2$$

$$C_b = c_{0b} + c_{1b}V + c_{2b}V^2$$

where, C_a, C_b : running load torque for each reciprocating direction (N·m)

c_{0a}, c_{0b} : constant term for each reciprocating direction (N·m)

c_{1a}, c_{1b} : coefficient of the primary term for each reciprocating direction [N·m/(km/h)]

c_{2a}, c_{2b} : coefficient of the quadratic term for each reciprocating direction [N·m/(km/h)²]

V : vehicle speed (km/h)

Average running resistance is obtained by the following equation:

$$C_{ave} = c_0 + c_1V + c_2V^2$$

$$\text{where, } c_0 = \frac{(c_{0a} + c_{0b})}{2}, \quad c_1 = \frac{(c_{1a} + c_{1b})}{2}, \quad c_2 = \frac{(c_{2a} + c_{2b})}{2}$$

C_{ave} : average running resistance of reciprocation (N·m)

c_0 : average constant term of reciprocation (N·m)

c_1 : average coefficient for primary term of reciprocation [N·m/(km/h)]

c_1 may be 0 if c_1V is less than 3 % of C_{ave} at vehicle speed at each measuring point. In this case, coefficients c_0 and c_2 shall be recalculated.

c_2 : average coefficient of the quadratic term of reciprocation [N·m/(km/h)²]

2.2.5 Correction for standard atmospheric conditions

2.2.5.1 Coasting method Correction for standard air temperature, atmospheric pressure and calm state shall be accomplished by the following equation:

2.2.5.1.1 General correction method

$$F^* = \{(f_0 - w_1) + f_1V\} \times \{1 + K_0(T - 20)\} + K_2f_2V^2$$

where, F^* : corrected running resistance (N)

f_0 : constant term (N)

- f_1 : coefficient of the primary term [N/(km/h)]
 f_2 : coefficient of the quadratic term [N/(km/h)²]
 w_1 : wind correction (N). This is obtained by the following equation:

$$w_1 = 3.6^2 \times f_2 V_w^2$$

where, V_w is the average of the absolute value for test road wind velocity (m/s)

- V : vehicle speed (km/h)
 T : average temperature of test road (°C)
 K_0 : correction coefficient for rolling resistance

$$K_0 = 8.1 \times 10^{-3} (°C^{-1})$$

- K_2 : correction coefficient for air resistance

$$K_2 = \frac{T + 273}{293} \times \frac{100}{P}$$

where, P : average atmospheric pressure of test road (kPa)

2.2.5.1.2 Correction method for low vehicle speeds When the vehicle speed at the measuring point is 50 km/h or under, the following correction method shall normally be used:

- a) Running resistance is expressed by the following binomial quadratic equation applying the F_j data specified in **2.2.3.1.4**:

$$F' = f_0' + f_2' V^2$$

- b) Coefficient of each term is corrected for atmospheric conditions.

$$f_0'^* = (f_0' - w_1') \times \{1 + K_0(T - 20)\}$$

$$f_2'^* = K_2 f_2'$$

where, $f_0'^*$: constant term in the binomial regression equation corrected for standard atmospheric conditions (N)

$f_2'^*$: coefficient of the quadratic term in the binomial regression equation corrected for standard atmospheric conditions [N/(km/h)²]

w_1' : wind correction value in the binomial regression equation (N). This is obtained by the following equation:

$$w_1' = 3.6^2 \times f_2' V_w^2$$

- c) Running resistance after correction for atmospheric conditions is obtained by the following equation:

$$F'^* = (f_0 + \Delta f_0') + f_1 V + (f_2 + \Delta f_2') V^2$$

where, F'^* : corrected running resistance (N)
 $\Delta f_0'$: amount of change due to correction of the constant term in the quadratic regression equation (N)

$$\Delta f_0' = f_0'^* - f_0'$$

 $\Delta f_2'$: amount of change due to correction of the quadratic term coefficient in the quadratic regression equation [N/(km/h)²]

$$\Delta f_2' = f_2'^* - f_2'$$

 f_0, f_1, f_2 : coefficient of each term of running resistance specified in **2.2.3.1.4** (N), [N/(km/h)], [N/(km/h)²]

2.2.5.2 Wheel torque method Correction for standard air temperature, atmospheric pressure and calm state shall be accomplished by the following:

2.2.5.2.1 General correction method

$$C^* = \{(c_0 - w_2) + c_1 V\} \times \{1 + K_0 (T - 20)\} + K_2 c_2 V^2$$

where, C^* : corrected running load torque (N · m)
 c_0 : constant term (N · m)
 c_1 : coefficient of the primary term [N · m/(km/h)]
 c_2 : coefficient of the quadratic term [N · m/(km/h)²]
 w_2 : wind corrected value (N) is obtained by the following equation:

$$w_2 = 3.6^2 \times c_2 V_w^2$$

where, V_w : average of the absolute value of test road wind velocity (m/s)

T : average air temperature of test road (°C)

K_0 : rolling resistance correction coefficient

$$K_0 = 8.1 \times 10^{-3} (^\circ\text{C}^{-1})$$

K_2 : air resistance correction coefficient

$$K_2 = \frac{T + 273}{293} \times \frac{100}{P}$$

where, P : average atmospheric pressure of test road (kPa)

2.2.5.2.2 Correction method for low vehicle speeds When the vehicle speed at the measuring point is 50 km/h or under, the following correction method shall normally be used:

- a) Running load torque is expressed by the following binomial quadratic equation applying the data $C_{jma,i}$ and $C_{jmb,i}$ specified in **2.2.4.5** and $V_{jma,i}$ and $V_{jmb,i}$ specified in **2.2.4.6**:

$$C_a' = c_{0a}' + c_{2a}'V^2$$

$$C_b' = c_{0b}' + c_{2b}'V^2$$

where, C_a' , C_b' : running load torque in each reciprocating direction in the binomial regression equation (N·m)

c_{0a}' , c_{0b}' : constant term of each reciprocating direction in the binomial regression equation (N·m)

c_{2a}' , c_{2b}' : coefficient of the quadratic term of each reciprocating direction in the binomial regression equation [N·m/(km/h)²]

Average running resistance is obtained by the following equation:

$$C_{ave}' = c_0' + c_2'V^2$$

where, C_{ave}' : average running resistance of reciprocation in the binomial regression equation (N·m)

c_0' : average constant term of reciprocation in the binomial regression equation (N·m)

$$c_0' = \frac{(c_{0a}' + c_{0b}')}{2}$$

c_2' : average coefficient of the quadratic term of reciprocation in the binomial regression equation [N·m/(km/h)²]

$$c_2' = \frac{(c_{2a}' + c_{2b}')}{2}$$

b) Coefficient of each term corrected for atmospheric conditions is obtained.

$$c_0'^* = (c_0' - w_2') \times \{1 + K_0(T - 20)\}$$

$$c_2'^* = K_2 c_2'$$

where, $c_0'^*$: corrected running load torque (N·m)

$c_2'^*$: coefficient of the quadratic term in the binomial regression equation corrected for standard atmospheric condition [N·m/(km/h)²]

w_2' : wind correction value in the binomial regression equation (N). This is obtained by the following equation:

$$w_2' = 3.6^2 \times c_2' V_w^2$$

c) Running load torque after correction for atmospheric conditions is obtained by the following equation:

$$C'^* = (c_0 + \Delta c_0') + c_1 V + (c_2 + \Delta c_2') V^2$$

where, C'^* : constant term in the binomial regression equation corrected for standard atmospheric conditions (N·m)

$\Delta c_0'$: amount of change due to correction of the constant term in the binomial regression equation ($\text{N} \cdot \text{m}$)

$$\Delta c_0' = c_0'^* - c_0'$$

$\Delta c_2'$: amount of change due to correction of the quadratic term coefficient in the binomial regression equation [$\text{N} \cdot \text{m}/(\text{km}/\text{h})^2$],

$$\Delta c_2' = c_2'^* - c_2'$$

c_0, c_1, c_2 : coefficient of each term of running resistance specified in **2.2.4.7** ($\text{N} \cdot \text{m}$), [$\text{N} \cdot \text{m}/(\text{km}/\text{h})$], [$\text{N} \cdot \text{m}/(\text{km}/\text{h})^2$]

2.3 Measuring running resistance by bench method Air resistance and rolling resistance shall be measured separately in the test chamber without running the vehicle on the test road, and their sum shall be considered to be the running resistance.

2.3.1 Measuring air resistance by wind tunnel

2.3.1.1 Wind tunnel specifications Specifications of the wind tunnel, test method and correction method shall be sufficient for obtaining air resistance equivalent to on-road conditions (hereafter referred to as “ SC_d ”).

2.3.1.2 Test procedures Height of the vehicle, wheel alignment, etc. shall be adjusted to the state designated by the vehicle manufacturer and the vehicle shall be placed appropriately in the wind tunnel so that air flow may be parallel with the axis of the vehicle's running direction. The vehicle's engine hood, windows, air conditioning system, and headlights covers shall be closed. The vehicle shall be secured to minimize the effects on the air flow. Air shall be sent to the wind tunnel according to the specified test procedures and SC_d shall be measured. Although a wind velocity of 140 km/h is recommended for the test, anything above 80 km/h is acceptable.

If there is more than a 1 % difference between two consecutive measurements, the vehicle wind tunnel shall be checked and conditions corrected as required and further two consecutive measurements shall be taken. This shall be repeated until the difference between the two consecutive measurements is 1 % or under. The average of the two final measurements shall then be adopted. Air resistance is obtained by the following equation:

$$F_{\text{aero}} = \frac{1}{3.6^2} \times \frac{\rho_0 SC_d V^2}{2}$$

where, F_{aero} : air resistance (N)

ρ_0 : standard density of atmosphere (kg/m^3)

S : frontal projected area (m^2)

C_d : air resistance coefficient

V : vehicle speed (km/h)

SC_d measured in a wind tunnel shall be corrected as necessary to correspond appropriately to on-road SC_d .

2.3.2 Measuring rolling resistance by chassis dynamometer

2.3.2.1 Chassis dynamometer specifications The chassis dynamometer used for measuring rolling resistance shall be a single roller type (applies to both front and rear units for four-wheel vehicles) and the roller diameter shall be 1.2 m or over. The roller surface shall be flat and smooth. The air blower for cooling shall have a nozzle with an opening of 0.4 m² or over and the accuracy of wind velocity with regard to vehicle speed shall be ± 2 km/h.

2.3.2.2 Selection of vehicle speed at measuring point To be in compliance with 2.2.3.1.1.

2.3.2.3 Test procedures Test procedures shall be in accordance with the following specifications: Rolling resistance shall be measured separately for driving wheels and non-driving wheels. Measurement may be taken simultaneously when using a four-wheel chassis dynamometer. An air blower shall be operated during tests.

- a) Vehicle condition is adjusted as specified in 2.2.2.1.1.
- b) The test chamber temperature shall be adjusted to 20^{+6}_{-2} °C. The chassis dynamometer shall be warmed-up according to the specified method and the mechanical loss torque (force converted to the roller surface) of the chassis dynamometer measured.
- c) Non-driving wheels shall be placed appropriately on the chassis dynamometer. Non-driving wheels are driven by the chassis dynamometer and warm-up shall be performed at the highest measurement point speed until frictional conditions of the vehicle are established (approximately 30 min) and rolling resistance is measured immediately after the warm-up.

Test vehicle speed shall be gradually decreased and rolling resistance measured at each measurement point speed down to the minimum measurement point speed. Vehicle speed shall again be increased to the maximum measurement point speed and a second measurement completed. If there is more than a 4 % difference between two consecutive measurements, the vehicle and chassis dynamometer shall be checked and conditions corrected as required and further two consecutive measurements shall be taken. This shall be repeated until the difference between the two consecutive measurements is 4 % or under at every measurement point speed. The average of the two final measurements shall then be adopted.

- d) Driving wheels shall be placed appropriately on the chassis dynamometer. The vehicle transmission shall be set to the appropriate gear position and warm-up shall be performed at the highest measurement point speed until the frictional conditions of the vehicle are stabilized (approximately 30 min) by self-advancing. Rolling resistance shall then be measured immediately after warm-up.

The transmission gear shall be in the neutral position when measuring rolling resistance.

For a manual transmission, the clutch shall be engaged and the engine held in the idling state. The test vehicle speed shall be gradually decreased and rolling resistance measured at each measurement point speed until the minimum

measurement point speed. Vehicle speed shall again be increased to the maximum measurement point speed and a second measurement made. If there is more than a 4 % difference between two consecutive measurements, the vehicle and chassis dynamometer shall be checked and conditions corrected as required and further two consecutive measurements shall be taken. This shall be repeated until the difference between the two consecutive measurements is 4 % or under at every measurement point speed. The average of the two final measurements shall then be adopted.

- e) Rolling resistance measured by the chassis dynamometer shall be corrected as necessary so as to corresponding appropriately to on-road rolling resistance.

Information : An example of correction of rolling resistance measured by a chassis dynamometer corresponding to on-road conditions is shown in Annex 4 (informative).

2.3.2.4 Test results Rolling resistance at each measurement point speed is obtained by the following equation.

$$Rr_{t,j} = Rr_{f,j} + Rr_{r,j} - (Rr_{lossf,j} + Rr_{lossr,j})$$

where, $Rr_{t,j}$: total rolling resistance (N)

$Rr_{f,j}$: rolling resistance of front wheel including chassis dynamometer loss (N)

$Rr_{r,j}$: rolling resistance of rear wheel including chassis dynamometer loss (N)

$Rr_{lossf,j}$: mechanical loss of the front axle of chassis dynamometer (N)

$Rr_{lossr,j}$: mechanical loss of the rear axle of chassis dynamometer (N)

Remarks : When displayed torque is corrected for mechanical chassis dynamometer loss, $Rr_{lossf,j}$ and $Rr_{lossr,j}$ are considered 0 for calculation.

2.3.3 Calculating total running resistance Total running resistance at each vehicle speed by the bench test is obtained by the following equation:

$$F_j = \frac{1}{3.6^2} \times \frac{\rho_0 S C_d V_j^2}{2} + Rr_{t,j}$$

where, F_j : total running resistance (N)

ρ_0 : standard density of atmosphere (kg/m³)

S : frontal projected area (m²)

C_d : air resistance coefficient

V_j : vehicle speed (km/h)

The equation for the running resistance curve is obtained by quadratic regression using data pair (V_j , F_j).

$$F = f_0 + f_1 V + f_2 V^2$$

3 Setting running resistance on the chassis dynamometer

3.1 Tolerance of required measuring accuracy Measuring accuracy during testing shall be as follows. Equipment used for measurement of each test item shall be maintained and calibrated based on the guidance for handling specified by the manufacturer of the equipment concerned.

- a) Roller speed: $\pm 0.5 \text{ km/h}$ or $\pm 1 \%$, whichever is greater
- b) Roller surface conversion: $\pm 10 \text{ N}$ or $\pm 0.1 \%$ of full scale whichever is greater
- c) Time (coasting time): $\pm 20 \text{ ms}$ or $\pm 0.1 \%$, whichever is greater
- d) Wheel torque: $\pm 3 \text{ N}\cdot\text{m}$ or $\pm 0.5 \%$, whichever is greater
- e) Chamber temperature: $\pm 1 \text{ }^{\circ}\text{C}$
- f) Tyre air pressure: $\pm 5 \text{ kPa}$

3.2 Test preparations

3.2.1 Parameter settings The following parameters shall be set before the test:

- a) Target running resistance
- b) Reference vehicle speed

3.2.2 Test chamber settings

3.2.2.1 Roller The surface of the roller on the chassis dynamometer shall be clean and dry, and in a condition that will prevent the tyre from skidding. With twin-roller chassis dynamometers, the two rollers must be in the same state, coupled or uncoupled, during load setting for this and for the fuel consumption test to be performed later. Further, roller speed shall be obtained from the coupled roller with a load absorbing device.

3.2.2.2 Chamber temperature The chamber temperature shall be $25 \text{ }^{\circ}\text{C} \pm 5 \text{ }^{\circ}\text{C}$. However, this may be changed depending on the test objective.

3.2.3 Preparing the chassis dynamometer

3.2.3.1 Equivalent inertia weight Equivalent inertia weight of the chassis dynamometer shall be set to a value equivalent to the mass of the test vehicle.

Information : Representative value of equivalent inertia weight of 10 • 15 mode test is shown in attached table 4 of Annex 11 (informative).

3.2.3.2 Chassis dynamometer warm-up Warm-up of the chassis dynamometer shall be performed according to the recommendation of the manufacturer or other appropriate method so that mechanical loss may be stabilized.

3.2.4 Preparing the vehicle