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Mopeds — Measurement method for gaseous exhaust emissions and fuel consumption —

Part 1:
General test requirements

Cyclomoteurs — Méthode de mesure des émissions de gaz polluants et de consommation de combustible —

Partie 1: Exigences générales d'essai

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 6855-1 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 23, *Mopeds*.

ISO 6855-1 cancels and replaces ISO 6855:1983 and ISO 7859:2000, both of which have been technically revised.

ISO 6855 consists of the following parts, under the general title *Mopeds — Measurement method for gaseous exhaust emissions and fuel consumption*:

— *Part 1: General test requirements*

— *Part 2: Test cycles and specific test conditions*

— *Part 3: Fuel consumption measurement at a constant speed*

Introduction

For measurement of moped fuel consumption, the carbon balance method, where the fuel consumption is calculated from analysis of the carbon quantity in the exhaust gas, is now widely used in addition to the conventional fuel flow measurement. Therefore, the measurement of exhaust gas and that of fuel consumption are inseparably related to each other.

ISO 6855 now covers in one single series of standards the two subjects that were previously covered separately by ISO 6855:1983 and by ISO 7859:2000. This part of ISO 6855 defines fundamental elements such as the measurement accuracy, test vehicle conditions and the details of the carbon balance method. Measurement of gaseous exhaust gas emissions and fuel consumption of test cycles can be conducted with this part of ISO 6855 and ISO 6855-2. Together with ISO 6855-3, they also give details of those measurements at a constant speed.

While the most up-to-date technologies are reflected in the ISO 6855 series, further technical development in the following aspects will be necessary in the future, when measurement of exhaust gas at a lower level is required:

— cleaning of the background air (i.e the air in the test room which is used for the dilution air);

— heating of the sampling line;

— control of the test room humidity;

— the exhaust gas analysis system for low-level emissions;

— consideration for the evaporated fuel from the test moped.

In addition to the above future issues, the chassis dynamometer with electrically simulated inertia is at the stage of practical application. Standardization of the verification method and the allowance of simulated inertia would be necessary for this recent development.

Mopeds — Measurement method for gaseous exhaust emissions and fuel consumption —

Part 1:
General test requirements

1 Scope

This part of ISO 6855 specifies the general test requirements for measurement for the gaseous exhaust emissions from mopeds, and for determining the fuel consumption of mopeds as defined in ISO 3833. It is applicable to mopeds equipped with a spark ignition engine (four-stroke engine, two-stroke engine or rotary piston engine).

2 Normative references

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

ISO 3833, *Road vehicles — Types — Terms and definitions*

ISO 6855-2:2012, *Mopeds — Measurement method for gaseous exhaust emissions and fuel consumption — Part 2: Test cycles and specific test conditions*

ISO 6855-3:2012, *Mopeds — Measurement method for gaseous exhaust emissions and fuel consumption — Part 3: Fuel consumption measurement at a constant speed*

ISO 28981, *Mopeds — Methods for setting the running resistance on a chassis dynamometer*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3833 and the following apply.

3.1
moped kerb mass
dry mass of the moped to which is added the mass of the following:

— fuel: tank filled at least to 90 % of the capacity specified by the manufacturer;

— auxiliary equipment usually supplied by the manufacturer in addition to that necessary for normal operation [tool-kit, carrier(s), windscreen(s), protective equipment, etc.]

3.2
reference mass of the moped
kerb mass of the moped increased by a uniform figure of 75 kg, which represents the mass of a rider

3.3
equivalent inertia
total inertia of the rotating masses of the test bench, determined with respect to the reference mass of the moped

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3.4
gaseous exhaust emissions
carbon monoxide, hydrocarbons, nitrogen oxides (gaseous pollutants) and carbon dioxide emitted from mopeds

4 Symbols

Table 1 — Symbols

Symbols	Definition	Unit [a]
a	mixing ratio of lubrication oil and fuel	—
$c_{CO,d}$	carbon monoxide concentration in the dilution air	ppm
$c_{CO,dm}$	carbon monoxide concentration in the dilution air with the water vapour and carbon dioxide absorbent	ppm
$c_{CO,e}$	carbon monoxide concentration in the diluted exhaust mixture	ppm
$c_{CO,ec}$	volumetric concentration of carbon monoxide in the diluted exhaust mixture, corrected to take account of carbon monoxide in the dilution air	ppm
$c_{CO,em}$	carbon monoxide concentration in the diluted exhaust mixture with the water vapour and carbon dioxide absorbent	ppm
$c_{CO2,d}$	carbon dioxide concentration in the dilution air	%
$c_{CO2,e}$	carbon dioxide concentration in the diluted exhaust mixture	%
$c_{CO2,ec}$	volumetric concentration of carbon dioxide in the diluted exhaust mixture, corrected to take account of carbon dioxide in the dilution air	%
$c_{NOx,d}$	nitrogen oxides concentration in the dilution air	ppm
$c_{NOx,e}$	nitrogen oxides concentration in the diluted exhaust mixture	ppm
$c_{NOx,ec}$	volumetric concentration of nitrogen oxides in the diluted exhaust mixture, corrected to take account of nitrogen oxides in the dilution air	ppm
$c_{O2,d}$	oxygen concentration in the dilution air	%
$c_{Pi,ec}$	concentration of the pollutant i in the diluted exhaust mixture, corrected to take account of the amount of the pollutant i contained in the dilution air	ppm
$c_{THC,d}$	hydrocarbon concentration in the dilution air as measured in parts per million carbon equivalent	ppmC
$c_{THC,e}$	hydrocarbon concentration in the diluted exhaust mixture as measured in parts per million carbon equivalent	ppmC
$c_{THC,ec}$	volumetric concentration, expressed in parts per million carbon equivalent, of hydrocarbon in the diluted exhaust mixture, corrected to take account of hydrocarbon in the dilution air	ppmC
D_f	dilution factor	—
F_c	specific fuel consumption	km/L
F'_c	specific fuel consumption for lubrication oil mixed fuel	km/L
F_{c100}	fuel consumption per 100 km	L/100 km
F_o	lubrication oil consumption for the mixed fuel	km/L
H_a	absolute humidity in grams of water per kilogram of dry air	—
H_d	relative humidity of dilution air	%
H_r	relative humidity in the test room	%
H_0	standard relative humidity	%
[a]　　ppm = parts per million.		

Table 1 *(continued)*

Symbols	Definition	Unit [a]
K_H	humidity correction factor used for the calculation of the mass emissions of nitrogen oxides	—
K_1	venturi correction factor	—
K_2	ratio of pressure to temperature at the standard reference conditions	—
L	running distance actually travelled	km
m_{CO}	mass of carbon monoxide in the exhaust gas	g/km
m_{CO2}	mass of carbon dioxide in the exhaust gas	g/km
m_f	fuel consumed	g
m_{NOx}	mass of nitrogen oxides in the exhaust gas	g/km
m_{Pi}	mass emission of the pollutant i	g
m_{THC}	mass of hydrocarbon in the exhaust gas	g/km
N	number of revolutions of positive displacement pump during the test while samples are being collected	—
p_a	mean barometric pressure during the test in the test room	kPa
p_d	saturated water vapour pressure during the test in the test room	kPa
p_p	diluted exhaust mixture absolute pressure at the inlet of positive displacement pump	kPa
p_V	absolute pressure at the venturi inlet	kPa
$p_V(t)$	absolute pressure of the diluted exhaust mixture at the venturi inlet	kPa
p_0	total barometric pressure at the standard reference conditions	kPa
Q_a	measured flow rate of venturi at ambient conditions	L/s
Q_{cal}	measured flow rate of venturi using the other gas flowmeter	L/s
$R_{HC,ex}$	atom number ratio of hydrogen and carbon in the exhaust gas	—
$R'_{HC,ex}$	atom number ratio of hydrogen and carbon in the exhaust gas for lubrication oil mixed fuel	—
$R_{HC,f}$	atom number ratio of hydrogen and carbon in the fuel	—
$R_{HC,o}$	atom number ratio of hydrogen and carbon in the lubrication oil	—
$R_{OC,ex}$	atom number ratio of oxygen and carbon in the exhaust gas	—
$R'_{OC,ex}$	atom number ratio of oxygen and carbon in the exhaust gas for lubrication oil mixed fuel	—
$R_{OC,f}$	atom number ratio of oxygen and carbon in the fuel	—
$R_{OC,o}$	atom number ratio of oxygen and carbon in the lubrication oil	—
r_0	relative air density at the standard reference conditions	—
t	time	s
t_{test}	total test time	s
T_a	measured ambient temperature during the test in the test room	K
T_f	fuel temperature measured at the burette	K
T_p	temperature of diluted exhaust mixture at the positive displacement pump inlet during the test while samples are being collected	K
T_v	temperature at the venturi inlet	K
$T_v(t)$	temperature of diluted exhaust mixture at the venturi inlet	K
T_0	air temperature at the standard reference conditions	K

[a] ppm = parts per million.

Table 1 *(continued)*

Symbols	Definition	Unit [a]
T_1	mean dry bulb temperature during the test in the test room	K
T_2	mean wet bulb temperature during the test in the test room	K
V	measured volume of fuel consumed	L
V_d	dilution air volume	L
V_e	volume of the diluted exhaust mixture expressed corrected to the standard reference conditions	L/km
V_{ex}	exhaust gas volume	L
V_f	fuel volume of lubrication oil mixed fuel	L
$V_{i,e}$	volume of the diluted exhaust mixture in one test under the standard reference conditions	L
V_o	lubrication oil volume of lubrication oil mixed fuel	L
V_p	diluted exhaust mixture volume pumped by the positive displacement pump per one revolution	L
V_s	total diluted exhaust mixture volume during one test	L
α	coefficient of volumetric expansion for the fuel	K^{-1}
ρ_{CO}	carbon monoxide density at the standard reference conditions	g/L
ρ_{CO2}	carbon dioxide density at the standard reference conditions	g/L
ρ_f	fuel density at 293,15 K	g/L
ρ_{NOx}	nitrogen oxides density under the standard reference conditions, expressed in equivalent NO_2	g/L
ρ_o	lubrication oil density at 293,15 K	g/L
ρ_{Pi}	density of the pollutant i under the standard reference conditions	g/L
ρ_{THC}	hydrocarbon density at the standard reference conditions	g/L
ρ_0	air volumetric mass at the standard reference conditions	kg/m^3
[a] ppm = parts per million.		

5   Standard reference conditions

The standard reference conditions shall be as follows:

a)   total barometric pressure, p_0: 101,325 kPa;

b)   air temperature, T_0: 293,15 K;

c)   relative humidity, H_0: 65 %;

d)   air volumetric mass, ρ_0: 1,205 kg/m^3;

e)   relative air density, r_0: 0,931 9.

6   Tests

6.1   Measurement of gaseous exhaust emissions

6.1.1   Average gaseous exhaust emissions during conventional test cycles

The test shall be carried out in accordance with the method described in ISO 6855-2.

6.1.2   The gaseous exhaust emissions measurement at an idling speed

The test shall be carried out in accordance with the procedure described in ISO 6855-2.

6.2   Measurement of fuel consumption

6.2.1   Average fuel consumption during conventional test cycles

The test shall be carried out in accordance with the procedure described in ISO 6855-2.

6.2.2   Fuel consumption at a constant speed

The test shall be carried out in accordance with the procedure describedin ISO 6855-3.

7   Measurement equipment

Irrespective of the provisions specified below, any measurement system(s) may be used when the performance of the equipment is proven by the equipment manufacturer to be equivalent to CVS (constant volume sampling) system.

7.1   Chassis dynamometer

The chassis dynamometer shall be set in accordance with ISO 28981.

7.2   Gas-collection equipment

7.2.1   The gas-collection device, shall be a closed type device that can collect all exhaust gases at the moped exhaust outlet(s) while maintaining atmospheric pressure at the exhaust outlet(s). An open system may be used as well if it is confirmed that all the exhaust gases are collected. The gas collection shall be such that there is no condensation, which could appreciably modify the nature of exhaust gases at the test temperature.

7.2.2   A connecting tube, between the device and the exhaust gas sampling system. This tube, and the device, shall be made of stainless steel, or of some other material which does not affect the composition of the gases collected, and which withstands the temperature of these gases.

7.2.3   A heat exchanger, capable of limiting the temperature variation of the diluted exhaust mixture in the pump intake to ± 5 K throughout the test. This exchanger shall be equipped with a preheating system capable of bringing the exchanger to its operating temperature (with the tolerance of ± 5 K) before the test begins.

7.2.4   A positive displacement pump (PDP), to draw in the diluted exhaust mixture. This pump is equipped with a motor having several strictly controlled uniform speeds. The pump capacity shall be large enough to ensure the intake of all the exhaust gases.

7.2.5   A critical flow venturi (CFV) may also be used.

7.2.6   A device to allow continuous recording of the temperature of diluted exhaust mixture entering the pump.

7.2.7   Two gauges:

— one to ensure the pressure depression of the diluted exhaust mixture entering the pump, relative to atmospheric pressure;

— one to measure the dynamic pressure variation of the positive displacement pump.

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7.2.8   A probe, located near to but outside the gas-collecting device, to collect, through a pump, a filter and a flowmeter, samples of the dilution air stream, at constant flow rates, throughout the test.

7.2.9   A sample probe, pointed upstream into the diluted exhaust mixture flow, upstream of the positive displacement pump or the critical flow venturi to collect, through a pump, a filter and a flowmeter, samples of the diluted exhaust mixture, at constant flow rates, throughout the test.

The minimum sample flow rate in the two sampling devices described in 7.2.8 and 7.2.9 shall be 150 L/h.

7.2.10   Three way valves, on the sampling system, described in 7.2.8 and 7.2.9, to direct the samples either to their respective bags or to the outside throughout the test.

7.2.11   Gas-tight collection bags, for dilution air and diluted exhaust mixture of sufficient capacity so as not to impede normal sample flow and which will not change the nature of the gaseous exhaust emissions concerned.

The bags shall have an automatic self-locking device, and shall be easily and tightly fastened either to the sampling system or the analysing system at the end of the test.

7.2.12   A revolution counter, to count the revolutions of the positive displacement pump throughout the test.

Good care shall be taken with the connecting method and the material or configuration of the connecting parts because there is a possibility that each section (e.g. the adapter and the coupler) of the sampling system will become very hot. If the measurement cannot be performed normally due to heat-damages of the sampling system, an auxiliary cooling device may be used as long as the exhaust gases are not affected.

NOTE 1   With open type devices, there is a risk of incomplete gas collection and gas leakage into the test room, so it is important to make sure that there is no leakage throughout the sampling period.

NOTE 2   If a constant CVS flow rate is used throughout the test cycle that includes low and high speeds all in one, it is advisable that special attention be paid because of higher risk of water condensation in high speed range.

7.3   Analytical equipment

7.3.1   The sample probe shall consist of a sampling tube leading into the collecting bags, or of a drainage tube. This sample probe shall be made of stainless steel or of some other material that will not adversely affect the composition of the gases to be analysed. The sample probe as well as the tube taking the gases to the analyser shall be at ambient temperature.

7.3.2   Analysers shall be of the following types:

a)   non-dispersive type with absorption in the infrared for carbon monoxide and carbon dioxide;

b)   flame ionization type for total hydrocarbons (diluted measurements);

c)   non-dispersive type with absorption in the infrared for hydrocarbons (direct measurements);

d)   chemiluminescence type for nitrogen oxides.

7.4   Cooling equipment

Throughout the test, a variable speed cooling blower shall be positioned in front of the moped, so as to direct the cooling air to the moped in a manner which simulates actual operating conditions. The blower speed shall be such that, within the operating range of 10 to 50 km/h, the linear velocity of the air at the blower outlet is within ± 5 km/h of the corresponding roller speed. At roller speeds of less than 10 km/h, air velocity may be zero.

As far as possible, the air speed shall be constant across the whole outlet section.

The blower outlet shall have a cross-section area of at least 0,2 m² and the bottom of the blower outlet shall be between 5 cm and 20 cm above floor level. The blower outlet shall be perpendicular to the longitudinal axis of the moped between 30 cm and 45 cm in front of its front wheel. The device used to measure the linear velocity of the air shall be located at between 0 cm and 20 cm from the air outlet.

7.5 Fuel consumption measurement

7.5.1 One of the following methods shall be used to measure the fuel consumption, depending on the characteristics of each method and on the type of test to be performed (conventional test cycle or constant speed):

a) carbon balance method;

b) volumetric method;

c) gravimetric method;

d) flowmeter method.

The carbon balance method shall be applied in accordance with 12.1.

Other methods may be used if it can be proved that the results given are equivalent.

7.5.2 Fuel shall be supplied to the engine by a device capable of measuring the quantity of fuel supplied with an accuracy of ± 2 % in accordance with Annex A, and which does not interfere with the supply of fuel to the engine. When the measuring system is volumetric, the temperature of the fuel in the device or in the device outlet shall be measured.

Switching from the normal supply system to the measuring supply system shall be done by a valve system and shall take no more than 0,2 s.

7.5.3 Annex A gives the description and the methods of use of the appropriate devices for fuel flow measurement.

7.6 Accuracy of instruments and measurements

7.6.1 The distance travelled by the moped shall be measured with an accuracy of ± 1 %.

7.6.2 The speed of the moped shall be measured with an accuracy of ± 1 % to the resolution of 0,1 km/h. For speeds less than 10 km/h, the speed shall be measured to the resolution of 0,1 km/h.

7.6.3 The ambient temperatures and the temperatures considered in 7.2.3 and 7.2.6 shall be measured with an accuracy of ± 2 K.

7.6.4 The atmospheric pressure shall be measured with an accuracy of ± 0,2 kPa.

7.6.5 The relative humidity of the ambient air shall be measured with an accuracy of ± 5 %.

7.6.6 The pressures considered in 7.2.7 shall be measured with an accuracy of ± 0,4 kPa.

7.6.7 The analysers shall have a measuring range compatible with the accuracy required to measure the content of the various pollutants and carbon dioxide with an accuracy of ± 1 %, regardless of the accuracy of the calibration gases. The overall response time of the analysing circuit shall be less than 1 min.

7.6.8 The cooling air speed shall be measured with an accuracy of ± 5 km/h.

7.6.9 The duration of cycles and gas collection shall be conducted with an accuracy of ± 1 s. These times shall be measured with an accuracy of 0,1 s.

7.6.10 The total volume of the diluted exhaust mixture shall be measured with an accuracy of ± 3 %.

7.6.11 The total flow rate and the sampling flow rates shall be steady with an accuracy of ± 5 %.

7.6.12 The wind speed on the test road shall be measured with an accuracy of ± 5 % to the resolution of 0,1 m/s.

8 Preparing the test

8.1 Engine fuel and lubricants

The test fuel shall be selected in accordance with the manufacturer's requirements and the specification of test fuel shall be reported. An example of the record form is given in Annex B.

With regard to grade and quantity of oil, the lubrication of the engine shall comply with the manufacturer's recommendation.

8.2 Description of the test moped

The main specifications of the moped shall be provided in accordance with ISO 6855-2:2012, Annexes A and B and with ISO 6855-3:2012, Annex B.

8.3 Conditioning/preparation of the test moped

8.3.1 The engine, transmission and moped shall be run in properly in accordance with the manufacturer's requirements.

8.3.2 The moped shall be adjusted in accordance with the manufacturer's requirements (e.g. the viscosity of the oils, tyre pressures) or, if there is any alteration, the full description shall be given in the test report.

8.3.3 The distribution of the load between the wheels shall be in conformity with the manufacturer's instructions.

8.4 Adjustment of the analytical apparatus

8.4.1 Calibration of the analysers

The calibration gas at the indicated pressure, compatible with the correct functioning of the equipment, shall be passed through the analyser.

The curve of the analyser's deviations shall be drawn as a function of the contents of the various gas cylinders used.

8.4.2 Adjustment of the analysers

The adjustment of the analysers can then be carried out with only one calibration gas having an established content.

8.4.3   Overall response time of the apparatus

The gas from the cylinder that contains the maximum concentration shall be introduced into the end of the sampling probe. A check shall be made to ensure that the indicated value corresponding to the maximum deviation is reached in less than 1 min. If this value is not reached, the analysing circuit shall be inspected from end to end for leaks.

9   System check procedure

9.1   Accuracy of the CVS system

The total accuracy of the CVS system and analytical system shall be determined by introducing a known mass of a pollutant gas into the system while it is being operated as if during a normal test and then analysing and calculating the pollutant mass according to Formula (1).

$$m_{Pi} = V_{i,e} \times \rho_{Pi} \times c_{Pi,ec} \times 10^{-6} \tag{1}$$

There is no humidity correction for hydrocarbon and carbon monoxide.

The two techniques in 9.2 and 9.3 are known to give sufficient accuracy.

9.2   Metering a constant flow of pure gas (CO or C_3H_8) using a critical flow orifice

A known quantity of pure gas (CO or C_3H_8) is fed into the CVS system through the calibrated critical orifice. If the inlet pressure is high enough, the flow-rate (q), which is adjusted by means of the critical flow orifice, is independent of orifice outlet pressure (critical flow). If deviations exceeding 5 % occur, the cause of the malfunction shall be located and determined. The CVS system is operated as in a gaseous exhaust emission test for about 5 to 10 min. The gas collected in the sampling bag is analysed by the usual equipment and the result compared to the concentration of the gas samples which was known beforehand.

9.3   Metering a limited quantity of pure gas (CO or C_3H_8) by means of a gravimetric technique

The following gravimetric procedure may be used to verify the CVS system. The weight of a small cylinder filled with either carbon monoxide or propane is determined with a precision of ± 0,01 g. For about 5 to 10 min, the CVS system is operated as in a normal gaseous exhaust emission test, while CO or propane is injected into the system. The quantity of pure gas involved is determined by means of differential weighing. The gas accumulated in the bag is then analysed by means of the equipment normally used for exhaust-gas analysis. The results are then compared to the concentration figures computed previously.

10   Procedure for sampling, analysing and measuring the volume of gaseous exhaust emissions

10.1   Operations to be carried out before the moped start up

A schematic diagram is shown in Figure 1 for the representative closed type CVS system with CFV and Figure 2 for the representative closed type CVS system with PDP.
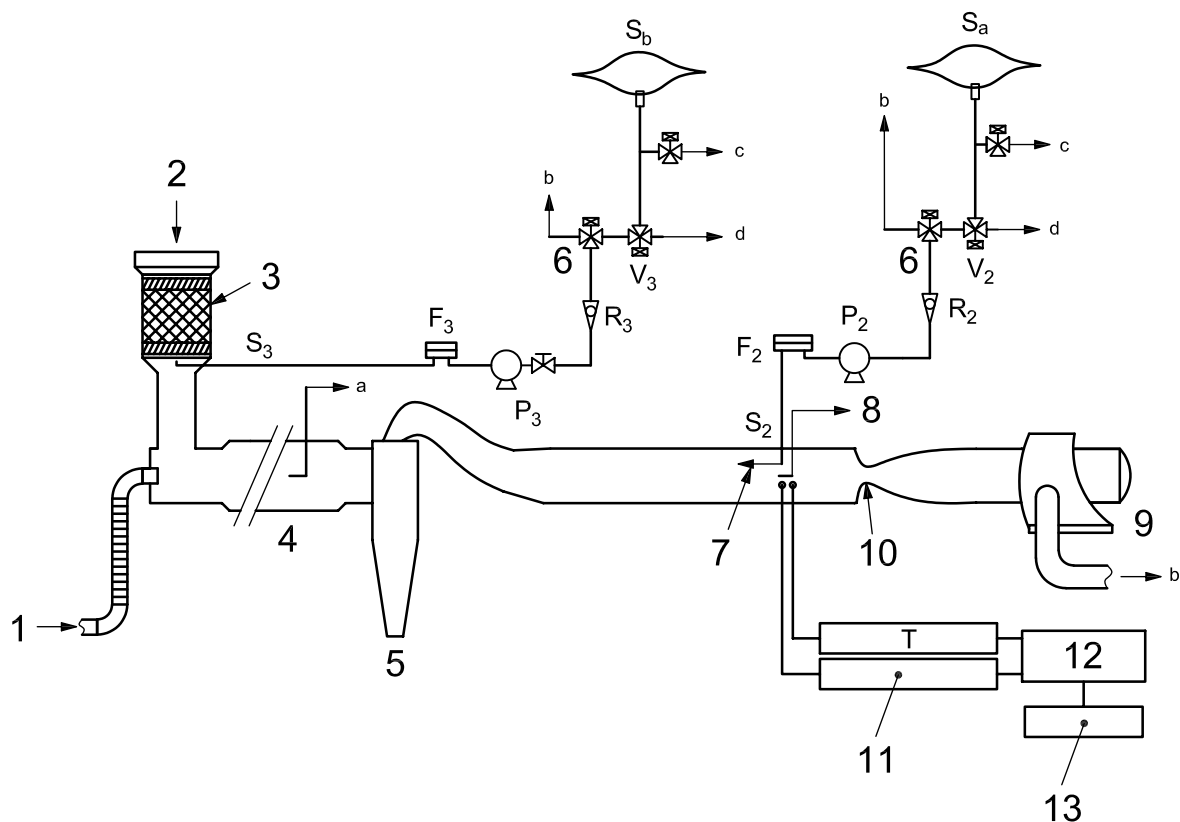
Key

1	exhaust gas	11	pressure gauge
2	dilution air	12	calculator
3	dilution air filter	13	integrator
4	mixing chamber	F_2, F_3	filters
5	cyclone	P_2, P_3	pumps
6	diversion valve	R_2, R_3	flowmeters
7	sampling venturi	S_a, S_b	sampling bags
8	continuous sampling probe	S_2, S_3	probes
9	blower	T	temperature gauge
10	main critical flow venturi	V_2, V_3	valves

[a]   To HFID; special sampling line when HFID is used.

[b]   To atmosphere.

[c]   To exhaust pump.

[d]   To analysing system.

Figure 1 — A schematic diagram for the representative closed type CVS system with CFV
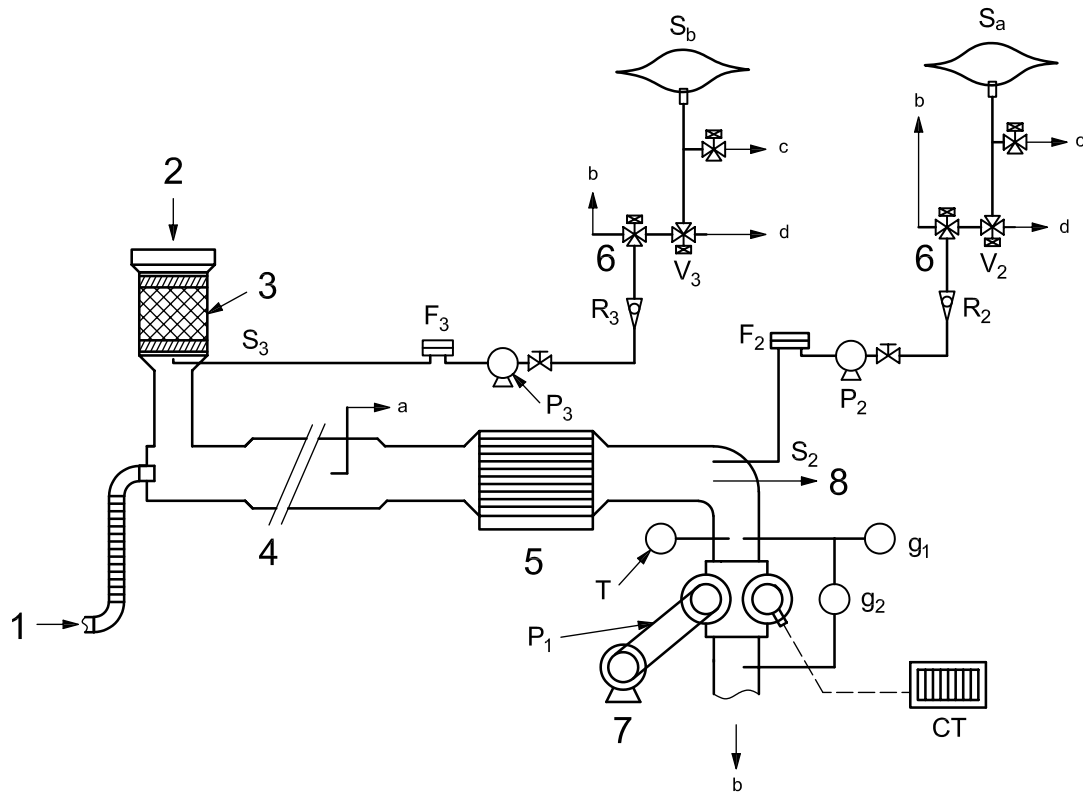
Key

1	exhaust gas	F_2, F_3	filters
2	dilution air	g_1, g_2	pressure gauges
3	dilution air filter	P_1	positive displacement pump
4	mixing chamber	P_2, P_3	pumps
5	heating exchanger	R_2, R_3	flowmeters
6	diversion valve	S_a, S_b	sampling bags
7	motor	S_2, S_3	probes
8	continuous sampling probe	T	temperature gauge
CT	revolution counter	V_2, V_3	valves

[a] To HFID; special sampling line when HFID is used.

[b] To atmosphere.

[c] To exhaust pump.

[d] To analysing system.

Figure 2 — A schematic diagram for the representative closed type CVS system with PDP

10.1.1 The bags for collecting the samples (S_a and S_b) are emptied and sealed.

10.1.2 The positive displacement pump (P_1) is activated without starting up the revolution counter.

10.1.3 The pumps (P_2 and P_3) for taking the samples are activated with the valves set to divert the gases produced into the atmosphere; the flow through valves (V_2 and V_3) is regulated.

10.1.4 The following recording devices are put into operation: the temperature gauge (T) and the pressure gauges (g_1 and g_2).

10.1.5 The revolution counter (CT) and the roller revolution counter are set to zero.

10.2 Beginning of sampling and volume measurement

10.2.1 The operations specified in 10.2.2 to 10.2.5 are performed simultaneously.

10.2.2 The diversion valves are set to collect the samples, which have previously been directed towards the atmosphere, continuously through probes (S_2 and S_3) in bags (S_a and S_b).

10.2.3 The moment at which the test begins is indicated on the analogue graphs which record results from the temperature gauge T and the differential pressure gauges (g_1 and g_2).

10.2.4 The counter which records the total number of revolutions of pump (P_1) is started up.

10.2.5 The device which directs a flow of air at the moped, referred to in 7.4, is started up.

10.3 End of sampling and volume measurement

10.3.1 At the end of the test cycle, the operations described in 10.3.2 to 10.3.5 are performed simultaneously.

10.3.2 The diversion valves shall be set to close bags (S_a and S_b) and to discharge into the atmosphere the samples sucked in by pumps (P_2 and P_3) through probes (S_2 and S_3).

10.3.3 The moment at which the test finishes shall be indicated on the analogue graphs referred to in 10.2.3.

10.3.4 The pump (P_1) revolution counter is stopped.

10.3.5 The device which directs a flow of air at the moped, referred to in 7.4, is stopped.

10.4 Analysis

10.4.1 The exhaust gases contained in the bag shall be analysed as soon as possible, unless otherwise specified in ISO 6855-2.

10.4.2 Prior to each sample analysis, the analyser range to be used for each pollutant shall be set to zero with the appropriate span gas.

10.4.3 The analysers shall then be set to the calibration curves by means of span gases of nominal concentrations of 70 % to 100 % of the range.

10.4.4 The analysers' zeros shall then be rechecked. If the reading differs by more than 2 % of the range from that set in 10.4.2, the procedure is repeated.

10.4.5 The samples shall then be analysed.

10.4.6 After the analysis, zero and span points shall be rechecked using the same gases. If these rechecks are within 2 % of those in 10.4.3, the analysis is considered acceptable.

10.4.7 At all points in this clause the flow rates and pressures of the various gases shall be the same as those used during calibration of the analysers.

10.4.8 The figure adopted for the concentration of each gaseous exhaust emission is that read off after stabilization of the measuring device.

10.5 Measuring the driving distance

The distance actually travelled, expressed in km, is obtained by multiplying the total number of revolutions shown on the revolution counter by the size of the roller.

10.6 Open type CVS system

When the open type CVS system is used in the test facility, the exhaust gas shall not leak from the connecting part of the sampling pipe(s) of CVS system and tailpipe(s) of test moped. The exhaust gas leakage shall be checked.

NOTE   The exhaust gas leakage check method is described in Annex C.

11 Determination of the quantity of gaseous exhaust emissions

11.1 Total diluted exhaust mixture volume corrected to the standard reference conditions

The total diluted exhaust mixture volume flowed into the CVS system during the test shall be calculated and corrected to the standard reference conditions of temperature and pressure. In the case of the CVS system equipped with the CFV the procedure in 11.1.1 shall be used, and for the CVS system equipped with the PDP the procedure in 11.1.2 shall be used.

11.1.1 Total diluted exhaust mixture volume for the CVS system with CFV

The diluted exhaust mixture volume for the CVS system equipped with the CFV shall be obtained from Formulae (2) and (3):

$$V_e = V_s \times \frac{1}{L} \tag{2}$$

$$V_s = K_1 \int_0^{t_{test}} \frac{p_v(t)}{\sqrt{T_v(t)}} dt \tag{3}$$

The venturi correction factor, K_1, shall be determined from the measured flow rate of venturi, Q_{cal}, using the other gas flowmeter (e.g. the laminar flowmeter) and the venturi correction factor shall be calculated from Formulae (4) and (5):

$$K_1 = Q_{cal} \times \frac{\sqrt{T_v}}{p_v} \tag{4}$$

$$Q_{cal} = K_2 \times Q_a \frac{p_a}{T_a} \tag{5}$$

The ratio of pressure to temperature at the standard reference conditions, K_2, shall be

$K_2 = 293,15/101,325 = 2,893$.

11.1.2 Total diluted exhaust mixture volume for the CVS system with PDP

The volume of diluted exhaust mixture pumped during the test, V_e, shall be calculated by Formula (6).

$$V_e = K_2 \times V_p \times N \times \frac{p_p}{T_p} \times \frac{1}{L} \tag{6}$$

The diluted exhaust mixture volume pumped by the PDP per one revolution, V_p, is dependent upon the variation of dynamic pressure of the PDP.

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The diluted exhaust mixture absolute pressure at the inlet of PDP, p_p, is the difference between atmospheric pressure and the depression at the inlet to the PDP while samples are being collected.

11.2 Exhaust gas sampling and the dilution factor

11.2.1 Exhaust gas sampling

The whole exhaust gas emitted from the tail pipe of the test moped shall be flowed into the CVS system, and the adequate volume to analyse the diluted exhaust mixture (e.g. 50 L –100 L) shall be collected in the bag.

11.2.2 Dilution factor

The dilution factor, D_f, shall be calculated by Formula (7). (Detailed information is given in Annex D.)

It is recommended that the amount of the dilution air be determined so that the dilution factor becomes 8 or more to prevent the water condensation in the CVS system.

The dilution factor is defined as the volume ratio of the diluted exhaust mixture to the exhaust gas.

$$D_\text{f} = \frac{100 \big/ \left\{ 1 + \left(R_\text{HC,ex}/2 \right) + \left[\left(4 + R_\text{HC,ex} \right) \big/ 4 - \left(R_\text{OC,ex}/2 \right) \right] \times \left[\left(100 - c_\text{O2,d} \right) \big/ c_\text{O2,d} \right] \right\}}{c_\text{CO2,e} + \left(c_\text{THC,e} + c_\text{CO,e} \right) \times 10^{-4}} \tag{7}$$

The oxygen concentration in the dilution air $c_\text{O2,d}$, in percent, is assumed to be 20,9 %.

$R_\text{HC,ex}$ and $R_\text{OC,ex}$ values shall be determined by the contents analysis of the exhaust gas.

If it is not possible to measure $R_\text{HC,ex}$ and $R_\text{OC,ex}$, the $R_\text{HC,ex}$ value of 1,85 for gasoline and 2,64 for LPG, and the $R_\text{OC,ex}$ value of 0, which is common for these fuels, may be used on condition that no oxygen-contained additives such as alcohol are mixed with the fuels. If the test fuel contains such additives, $R_\text{HC,ex}$ and $R_\text{OC,ex}$ shall be determined by the contents analysis of the exhaust gas.

When the $R_\text{HC,ex}$ value of 1,85 or 2,64, and the $R_\text{OC,ex}$ value of zero are used, the dilution factor can be calculated by Formulae (8) or (9), which are the transformations of Formula (7).

For gasoline,

$$D_\text{f} = \frac{13,40}{c_\text{CO2,e} + \left(c_\text{THC,e} + c_\text{CO,e} \right) \times 10^{-4}} \tag{8}$$

For LPG,

$$D_\text{f} = \frac{11,62}{c_\text{CO2,e} + \left(c_\text{THC,e} + c_\text{CO,e} \right) \times 10^{-4}} \tag{9}$$

11.3 Mass of the gaseous exhaust emissions

11.3.1 Mass of carbon monoxide (expressed in grams per test phase)

The quantity of carbon monoxide in the exhaust gas shall be calculated by Formula (10):

$$m_\text{CO} = V_\text{e} \times \rho_\text{CO} \times c_\text{CO,ec} \times 10^{-6} \tag{10}$$

The carbon monoxide density, ρ_CO, in grams per litre, at standard reference conditions shall be 1,16 g/L.

The volumetric concentration of carbon monoxide in the diluted exhaust mixture, corrected to take account of carbon monoxide in the dilution air, $c_{CO,ec}$, shall be determined by Formula (11):

$$c_{CO,ec} = c_{CO,e} - c_{CO,d}\left(1 - \frac{1}{D_f}\right) \tag{11}$$

If the absorbent intended to remove water vapour and carbon dioxide from the diluted exhaust mixture is used, $c_{CO,e}$ and $c_{CO,d}$ shall be corrected by Formulae (12) and (13):

$$c_{CO,e} = \left[1 - \left(0,01 + 0,005 \times R_{HC,f}\right)c_{CO2,e} - 0,000323 H_d\right]c_{CO,em} \tag{12}$$

$$c_{CO,d} = \left(1 - 0,000323 H_d\right)c_{CO,dm} \tag{13}$$

11.3.2 Mass of hydrocarbons (expressed in grams per test phase)

The quantity of hydrocarbon in the exhaust gas shall be calculated by Formula (14):

$$m_{THC} = V_e \times \rho_{THC} \times c_{THC,ec} \times 10^{-6} \tag{14}$$

The hydrocarbon density, ρ_{THC}, in grams per litre, at standard reference conditions shall be determined by Formula (15):

$$\rho_{THC} = \frac{1,008 R_{HC,ex} + 12,01}{22,4} \times \frac{273,15}{293,15} \tag{15}$$

$R_{HC,ex}$ shall be determined from the contents analysis of exhaust gas. If it is not possible to measure the $R_{HC,ex}$, the $R_{HC,ex}$ may be 1,85 for gasoline and 2,64 for LPG.

The volumetric concentration, expressed in parts per million carbon equivalent, of hydrocarbon in the diluted exhaust mixture, corrected to take account of hydrocarbon in the dilution air, $c_{THC,ec}$, shall be determined by Formula (16):

$$c_{THC,ec} = c_{THC,e} - c_{THC,d}\left(1 - \frac{1}{D_f}\right) \tag{16}$$

The diluted exhaust mixture shall be stored in the sampling bag and the hydrocarbon concentration in the diluted exhaust mixture, $c_{THC,e}$, shall be measured by the flame ionization detection (FID) analyser. It is recommended to use a heated exhaust gas sampling line when there is a possibility of water condensation in the exhaust gas sampling line. In this case, the use of heated flame ionization detection (HFID) analyser is also recommended if available.

The value shall be calculated by Formula (17):

$$c_{THC,e} = \frac{\int_0^{t_{test}} C_{THC}\,dt}{t_{test} - 0} \tag{17}$$

11.3.3 Mass of nitrogen oxides (expressed in grams per test phase)

The quantity of nitrogen oxides in the exhaust gas shall be calculated by Formula (18):

$$m_{NOx} = V_e \times \rho_{NOx} \times c_{NOx,ec} \times K_H \times 10^{-6} \tag{18}$$

The nitrogen dioxides density, ρ_{NOx}, in grams per litre, under the standard reference conditions, expressed in equivalent NO_2, shall be 1,91 g/L.

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The volumetric concentration of nitrogen oxides in the diluted exhaust mixture, corrected to take account of nitrogen oxides in the dilution air, $c_{NOx,ec}$, shall be determined by Formula (19):

$$c_{NOx,ec} = c_{NOx,e} - c_{NOx,d}\left(1 - \frac{1}{D_f}\right) \tag{19}$$

The humidity correction factor, K_H, shall be defied by Formula (20):

$$K_H = \frac{1}{1 - 0,0329 \times (H_a - 10,71)} \tag{20}$$

where

$$H_a = \frac{6,211 H_r \times p_d}{p_a - \left[(p_d \times H_r)/100\right]} \tag{21}$$

11.3.4 Mass of carbon dioxide (expressed in grams per test phase)

The quantity of carbon dioxide in the exhaust gas shall be calculated by Formula (22):

$$c_{CO2} = V_e \times \rho_{CO2} \times c_{CO2,ec} \times 10^{-2} \tag{22}$$

The carbon dioxide density, ρ_{CO2}, in grams per litre, at the standard reference conditions shall be 1,83 g/L.

The volumetric concentration of carbon dioxide in the diluted exhaust mixture, corrected to take account of carbon dioxide in the dilution air, $c_{CO2,ec}$, shall be determined by Formula (23):

$$c_{CO2,ec} = c_{CO2,e} - c_{CO2,d}\left(1 - \frac{1}{D_f}\right) \tag{23}$$

12 Determination of the fuel consumption

12.1 Carbon balance method

12.1.1 Fuel consumption for four-stroke engines

Formula (24) shall be used for the calculation of fuel consumption. (Detailed information is given in Annex E.)

$$F_c = \frac{12,01}{12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}}$$
$$\times \frac{\rho_f}{(12,01/44,01)m_{CO2} + (12,01/28,01)m_{CO} + \left[12,01/\left(12,01 + 1,008 R_{HC,ex} + 16,00 R_{OC,ex}\right)\right]m_{THC}} \tag{24}$$

$R_{HC,ex}$, $R_{OC,ex}$, $R_{HC,f}$ and $R_{OC,f}$ shall be determined by the contents analysis of the exhaust gas or the fuel. The simplified determination method of $R_{HC,f}$ and $R_{OC,f}$ specified in Annex F may be applied to gasoline.

If it is not possible to measure $R_{HC,ex}$, and $R_{OC,ex}$, the $R_{HC,ex}$ value of 1,85 for gasoline and 2,64 for LPG, and the $R_{OC,ex}$ value of zero, which is common for these fuels, may be used.

If it is not possible to determine $R_{HC,f}$ and $R_{OC,f}$, the equal values of $R_{HC,ex}$ (1,85 for gasoline and 2,64 for LPG) and $R_{OC,ex}$ (zero for all these fuels) may be applied to $R_{HC,f}$ and $R_{OC,f}$ on condition that no oxygen-contained additives such as alcohol are mixed with the fuels. If the test fuel contains such additives, $R_{HC,ex}$, $R_{OC,ex}$, $R_{HC,f}$ and $R_{OC,f}$ shall be determined by the contents analysis of the exhaust gas and of the fuel.

When the $R_{HC,ex}$ and $R_{HC,f}$ values of 1,85 for gasoline and 2,64 for LPG and the $R_{OC,ex}$ and $R_{OC,f}$ values of zero are used, the fuel consumption can be calculated by Formulae (25) and (26), which are the transformation of Formula (24).

For gasoline four-stroke spark ignition engine,

$$F_c = \frac{0,866 \times \rho_f}{(0,273 \times m_{CO2}) + (0,429 \times m_{CO}) + (0,866 \times m_{THC})} \tag{25}$$

For LPG four-stroke spark ignition engines,

$$F_c = \frac{0,819 \times \rho_f}{(0,273 \times m_{CO2}) + (0,429 \times m_{CO}) + (0,819 \times m_{THC})} \tag{26}$$

12.1.2 Fuel consumption for two-stroke engines

When the lubrication oil is mixed with the fuel, it is necessary to know the lubrication oil/fuel mixing ratio to use the carbon balance method. The determination method is described in Annex G.

12.2 Fuel flow measurement method

Methods for fuel consumption are shown in Annex A.

12.2.1 Fuel consumption for four-stroke engines

12.2.1.1 Fuel consumption measured by the volumetric method

In cases where the fuel consumption is measured volumetrically, the fuel consumption, F_c, shall be calculated by Formula (27):

$$F_c = \frac{L}{V\left[1 + \alpha(T_0 - T_f)\right]} \tag{27}$$

For gasoline, the coefficient of volumetric expansion for the fuel, α shall be 0,001 K^{-1}.

12.2.1.2 Fuel consumption measured by the gravimetric method

In cases where the fuel consumption is measured gravimetrically, the fuel consumption, F_c, shall be calculated by Formula (28):

$$F_c = \frac{L \times \rho_f}{m_f} \tag{28}$$

12.2.1.3 Fuel consumption measured by the flowmeter method

In cases where the fuel consumption is measured by the flowmeter, the fuel consumption, F_c, shall be calculated by Formula (29):

$$F_c = \frac{L}{V} \tag{29}$$

12.2.2 Fuel consumption for two-stroke engines

The mixing ratio of lubrication oil and fuel is defined by Formula (30):

$$a = \frac{V_f}{V_o} \tag{30}$$

The fuel consumption shall be obtained by Formula (31). The specific fuel consumption for lubrication oil mixed fuel, F'_c shall be obtained by the same method in the case of excluding lubrication oil specified in 12.2.1.

$$F_c = F_c' \times \frac{a+1}{a} \tag{31}$$

12.3 Calculation of results in litres per 100 km

When the fuel consumption is expressed in litres per 100 km, Formula (32) shall be used.

$$F_{c100} = \frac{100}{F_c} \tag{32}$$

12.4 Criteria of the statistical accuracy for the fuel consumption measurements

When higher reliability of test data is required for the fuel consumption measurement test, the method using the criteria of the statistical accuracy as specified in Annex H may be applied.

Annex A
(normative)

Method and equipment for measuring fuel consumption by the fuel flow measurement method

A.1 Methods

A.1.1 Volumetric method

The volumetric method uses a container with a known volume, allowing the volume of the fuel consumed to be calculated.

This container may be a constant or variable volume type.

The constant volume container only allows the reading of a fixed quantity of fuel that has been determined beforehand. This prefixed quantity depends on container volume or markings on the container.

The variable volume container is one with division markings which allows the reading of a volume that has not been determined beforehand.

A.1.2 Gravimetric method

Gravimetric methods use a weighing device to determine the mass of fuel consumed. This device can be of the constant or variable mass type.

The constant mass device only allows the reading of a fixed quantity of fuel that has been determined beforehand. This fixed quantity depends on the device itself and on its characteristics.

The variable mass device allows the reading of a quantity of fuel that has not been determined beforehand.

A.1.3 Flowmeter method

The flowmeter method uses devices allowing measurement, in a continuous or discontinuous way, of the quantified mass or volume of fuel passing through during a certain interval.

The continuous device gives an indication with respect to the flow while the discontinuous type gives an indication based on counting small elementary volumes.

A.2 Installation of measuring equipment

A.2.1 General

A.2.1.1 Whatever the measuring method used, the installation of the equipment shall in no case significantly disturb or modify the fuel feed system of the moped, referring mainly to pressure drops, diameters and lengths of fuel feed pipes.

A.2.1.2 The conditions given in A.2.1.1 are considered to be met:

a) if the mounting of the installation for the volumetric or gravimetric methods is in accordance with Figures A.1, A.2, A.4 and A.5;

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b) if the mounting of the installation of the flowmeter method is in accordance with Figures A.3, A.6, A.7, A.8 and A.9, and the pressure drop across the system is less than 1 hPa.

When the flowmeter is installed in high-pressure pipe lines of fuel injection system, care shall be taken when setting the position of the flowmeter and the following points:

— the resisting pressure of parts of the flowmeter, (e.g. sensors, filters, pipes, etc.) shall be sufficiently higher than the fuel pressure;

— the pressure drops caused by parts of the flowmeter, (e.g. sensors, filters, pipes, etc.) shall not influence on the fuel injection pressure and the fuel flow rate;

— in cases where the intermittent flow or reflux occurs in the vicinity of the flowmeter, the pipe arrangement shall be improved or the flowmeter shall have the compensator for the intermittent flow and reflux;

— no vapour shall be generated in the pipes and the flowmeter.

A.2.1.3 Other installation locations may be used if it has been proved that these conditions do not influence the fuel feed of the moped.

A.2.1.4 To reduce the possibility of pressure loss in the fuel pipes, it is recommended that:

$$d_1 \leq d_2 \tag{A.1}$$

$$d_2 = d_3 \tag{A.2}$$

where

d_1 is the original fuel pipe diameter;

d_2 is the fuel pipe diameters of the measuring device;

d_3 is the fuel pipe diameters of the measuring device.

A.2.2 Volumetric method

A.2.2.1 A schematic diagram is shown in Figure A.1 for carburettor systems and Figure A.4 for injection systems.

A.2.2.2 Test conditions for the volumetric method for chassis dynamometer and road use shall be as follows:

a) the burette shall be placed at the side of the fuel tank in such a way that

$$h_a \leq h_u - h_l + 300 \tag{A.3}$$

where

h_a is the highest measured by burette, in millimetres;

h_u is the upper head of fuel, in millimetres;

h_l is the lower head of fuel, in millimetres;

b) care shall be taken that the pressure in the burette is not influenced by wind pressure acting on the air vent of the burette.

A.2.3 Gravimetric method

A.2.3.1 A schematic diagram is shown in Figure A.2 for carburettor systems and Figure A.5 for injection systems.

A.2.3.2 The mass of consumed fuel shall be measured with an accuracy of ± 1 % to the resolution of 0,1 g.

A.2.3.3 The density (mass/volume) shall be measured with an accuracy of 1 g/L and then converted to the reference conditions.

A.2.4 Flowmeter method

A.2.4.1 The flowmeter shall be designed in such a way that the overall pressure loss through the device is not greater than 1 hPa.

A.2.4.2 A schematic diagram of the flowmeter is shown in Figure A.3 for carburettor systems and in Figures A.6, A.7 A.8 and A.9 for injection systems.

A.2.4.3 Accuracy shall be within ± 1 % for the range of all the flows registered during that test.

Key
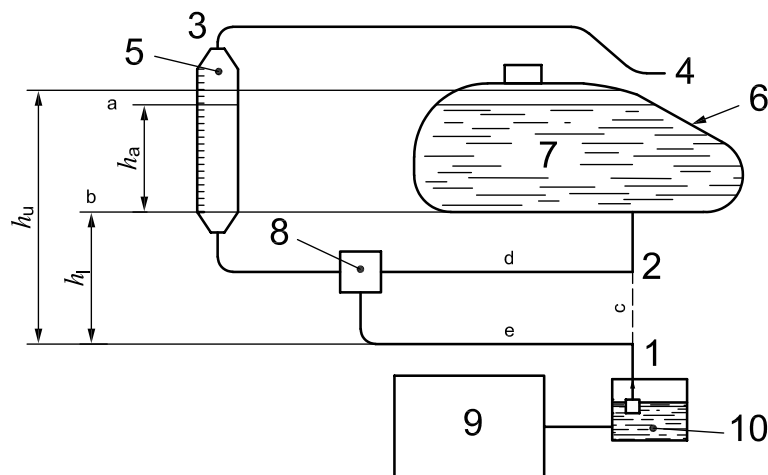
|			
1	carburettor fuel inlet	8	3-way valve
2	fuel tank outlet	9	engine
3	burette air vent	10	carburettor float chamber
4	burette air vent pipe	h_u	upper head of fuel, in millimetres
5	burette	h_l	lower head of fuel, in millimetres
6	fuel tank	h_a	height measured by burette, in millimetres
7	fuel		

[a]   On circuit.

[b]   Off circuit.

[c]   Original fuel pipe diameter, d_1.

[d]   Fuel pipe diameter of the measuring device, d_2.

[e]   Fuel pipe diameter of the measuring device, d_3.

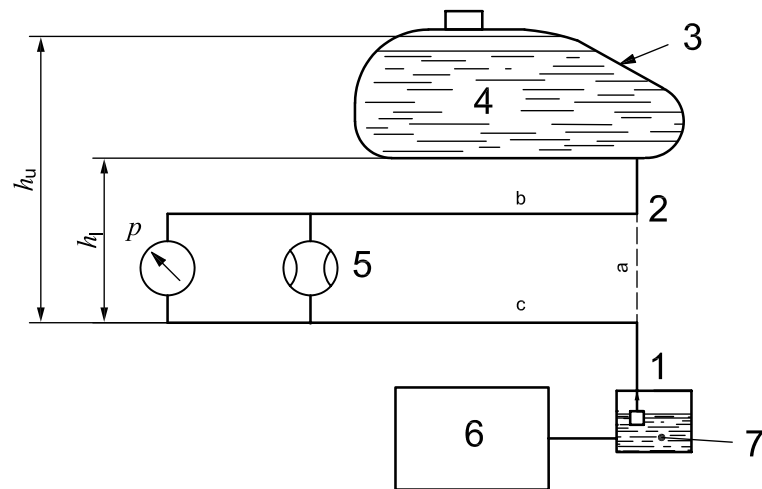**Figure A.1 — Volumetric method — Carburettor system**

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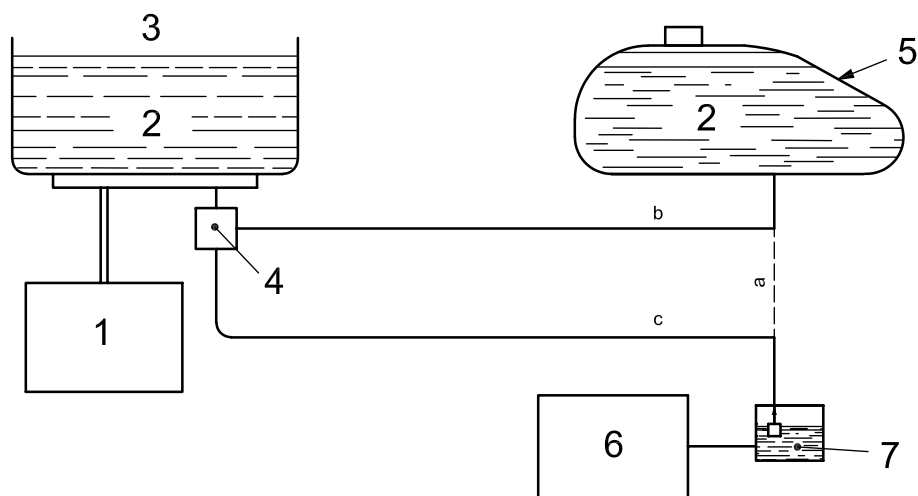
Key

|			
1	scales	5	fuel tank
2	fuel	6	engine
3	auxiliary tank	7	carburettor float chamber
4	3-way valve		

a   Original fuel pipe diameter, d_1.

b   Fuel pipe diameter of the measuring device, d_2.

c   Fuel pipe diameter of the measuring device, d_3.

Figure A.2 — Gravimetric method — Carburettor system

Key

1	carburettor fuel inlet	6	engine
2	fuel tank outlet	7	carburettor float chamber
3	fuel tank	h_u	upper head of fuel, in millimetres
4	fuel	h_l	lower head of fuel, in millimetres
5	flowmeter	p	pressure drop across flowmeter, in hectopascals

a   Original fuel pipe diameter, d_1.

b   Fuel pipe diameter of the measuring device, d_2.

c   Fuel pipe diameter of the measuring device, d_3.

Figure A.3 — Flowmeter method — Carburettor system

Key
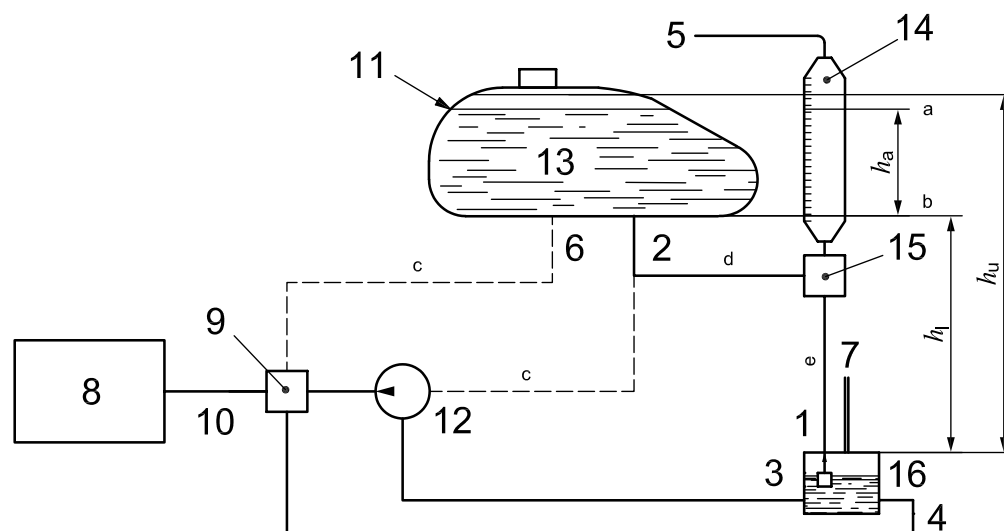
|			
1	leveller fuel inlet	11	fuel tank
2	fuel tank outlet	12	fuel pressure pump
3	leveller fuel outlet	13	fuel
4	leveller fuel inlet	14	burette
5	burette air vent pipe	15	3-way valve
6	fuel tank inlet	16	leveller
7	leveller air vent pipe	h_u	upper head of fuel, in millimetres
8	engine	h_l	lower head of fuel, in millimetres
9	fuel pressure regulator	h_a	height measured by burette, in millimetres
10	fuel injection		

a   On circuit.

b   Off circuit.

c   Original fuel pipe diameter, d_1.

d   Fuel pipe diameter of the measuring device, d_2.

e   Fuel pipe diameter of the measuring device, d_3.

Figure A.4 — Volumetric method — Fuel injection system
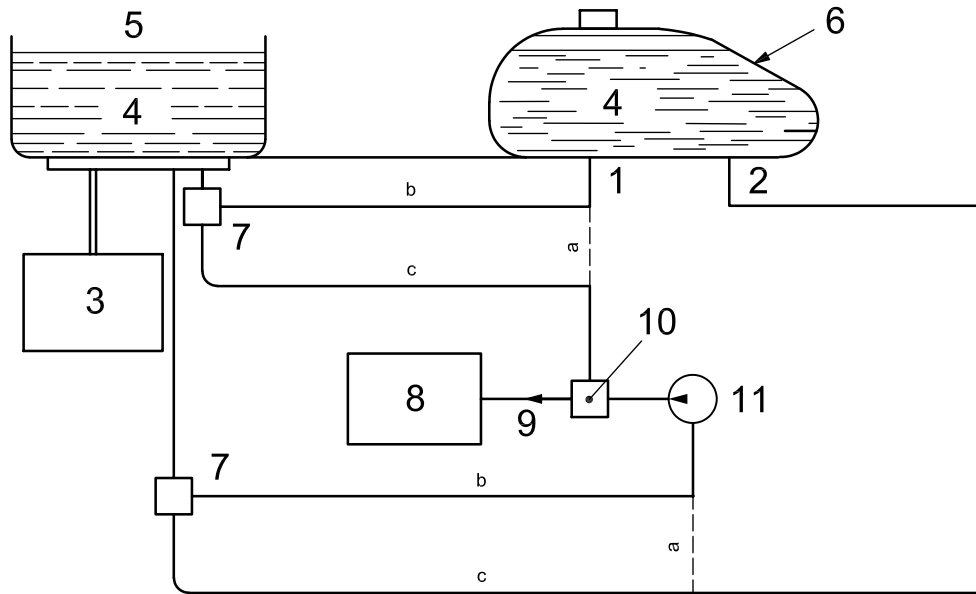
Key

1	fuel tank inlet	7	3-way valve
2	fuel tank outlet	8	engine
3	scales	9	fuel injection
4	fuel	10	fuel pressure regulator
5	auxiliary tank	11	fuel pressure pump
6	fuel tank		

a Original fuel pipe diameter, d_1.

b Fuel pipe diameter of the measuring device, d_2.

c Fuel pipe diameter of the measuring device, d_3.

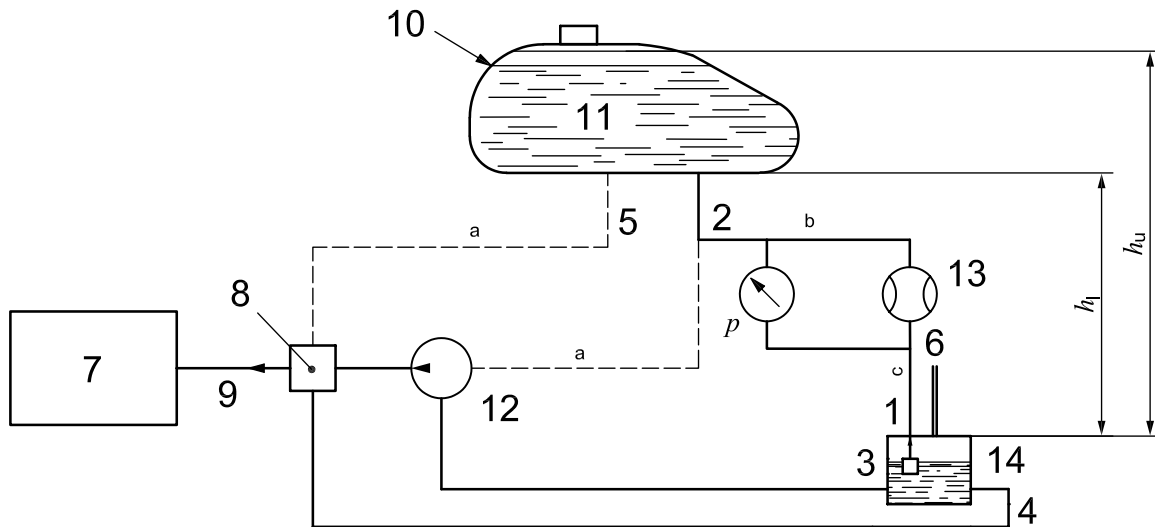**Figure A.5 — Gravimetric method — Fuel injection system**

Key

1	leveller fuel inlet	10	fuel tank
2	fuel tank outlet	11	fuel
3	leveller fuel outlet	12	fuel pressure pump
4	leveller fuel inlet	13	flowmeter
5	fuel tank inlet	14	leveller
6	leveller air vent pipe	h_u	upper head of fuel, in millimetres
7	engine	h_l	lower head of fuel, in millimetres
8	fuel pressure regulator	p	pressure drop across flowmeter, in hectopascals
9	fuel injection		

a   Original fuel pipe diameter, d_1.

b   Fuel pipe diameter of the measuring device, d_2.

c   Fuel pipe diameter of the measuring device, d_3.

Figure A.6 — Flowmeter method — Fuel injection system

Key
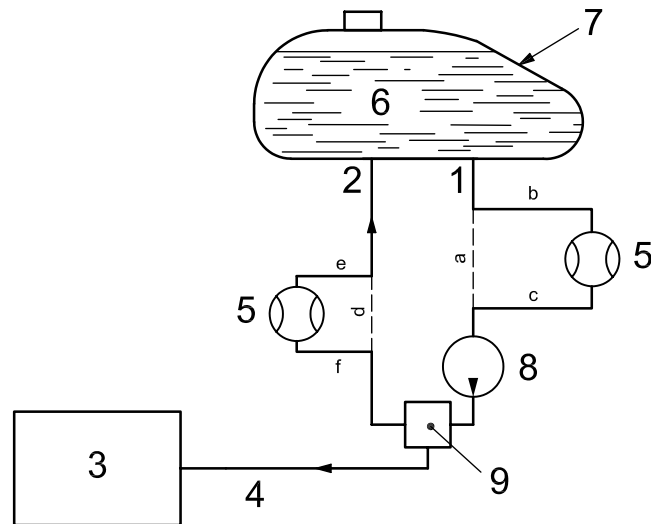
1	fuel tank outlet	6	fuel
2	fuel return	7	fuel tank
3	engine	8	fuel pressure pump
4	fuel injection	9	fuel pressure regulator
5	flowmeter		

a   Original fuel pipe diameter, d_1.

b   Fuel pipe diameter of the measuring device, d_2.

c   Fuel pipe diameter of the measuring device, d_3.

d   Original fuel pipe diameter, d_4.

e   Fuel pipe diameter of the measuring device, d_5.

f   Fuel pipe diameter of the measuring device, d_6.

Figure A.7 — Flowmeter method — Fuel injection system with fuel return — Type 1 method

Key

1	fuel tank outlet	6	fuel tank
2	fuel return	7	fuel pressure pump
3	engine	8	fuel pressure regulator
4	flowmeter	9	fuel injection
5	fuel		

[a] Original fuel pipe diameter, d_1.
[b] Fuel pipe diameter of the measuring device, d_2.
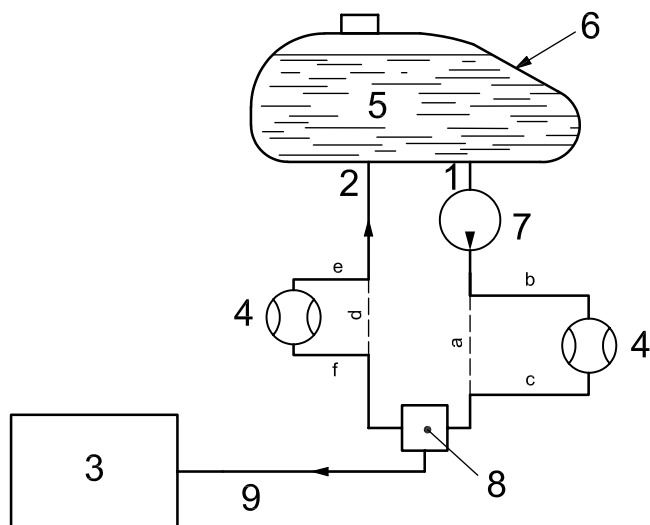[c] Fuel pipe diameter of the measuring device, d_3.
[d] Original fuel pipe diameter, d_4.
[e] Fuel pipe diameter of the measuring device, d_5.
[f] Fuel pipe diameter of the measuring device, d_6.

Figure A.8 — Flowmeter method — Fuel injection system with fuel return — Type 2 method

Key

1	fuel tank outlet	5	fuel
2	engine	6	fuel pressure pump
3	fuel pressure regulator	7	flowmeter
4	fuel tank	8	fuel injection

a   Original fuel pipe diameter, d_1.

b   Fuel pipe diameter of the measuring device, d_2.

c   Fuel pipe diameter of the measuring device, d_3.

Figure A.9 — Flowmeter method — Fuel injection system without fuel return

Annex B
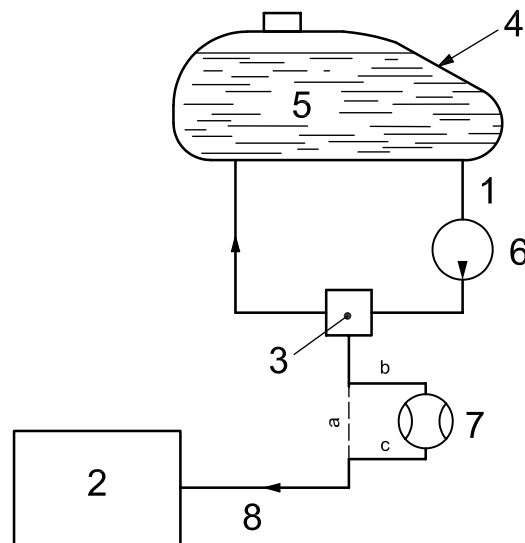## (informative)

Example for record form of test fuel specifications

Characteristic	Unit	Test method
Research octane number (RON)	–	ISO 5164
Relative density 15°C/4°C (specific gravity)	–	ISO 3675
Reid vapour pressure	kPa	ISO 3007
Distillation 　Initial boiling point 　10 % (volume) 　50 % (volume) 　90 % (volume) 　Final boiling point 　Residue	 °C °C °C °C °C %	ISO 3405
Hydrocarbon analysis 　Olefins 　Aromatics 　Saturates	 % % %	ISO 3837
Oxidation stability	min	ISO 7536
Existent gum	$mg/100mm^3$	ISO 6246
Sulfur content	%	ISO 4260, ISO 8754
Lead content 　Nature of scavenger 　Nature of lead alkyl	g/dm^3	ISO 3830
Carbon/hydrogen ratio	–	
Benzene	volume %	
MTBE	volume %	
Methanol	volume %	
Kerosene	volume %	
Mixture-ratio of fuels to lubricants	–	

Annex C
(informative)

Exhaust gas leakage check procedure for the open type CVS system

C.1   Exhaust gas leakage check procedure for the open type CVS system

The exhaust gas leakage check method specified in C.2 and C.3 may be used to verify the open type CVS system. The test shall be stopped and the CVS system shall be improved whatever the exhaust gas leakage is confirmed from either test.

A schematic diagram is shown in Figure C.1 for the representative open type CVS system with CFV and Figure C.2 for the representative open type CVS system with PDP.

Key
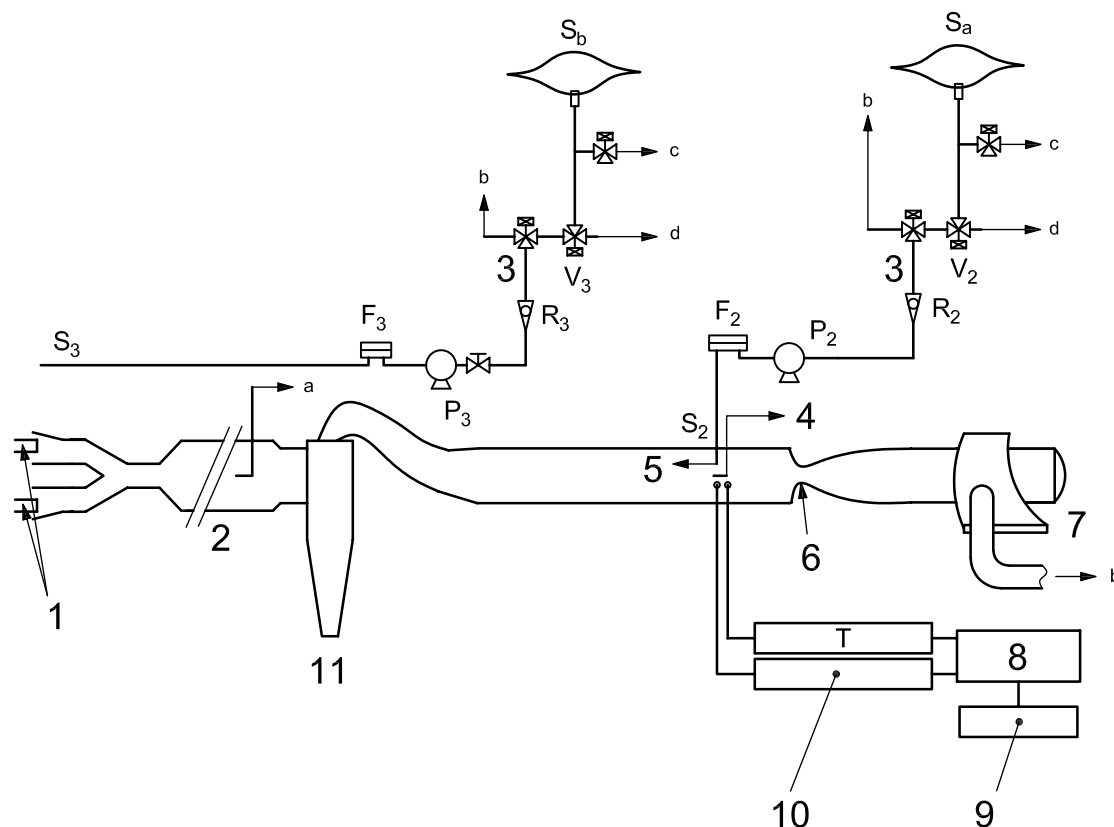
1	moped exhaust pipes	10	pressure gauge
2	mixing chamber	11	cyclone
3	diversion valve	F_2, F_3	filters
4	continuous sampling probe	P_2, P_3	pumps
5	sampling venturi	R_2, R_3	flowmeters
6	main critical flow venturi	S_a, S_b	sampling bags
7	blower	S_2, S_3	probes
8	calculator	T	temperature gauge
9	integrator	V_2, V_3	valves

a To HFID; special sampling line when HFID is used.

b To atmosphere.

c To exhaust pump.

d To analysing system.

Figure C.1 — A schematic diagram for the representative open type CVS system with CFV

Key
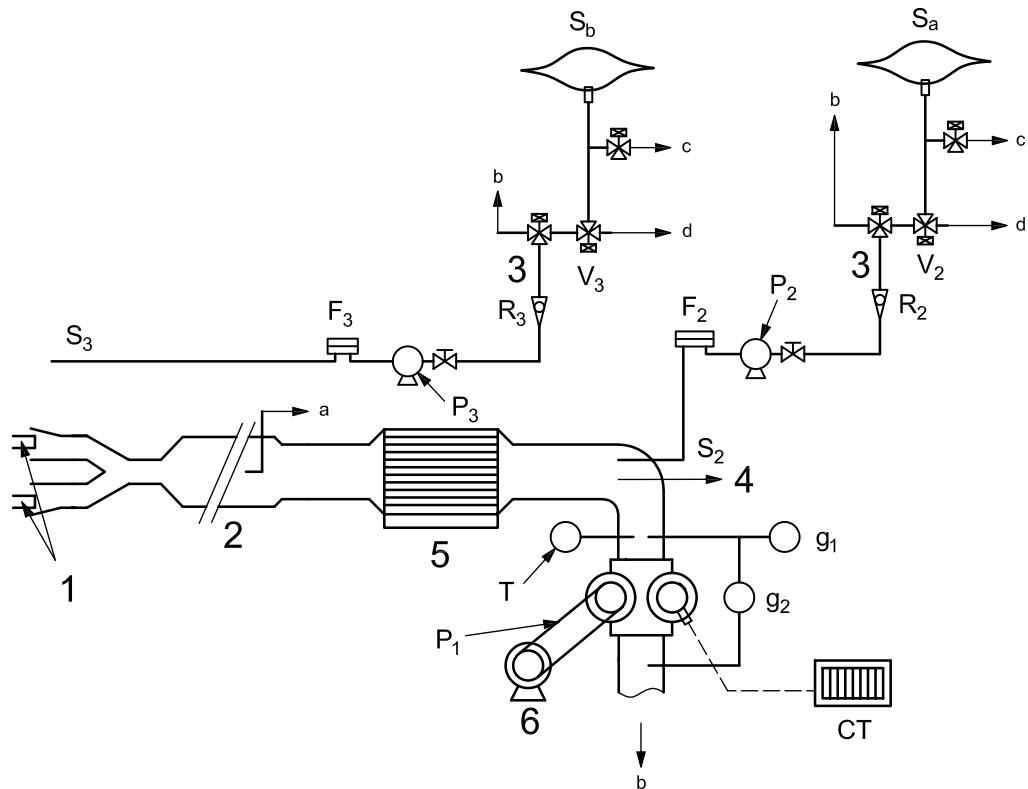
1	moped exhaust pipes	g_1, g_2	pressure gauges
2	mixing chamber	P_1	positive displacement pump
3	diversion valve	P_2, P_3	pumps
4	continuous sampling probe	R_2, R_3	flowmeters
5	heat exchanger	S_a, S_b	sampling bags
6	motor	S_2, S_3	probes
CT	revolution counter	T	temperature gauge
F_2, F_3	filters	V_2, V_3	valves

[a]   To HFID; special sampling line when HFID is used.

[b]   To atmosphere.

[c]   To exhaust pump.

[d]   To analysing system.

Figure C.2 — A schematic diagram for the representative open type CVS system with PDP

C.2   Principle of leakage check procedure by the fuel consumption measurement

The leakage check is based on the procedure described below:

a)   the fuel consumption shall be determined using the following two methods:

   1)   the carbon balance method with the gaseous exhaust emission,

   2)   the fuel flowmeter, the burette, the mass flowmeter and other fuel flow measuring methods;

b)   the fuel consumption shall be simultaneously measured by both methods. The exhaust gas leakage can be confirmed by comparison of the fuel consumption data results obtained by both the carbon balance and the fuel flow measuring method.

C.2.1 Leakage check procedure

The fuel consumption shall be simultaneously determined by both carbon balance and fuel flow measuring method in accordance with the test cycle specified in ISO 6855-2:2012, Clause 3.

The fuel flow measuring method (e.g. the volumetric method, gravimetric method and flowmeter methods specified in Annex A) shall be used. The measurement accuracy of fuel measuring system shall be in accordance with 7.5.2 and Annex A.

The moped preparation, the chassis dynamometer preparation, the rider mass and other specifications shall be in accordance with this part of ISO 6855.

The gaseous exhaust gas emission measurement and the fuel consumption calculation by the carbon balance method shall be determined in accordance with Clauses 11 and 12.

C.2.2 Criterion of exhaust gas leakage from the open type CVS system

The criterion of the fuel consumption error caused by the exhaust gas leakage of the open type CVS system shall be within 5 % when the fuel consumption error, E, shall be calculated by Formula (C.1),

$$E = \frac{F_{cCVS} - F_{cFlow}}{F_{cFlow}} \times 100\% \tag{C.1}$$

where

F_{cFlow} is the fuel consumption measured by the fuel flow measuring method, in km/L;

F_{cCVS} is the fuel consumption measured by the carbon balance method with the open type CVS system, in km/L.

C.3 Principle of leakage check procedure by the gaseous exhaust emissions measurement in the background air

The concentration of gaseous exhaust emissions in the air of test room (background air) would be increased by the leakage of the exhaust gas from open type CVS system. The exhaust gas leakage shall be verified from the background air measurements.

C.3.1 Leakage check procedure

C.3.1.1   The inlet of measurements system for the background air shall be located inside the test room. In cases where the dilution air for the CVS system is taken from the test room, a sample of dilution air can be used instead of the background air. Any doors and windows in the test room shall be closed.

C.3.1.2   The gaseous exhaust emissions concentrations in the background air shall be measured before the test commencement.

C.3.1.3   The gaseous exhaust emissions concentrations in the background air shall be measured during the test.

C.3.1.4   The gaseous exhaust emissions concentrations in the background air before and during the test shall be compared.

C.3.2 Verification of exhaust gas leakage

Exhaust gas leakage has not occurred when the measurement results of gaseous exhaust emission concentrations in the background air before and during the test are the same level. When the increase of all gaseous exhaust emission concentrations are confirmed, the exhaust gas has leaked from the

open type CVS system and the sampling system should be improved and checked again by using the prescribed procedure.

Annex D
(informative)

Determination of the dilution factor

D.1 Definition of the dilution factor

The dilution factor is defined as the volume ratio of diluted exhaust mixture to exhaust gas:

$$D_f = \frac{V_{ex} + V_d}{V_{ex}} \tag{D.1}$$

where

V_{ex} is exhaust gas volume;

V_d is dilution air volume.

D.2 Combustion reaction equation

The exhaust gas, in moles, produced from the combustion of 1 mol of fuel $C_xH_yO_z$ (for the numbers of carbon atom, x, of hydrogen atom, y, and of oxygen atom, z) is expressed by Formula (D.2):

$$C_xH_yO_z + \lambda\left(x + \frac{y}{4} - \frac{z}{2}\right)\left(1 \times O_2 + \frac{100 - c_{O2,d}}{c_{O2,d}} I\right) =$$
$$= n_a + n_b + n_c + n_d + n_e + n_f + \lambda\left(x + \frac{y}{4} - \frac{z}{2}\right)\left(\frac{100 - c_{O2,d}}{c_{O2,d}} I\right) \tag{D.2}$$

where

n_a is the number of carbon dioxide molecules in exhaust gas, moles;

n_b is the number of carbon monoxide molecules in exhaust gas, moles;

n_c is the number of oxygen molecules in exhaust gas, moles;

n_d is the number of unburned fuel $C_xH_yO_z$ molecules in exhaust gas, moles;

n_e is the number of hydrogen molecules in exhaust gas, moles;

n_f is the number of water molecules in exhaust gas, moles;

λ is the excess air factor;

I is the molecules of inert gases in the air;

$c_{O2,d}$ is the oxygen concentration in the dilution air, in percent.

Here, in the case of oxygen concentration in the dilution air $c_{O2,d}$, in percent, the contents of inert gas can be calculated by Formula (D.3).

$$I = \left[\lambda\left(x + \frac{y}{4} - \frac{z}{2}\right) \times \frac{100}{c_{O2,d}}\right] \times \frac{100 - c_{O2,d}}{100} = \lambda\left(x + \frac{y}{4} - \frac{z}{2}\right) \times \frac{100 - c_{O2,d}}{c_{O2,d}} \tag{D.3}$$

The numbers of carbon atom, x, of hydrogen atom, y, and of oxygen atom, z, are not changed before and after the combustion:

$$x = n_a + n_b + x n_d \tag{D.4}$$

$$y = n_d y + 2 n_e \times 2 n_f \tag{D.5}$$

$$z + 2\lambda \left(x + \frac{y}{4} - \frac{z}{2} \right) = 2 n_a + n_b + 2 n_c + z n_d + n_f \tag{D.6}$$

Here, the coefficient K is defined by Formula (D.7).

$$K = \frac{n_b \times n_f}{n_a \times n_e} \tag{D.7}$$

Formulae (D.5) and (D.7) are changed as follows:

$$n_e = \frac{y - y n_d - 2 n_f}{2} \tag{D.8}$$

$$n_f = \frac{n_a \times n_e \times K}{n_b} \tag{D.9}$$

By substituting Formula (D.9) into Formula (D.8), the number of hydrogen molecule in exhaust gas, n_e, in moles, is expressed by Formula (D.10):

$$n_e = \left(\frac{y}{2} - \frac{y n_d}{2} \right) \frac{n_b}{n_b + n_a \times K} = \frac{y}{2}(1 - n_d) \frac{n_b / (n_a \cdot K)}{(n_b / n_a \cdot K) + 1} \tag{D.10}$$

Formulae (D.5) and (D.7) are changed as follows:

$$n_f = \frac{y - y n_d - 2 n_e}{2} \tag{D.11}$$

$$n_e = \frac{n_b \times n_f}{n_a \times K} \tag{D.12}$$

By substituting Formula (D.11) into Formula (D.12), the number of water molecule in exhaust gas, n_f, in moles, is expressed by Formula (D.13):

$$n_f = \left(\frac{y}{2} - \frac{y \cdot n_d}{2} \right) \frac{n_a \cdot K}{n_a \cdot K + n_b} = \frac{y}{2}(1 - n_d) \frac{1}{(n_b / n_a \cdot K) + 1} \tag{D.13}$$

The number of oxygen molecule in exhaust gas, n_c, is obtained from Formula (D.6) as follows:

$$n_c = \frac{1}{2}\left[z + 2\lambda\left(x + \frac{y}{4} - \frac{z}{2}\right) - 2 \cdot n_a - n_b - z \cdot n_d - n_f\right] = \frac{z}{2} + \lambda\left(x + \frac{y}{4} - \frac{z}{2}\right) - n_a - \frac{n_b}{2} - \frac{z \cdot n_d}{2} - \frac{n_f}{2} \quad \text{(D.14)}$$

Formulae (D.4) and (D.5) are changed as follows:

$$n_a = x - n_b - x \cdot n_d \quad \text{(D.15)}$$

$$n_f = \frac{y}{2} - \frac{y \cdot n_d}{2} - n_e \quad \text{(D.16)}$$

Formulae (D.15) and (D.16) are substituted into Formula (D.14), as follows:

$$n_c = \frac{z}{2} + \lambda\left(x + \frac{y}{4} - \frac{z}{2}\right) - (x - n_b - x \cdot n_d) - \frac{n_b}{2} - \frac{z \cdot n_d}{2} - \left(\frac{y}{4} - \frac{y \cdot n_d}{4} - \frac{n_e}{2}\right)$$

$$= (\lambda - 1 + n_d)\left(x + \frac{y}{4} - \frac{z}{2}\right) + \frac{n_b}{2} + \frac{n_e}{2} \quad \text{(D.17)}$$

If Formula (D.10) is substituted into Formula (D.17), the number of oxygen molecule in exhaust gas, n_c, in moles, is expressed by Formula (D.18):

$$n_c = (\lambda - 1 + n_d)\left(x + \frac{y}{4} - \frac{z}{2}\right) + \frac{n_b}{2} + \frac{y}{4}(1 - n_d)\frac{n_b/n_a \cdot K}{(n_b/n_a \cdot K) + 1} \quad \text{(D.18)}$$

The exhaust gas consists of CO_2, CO, O_2, $C_xH_yO_z$, H_2, H_2O and inert gases in the air, therefore the exhaust gas c_{ex}, produced from 1 mol fuel, expressed in moles, is the sum of these contents and is expressed by Formula (D.19):

$$c_{ex} = n_a + n_b + n_c + n_d + n_e + n_f + \lambda\left(x + \frac{y}{4} - \frac{z}{2}\right)\frac{100 - c_{O2,d}}{c_{O2,d}}I$$

$$= n_a + n_b + (\lambda - 1 + n_d)\left(x + \frac{y}{4} - \frac{z}{2}\right) + \frac{n_b}{2} + \frac{y}{2}(1 - n_d)\frac{n_b/n_a \cdot K}{(n_b/n_a \cdot K) + 1} + n_d \quad \text{(D.19)}$$

$$+ \frac{y}{2}(1 - n_d)\frac{n_b/n_a \cdot K}{(n_b/n_a \cdot K) + 1} + \frac{y}{2}(1 - n_d)\frac{1}{(n_b/n_a \cdot K) + 1} + \lambda\left(x + \frac{y}{4} - \frac{z}{2}\right)\frac{100 - c_{O2,d}}{c_{O2,d}}I$$

Formula (D.15) is substituted into Formula (D.19), and Formula (D.19) is arranged the expression.

$$c_{ex} = -\frac{y}{4}(1 - n_d) + \frac{y}{2}(1 - n_d) + \frac{z}{2}(1 - n_d) + \frac{n_b}{2} + n_d + \frac{y}{4}(1 - n_d)\frac{n_b/n_a \cdot K}{(n_b/n_a \cdot K) + 1}$$

$$+ \lambda\left(x + \frac{y}{4} - \frac{z}{2}\right) + \lambda\left(x + \frac{y}{4} - \frac{z}{2}\right)\frac{100 - c_{O2,d}}{c_{O2,d}}I \quad \text{(D.20)}$$

Here, the air, c_{air}, in moles, is

$$c_{air} = \lambda\left(x + \frac{y}{4} - \frac{z}{2}\right) + \lambda\left(x + \frac{y}{4} - \frac{z}{2}\right)\frac{100 - c_{O2,d}}{c_{O2,d}} \tag{D.21}$$

Rearrange Formula (D.20) as follows:

$$
\begin{aligned}
c_{ex} &= \frac{y}{4}(1 - n_d) + \frac{y}{2}(1 - n_d) + \frac{z}{2}(1 - n_d) + \frac{n_b}{2} + n_d + \frac{y}{4}(1 - n_d)\frac{n_b/n_a \cdot K}{(n_b/n_a \cdot K) + 1} + c_{air} \\
&= \frac{n_b}{2} + n_d + \left[\frac{y}{4}\left(1 + \frac{n_b/n_a \cdot K}{(n_b/n_a \cdot K) + 1}\right) + \frac{z}{2}\right](1 - n_d) + c_{air}
\end{aligned}
\tag{D.22}
$$

The volume ratio of CO_2, CO, $C_xH_yO_z$ in exhaust gas is equal to mole fraction of these contents:

$$\frac{n_a}{c_{ex}} = c_{CO2,ex} \tag{D.23}$$

$$\frac{n_b}{c_{ex}} = c_{CO,ex} \tag{D.24}$$

$$\frac{n_d}{c_{ex}} = C_xH_yO_{z,ex} = \frac{c_{THC,ex}}{x} \tag{D.25}$$

where

$c_{CO2,ex}$ is the carbon dioxide concentration in the exhaust gas;

$c_{CO,ex}$ is the carbon monoxide concentration in the exhaust gas;

$c_{THC,ex}$ is the volume ratio of unburned fuel which is expressed by the equivalent number of carbon atom.

Formulae (D.23), (D.24) and (D.25) are substituted into Formula (D.22), as follows:

$$
\begin{aligned}
c_{ex} &= \frac{c_{ex} \cdot c_{CO,ex}}{2} + \frac{c_{ex} \cdot c_{THC,ex}}{x} \\
&+ \left\{\frac{y}{4}\left[1 + \frac{(c_{ex} \cdot c_{CO,ex})/(c_{ex} \cdot c_{CO2,ex} \cdot K)}{(c_{ex} \cdot c_{CO,ex})/(c_{ex} \cdot c_{CO2,ex} \cdot K) + 1}\right] + \frac{z}{2}\right\}\left(1 - \frac{c_{ex} \cdot c_{THC,ex}}{x}\right) + c_{air}
\end{aligned}
\tag{D.26}
$$

Both sides of Formula (D.26) are divided by c_{ex} and rearranged, as follows:

$$
c_{ex} = \frac{\dfrac{y}{4}\left[1 + \dfrac{(c_{CO,ex}/c_{CO2,ex} \cdot K)}{(c_{CO,ex}/c_{CO2,ex} \cdot K) + 1}\right] + \dfrac{z}{2} + c_{air}}{1 - \dfrac{c_{CO,ex}}{2} - \dfrac{c_{THC,ex}}{x} + \left\{\dfrac{y}{4}\left[1 + \dfrac{(c_{CO,ex}/c_{CO2,ex} \cdot K)}{(c_{CO,ex}/c_{CO2,ex} \cdot K) + 1}\right] + \dfrac{z}{2}\right\}\dfrac{c_{THC,ex}}{x}}
\tag{D.27}
$$

Here, the atom number ratio of hydrogen and carbon in the fuel, $R_{HC,f}$, is equal to that in the exhaust gas, $R_{HC,ex}$, and the atom number ratio of oxygen and carbon in the fuel, $R_{OC,f}$, is equal to that in the exhaust gas, $R_{OC,ex}$.

$$R_{HC,ex} = R_{HC,f} = \frac{y}{x} \tag{D.28}$$

$$R_{OC,ex} = R_{OC,f} = \frac{z}{x} \tag{D.29}$$

Formulae (D.28) and (D.29) are substituting Formula (D.27), as follows:

$$c_{ex} = \frac{x\left\{\dfrac{R_{HC,ex}}{4}\left[1+\dfrac{\left(c_{CO,ex}/c_{CO2,ex}\cdot K\right)}{\left(c_{CO,ex}/c_{CO2,ex}\cdot K\right)+1}\right]+\dfrac{R_{OC,ex}}{2}\right\}+c_{air}}{1-\dfrac{c_{CO,ex}}{2}-\dfrac{c_{THC,ex}}{x}+\left\{\dfrac{R_{HC,ex}}{4}\left[1+\dfrac{\left(c_{CO,ex}/c_{CO2,ex}\cdot K\right)}{\left(c_{CO,ex}/c_{CO2,ex}\cdot K\right)+1}\right]+\dfrac{R_{OC,ex}}{2}\right\}c_{THC,ex}} \tag{D.30}$$

D.3 Calculation of the dilution factor

Both sides of Formula (D.4) are divided by c_{ex} and Formulae (D.23), (D.24) and (D.25) are substituted.

$$\frac{x}{c_{ex}} = \frac{n_a}{c_{ex}} + \frac{n_b}{c_{ex}} + \frac{x\cdot n_d}{c_{ex}} \tag{D.31}$$

$$\therefore \frac{x}{c_{ex}} = c_{CO2,ex} + c_{CO,ex} + c_{THC,ex} \tag{D.32}$$

The number of carbon atoms is not changed after the exhaust gas is diluted by the dilution air. The carbon mole fraction in the diluted exhaust mixture is equal to the sum of volume fraction of carbon dioxide, carbon monoxide and total hydrocarbon similar to Formula (D.32):

$$\frac{x}{c_e} = \frac{c_{CO2,e}}{100} + \frac{c_{CO,e}}{1\,000\,000} + \frac{c_{THC,e}}{1\,000\,000} = \frac{c_{CO2,e}+\left(c_{CO,e}+c_{THC,e}\right)\times 10^{-4}}{100} \tag{D.33}$$

where

$c_{CO2,e}$ is the carbon dioxide concentration in the diluted exhaust mixture, in percent;

$c_{CO,e}$ is the carbon monoxide concentration in the diluted exhaust mixture, in ppm;

$c_{THC,e}$ is the hydrocarbon concentration in the diluted exhaust mixture, in ppm;

c_e is diluted exhaust mixture and $c_e = c_{ex} + c_{d'}$, in moles.

Therefore, from Formulae (D.1), (D.32) and (D.33), the dilution factor is expressed by Formula (D.34):

$$D_f = \frac{V_{ex} + V_d}{V_{ex}} = \frac{c_e}{c_{ex}} = \frac{\left\{ x \middle/ \left[c_{CO2,e} + \left(c_{CO,e} + c_{THC,e} \right) \times 10^{-4} \right] \right\} \middle/ 100}{x \middle/ \left(c_{CO2,ex} + c_{CO,ex} + c_{THC,ex} \right)}$$

$$= \frac{c_{CO2,ex} + c_{CO,ex} + c_{THC,ex}}{\left[c_{CO2,e} + \left(c_{CO,e} + c_{THC,e} \right) \times 10^{-4} \right] \middle/ 100}$$

(D.34)

Regarding the numerator of Formula (D.34), Formula (D.35) can be obtained from Formulae (D.30) and (D.32), as follows:

$$c_{CO2,ex} + c_{CO,ex} + c_{THC,ex} =$$

$$\frac{1 - \dfrac{c_{CO,ex}}{2} - \dfrac{c_{THC,ex}}{x} + \left\{ \dfrac{R_{HC,ex}}{4} \left[1 + \dfrac{\left(c_{CO,ex} / c_{CO2,ex} \cdot K \right)}{\left(c_{CO,ex} / c_{CO2,ex} \cdot K \right) + 1} \right] \right\} + \dfrac{R_{OC,ex}}{2} + c_{THC,ex}}{\left\{ \dfrac{R_{HC,ex}}{4} \left[1 + \dfrac{\left(c_{CO,ex} / c_{CO2,ex} \cdot K \right)}{\left(c_{CO,ex} / c_{CO2,ex} \cdot K \right) + 1} \right] + \dfrac{R_{OC,ex}}{2} \right\} + \dfrac{c_{air}}{x}}$$

(D.35)

Formula (D.21) is substituted into Formula (D.35), as follows:

$$c_{CO2,ex} + c_{CO,ex} + c_{THC,ex} =$$

$$\frac{1 - \dfrac{c_{CO,ex}}{2} - \dfrac{c_{THC,ex}}{x} + \left\{ \dfrac{R_{HC,ex}}{4} \left[1 + \dfrac{\left(c_{CO,ex} / c_{CO2,ex} \cdot K \right)}{\left(c_{CO,ex} / c_{CO2,ex} \cdot K \right) + 1} \right] + \dfrac{R_{OC,ex}}{2} \right\} c_{THC,ex}}{\left\{ \dfrac{R_{HC,ex}}{4} \left[1 + \dfrac{\left(c_{CO,ex} / c_{CO2,ex} \cdot K \right)}{\left(c_{CO,ex} / c_{CO2,ex} \cdot K \right) + 1} \right] + \dfrac{R_{OC,ex}}{2} \right\} + \dfrac{1}{x} \left[\lambda \left(x + \dfrac{y}{4} - \dfrac{z}{2} \right) + \lambda \left(x + \dfrac{y}{4} - \dfrac{z}{2} \right) \times \dfrac{100 - c_{O2,d}}{c_{O2,d}} \right]}$$

(D.36)

Formulae (D.28) and (D.29) are substituted in denominator of Formula (D.36), as follows:

$$c_{CO2,ex} + c_{CO,ex} + c_{THC,ex} =$$

$$\frac{1 - \dfrac{c_{CO,ex}}{2} - \dfrac{c_{THC,ex}}{x} + \left\{ \dfrac{R_{HC,ex}}{4} \left[1 + \dfrac{\left(c_{CO,ex} / c_{CO2,ex} \cdot K \right)}{\left(c_{CO,ex} / c_{CO2,ex} \cdot K \right) + 1} \right] + \dfrac{R_{OC,ex}}{2} \right\} c_{THC,ex}}{\left\{ \dfrac{R_{HC,ex}}{4} \left[1 + \dfrac{\left(c_{CO,ex} / c_{CO2,ex} \cdot K \right)}{\left(c_{CO,ex} / c_{CO2,ex} \cdot K \right) + 1} \right] + \dfrac{R_{OC,ex}}{2} \right\} + \left[\lambda \left(1 + \dfrac{R_{HC,ex}}{4} - \dfrac{R_{OC,ex}}{2} \right) + \lambda \left(1 + \dfrac{R_{HC,ex}}{4} - \dfrac{R_{OC,ex}}{2} \right) \times \dfrac{100 - c_{O2,d}}{c_{O2,d}} \right]}$$

(D.37)

Here, $c_{CO,ex} \ll 1$ and $c_{THC,ex} \ll 1$, therefore Formula (D.37) is changed as follows:

$$c_{CO2,ex} + c_{CO,ex} + c_{THC,ex} =$$

$$\frac{1}{\left[\left(R_{HC,ex}/4\right)+\left(R_{OC,ex}/2\right)\right]+\left\{\lambda\left[1+\left(R_{HC,ex}/4\right)-\left(R_{OC,ex}/2\right)\right]+\lambda\left[1+\left(R_{HC,ex}/4\right)-\left(R_{OC,ex}/2\right)\right]\times\left[\left(100-c_{O2,d}\right)/c_{O2,d}\right]\right\}}$$

(D.38)

If the mixture is stoichiometric air-fuel ratio, $\lambda = 1$, Formula (D.38) is changed as follows:

$$c_{CO2,ex} + c_{CO,ex} + c_{THC,ex}$$

$$= \frac{1}{\left[\left(R_{HC,ex}/4\right)+\left(R_{OC,ex}/2\right)\right]+\left[1+\left(R_{HC,ex}/4\right)-\left(R_{OC,ex}/2\right)\right]+\left[1+\left(R_{HC,ex}/4\right)-\left(R_{OC,ex}/2\right)\right]\times\left[\left(100-c_{O2,d}\right)/c_{O2,d}\right]}$$

$$= \frac{1}{1+\left(R_{HC,ex}/2\right)+\left[1+\left(R_{HC,ex}/4\right)-\left(R_{OC,ex}/2\right)\right]\times\left[\left(100-c_{O2,d}\right)/c_{O2,d}\right]}$$

(D.39)

Therefore, the dilution factor is determined from Formulae (D.34) and (D.39), as follows:

$$D_f = \frac{c_{CO2,ex} + c_{CO,ex} + c_{THC,ex}}{\left[c_{CO2,ex}+\left(c_{CO,ex}+c_{THC,ex}\right)\times10^{-4}\right]/100}$$

$$= \frac{1/\left\{1+\left(R_{HC,ex}/2\right)+\left[1+\left(R_{HC,ex}/4\right)-\left(R_{OC,ex}/2\right)\right]\times\left[\left(100-c_{O2,d}\right)/c_{O2,d}\right]\right\}}{\left[c_{CO2,e}+\left(c_{CO,e}+c_{THC,e}\right)\times10^{-4}\right]/100}$$

(D.40)

$$\therefore D_f = \frac{100/\left\{1+\left(R_{HC,ex}/2\right)+\left[\left(4+R_{HC,ex}\right)/4-\left(R_{OC,ex}/2\right)\right]\times\left[\left(100-c_{O2,d}\right)/c_{O2,d}\right]\right\}}{c_{CO2,ex}+\left(c_{CO,ex}+c_{THC,ex}\right)\times10^{-4}}$$

The $R_{HC,ex}$ value (which is 1,85 for gasoline and 2,64 for LPG) is used and $R_{OC,ex}$ is zero. Formulae (D.41) and (D.42) shall be used for the calculation of dilution factor and fuel consumption.

The oxygen concentration in the dilution air $c_{O2,d}$, calculated in percent, is assumed to be 20,9 %.

For gasoline,

$$D_f = \frac{13,40}{c_{CO2,e}+\left(c_{THC,e}+c_{CO,e}\right)\times10^{-4}}$$

(D.41)

For LPG,

$$D_f = \frac{11,62}{c_{CO2,e}+\left(c_{THC,e}+c_{CO,e}\right)\times10^{-4}}$$

(D.42)

NOTE   Formula (D.40) (dilution factor) is defined at the stoichiometric air-fuel ratio ($\lambda = 1$). Therefore, an error will occur when the air-fuel ratio during the test is further apart from the stoichiometric air-fuel ratio. However, the influence on calculation of gaseous exhaust emissions can be neglected, as long as the concentrations of the gaseous exhaust emissions are sufficiently higher than those of the dilution air. If the concentrations of the gaseous exhaust emissions in the diluted exhaust mixture are very low, it is advisable that attention be paid to the difference of the concentrations between the diluted exhaust mixture and the dilution air.

D.4 Calculation of the volumetric concentration of contents in the diluted exhaust mixture, corrected to take account of pollution in the dilution air

The volumetric concentration of contents, Pi, in the diluted exhaust mixture, $c_{Pi,e}$, is determined by Formula (D.43):

$$c_{Pi,e} = \frac{V_{ex}}{V_{ex} + V_d} c_{Pi,ex} + \frac{V_d}{V_{ex} + V_d} c_{Pi,d} \qquad (D.43)$$

where

$c_{Pi,e}$ is the concentration of the pollutant i in the diluted exhaust mixture;

$c_{Pi,ex}$ is the concentration of the pollutant i in the exhaust gas;

$c_{Pi,d}$ is the concentration of the pollutant i in the dilution air.

The concentration of the pollutant i in the diluted exhaust mixture, corrected to take account of the amount of the pollutant i contained in the dilution air, $c_{Pi,ec}$, is determined by Formula (D.45).

$$c_{Pi,ec} = \frac{V_{ex}}{V_{ex} + V_d} c_{Pi,ex} = c_{Pi,e} - \frac{V_d}{V_{ex} + V_d} c_{Pi,d}$$

$$= c_{Pi,e} - \left(\frac{V_{ex} + V_d}{V_{ex} + V_d} - \frac{V_{ex}}{V_{ex} + V_d} \right) c_{Pi,d} = c_{Pi,e} - c_{Pi,d} \left(1 - \frac{1}{D_f} \right) \qquad (D.44)$$

Annex E
(informative)

Principle of the carbon balance method

E.1 Four-stroke engines

In the carbon balance method, the fuel consumption is determined from the carbon balance between the quantity of carbon in consumed fuel and exhaust gas.

The quantity of carbon in the consumed fuel, $m_{C,f}$ is expressed by Formula (E.1):

$$m_{C,f} = \frac{12,01}{12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}} \times \frac{\rho_f}{F_c} \tag{E.1}$$

The quantity of carbon in the exhaust gas, $m_{C,ex}$ is expressed by Formula (E.2):

$$m_{C,ex} = \frac{12,01}{44,01} m_{CO2} + \frac{12,01}{28,01} m_{CO} + \frac{12,01}{12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}} m_{THC} \tag{E.2}$$

The quantity of carbon in the consumed fuel is equal to the quantity of carbon in the exhaust gas, therefore

$$m_{C,f} = m_{C,ex} \tag{E.3}$$

$$\frac{12,01}{12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}} \times \frac{\rho_f}{F_c}$$
$$= \frac{12,01}{44,01} m_{CO2} + \frac{12,01}{28,01} m_{CO} + \frac{12,01}{12,01 + 1,008 R_{HC,ex} + 16,00 R_{OC,ex}} m_{THC} \tag{E.4}$$

The fuel consumption shall be determined by Formula (E.5).

$$F_C = \frac{12,01}{12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}}$$
$$\times \frac{\rho_f}{(12,01/44,01) m_{CO2} + (12,01/28,01) m_{CO} + \left[12,01 / \left(12,01 + 1,008 R_{HC,ex} + 16,00 R_{OC,ex} \right) \right] m_{THC}} \tag{E.5}$$

The $R_{HC,ex}$ and $R_{OC,ex}$ values shall be determined from the contents analysis of exhaust gas. If it is not possible to measure $R_{HC,ex}$, the $R_{HC,ex}$ value which is 1,85 for gasoline and 2,64 for LPG may be used, and $R_{OC,ex}$ may be zero.

The $R_{HC,f}$ and $R_{OC,f}$ values shall be determined from the contents analysis of fuel. The simplified determination method specified in Annex F can be applied for gasoline.

If it is not possible to determine $R_{HC,f}$ and $R_{OC,f}$, the equal values of $R_{HC,ex}$ (1,85 for gasoline and 2,64 for LPG) and $R_{OC,ex}$ (zero for all these fuels) may be applied to $R_{HC,f}$ and $R_{OC,f}$.

E.2 Two-stroke engines

In the case where the lubrication oil is mixed with the fuel, e.g. two-stroke spark ignition engine, the quantity of carbon in the consumed fuel and lubrication oil, $m_{C,Fo}$, is expressed by Formula (E.6):

$$m_{C,Fo} = \frac{12,01}{12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}} \times \frac{\rho_f}{F_c} + \frac{12,01}{12,01 + 1,008 R_{HC,o} + 16,00 R_{OC,o}} \times \frac{\rho_o}{F_o} \qquad (E.6)$$

The mixing ratio of lubrication oil and fuel is defined by Formula (E.7):

$$a = \frac{1/F_o}{1/F_c} = \frac{F_c}{F_o} \qquad (E.7)$$

In the case where the mixing ratio, a, is maintained at constant, Equation (F.6) is arranged as follows:

$$m_{C,Fo} = \frac{12,01}{12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}} \times \frac{\rho_f}{F_c} + \frac{12,01}{12,01 + 1,008 R_{HC,o} + 16,00 R_{OC,o}} \times \frac{a\rho_o}{F_c} \qquad (E.8)$$

The quantity of carbon in the exhaust gas is expressed by Formula (E.9):

$$m_{C,ex} = \frac{12,01}{44,01} m_{CO2} + \frac{12,01}{28,01} m_{CO} + \frac{12,01}{12,01 + 1,008 R'_{HC,ex} + 16,00 R'_{OC,ex}} m_{THC} \qquad (E.9)$$

The quantity of carbon in the consumed fuel is equal to the quantity of carbon in the exhaust gas, therefore

$$m_{C,fo} = m_{C,ex} \qquad (E.10)$$

The fuel consumption shall be determined by Formula (E.11).

$$F_C = \frac{\rho_f / (12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}) + a\rho_f / (12,01 + 1,008 R_{HC,o} + 16,00 R_{OC,o})}{(m_{CO2}/44,01) + (m_{CO}/28,01) + \left[m_{THC} / (12,01 + 1,008 R'_{HC,ex} + 16,00 R'_{OC,ex}) \right]} \qquad (E.11)$$

$R'_{HC,ex}$ and $R'_{OC,ex}$ in the case of including lubrication oil, shall be determined from the contents analysis of exhaust gas.

If it is not possible to measure $R'_{HC,ex}$ and $R'_{OC,ex}$, the following method can be applied. These formulae are based on the assumption that lubricating oil is completely burned.

The $R'_{HC,ex}$ and $R'_{OC,ex}$ shall be determined by numbers of carbon atom, x, hydrogen atom, y and oxygen atom, z in the lubrication oil mixed fuel.

The numbers of carbon atom, x, of hydrogen atom, y and of oxygen atom, z in the lubrication oil mixed fuel is determined by Formulae (E.12), (E.13) and (E.14).

$$x = \frac{12,01}{\rho_f + a\rho_o} \left(\frac{\rho_f}{12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}} + \frac{a\rho_o}{12,01 + 1,008 R_{HC,o} + 16,00 R_{OC,o}} \right) \qquad (E.12)$$

$$y = \frac{1,008}{\rho_f + a\rho_o} \left(\frac{R_{HC,f} \times \rho_f}{12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}} + \frac{a R_{HC,o} \times \rho_o}{12,01 + 1,008 R_{HC,o} + 16,00 R_{OC,o}} \right) \qquad (E.13)$$

$$z = \frac{16,00}{\rho_f + a\rho_o} \left(\frac{R_{OC,f} \times \rho_f}{12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}} + \frac{a R_{OC,o} \times \rho_o}{12,01 + 1,008 R_{HC,o} + 16,00 R_{OC,o}} \right) \tag{E.14}$$

$R'_{HC,ex}$ in the case of including lubrication oil, shall be determined by Formula (E.15):

$$R'_{HC,ex} = \frac{y}{x} = \frac{1,008}{12,01}$$
$$\times \frac{\left(12,01 + 1,008 R_{HC,o} + 16,00 R_{OC,o}\right) R_{HC,f} \times \rho_f + \left(12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}\right) a \times R_{HC,o} \times \rho_o}{\left(12,01 + 1,008 R_{HC,o} + 16,00 R_{OC,o}\right) \times \rho_f + \left(12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}\right) a \times \rho_o} \tag{E.15}$$

$R'_{OC,ex}$ in the case of including lubrication oil, shall be determined by Formula (E.16):

$$R'_{OC,ex} = \frac{z}{x} = \frac{16,00}{12,01}$$
$$\times \frac{\left(12,01 + 1,008 R_{HC,o} + 16,00 R_{OC,o}\right) R_{OC,f} \times \rho_f + \left(12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}\right) a \times R_{OC,o} \times \rho_o}{\left(12,01 + 1,008 R_{HC,o} + 16,00 R_{OC,o}\right) \times \rho_f + \left(12,01 + 1,008 R_{HC,f} + 16,00 R_{OC,f}\right) a \times \rho_o} \tag{E.16}$$

$R_{HC,f}$ and $R_{OC,f}$ shall be determined from the contents analysis of fuel. The simplified determination method specified in Annex F can be applied for gasoline. If it is not possible to determine $R_{HC,f}$ and $R_{OC,f}$, the equal values of $R_{HC,ex}$ [1,85 for gasoline and 2,64 for LPG and $R_{OC,ex}$ (zero for all these fuels)] may be applied to $R_{HC,f}$ and $R_{OC,f}$.

Annex F
(informative)

Simplified determination method of the atom number ratio of hydrogen and carbon, and that of oxygen and carbon in gasoline

This annex specifies the simplified method for determining the atom number ratio of hydrogen and carbon and the atom number ratio of oxygen and carbon in gasoline.

In this simplified method, $R_{HC,f}$ in mol/mol, and $R_{OC,f}$ in mol/mol, in the test fuel are determined from the fuel specifications, as follows:

$$R_{HC,f} = \frac{12,01 \times (R_H/100)}{1,008 \times \left[1 - (R_H/100) - (R_O/100)\right]} \tag{F.1}$$

$$R_{OC,f} = \frac{12,01 \times (R_O/100)}{16,00 \times \left[1 - (R_H/100) - (R_O/100)\right]} \tag{F.2}$$

where

R_H is the hydrogen mass fraction in the test fuel, in percent;

R_O is the oxygen mass fraction in the test fuel, in percent.

The hydrogen mass fraction in the test fuel, R_H shall be obtained as follows:

$$R_H = \frac{9,193 + 0,01586\theta^* - 10,382 A_m/100}{\rho_f/1000} + 0,006174\frac{A_m}{100}\theta^* + 7,974\frac{A_m}{100} - 0,01475\theta^* + 1,953 \tag{F.3}$$

$$\theta^* = \frac{\theta_{10} + \theta_{50} + \theta_{90}}{3} \tag{F.4}$$

where

θ_{10} is the 10 percent distillation point, in °C;

θ_{50} is the 50 percent distillation point, in °C;

θ_{90} is the 90 percent distillation point, in °C;

A_m is the volume fraction of aromatic hydrocarbons in the test fuel, in percent.

NOTE 1   If alcohol-contained fuel is used, there is a possibility that larger error on R_H may result.

NOTE 2   According to ISO 80000-9, the actual symbol for the mass should be written as w_H and w_O, not R_H and R_O. However, ISO admits the use of these symbols under the condition that they are corrected when each of ISO 6460 and ISO 6855 is revised in future, because the same symbols are currently used in ISO 6460-1.

If the oxygen-containing contents are included in the test fuel, and the volume fraction of aromatic hydrocarbons in the fuel is indicated by the ratio of aromatic hydrocarbons volume to the fuel volume,

excluding the oxygen-containing contents, the volume fraction of aromatic hydrocarbons in the test fuel, A_m, shall be calculated by Equation (F.5):

$$A_m = \left(1 - \frac{B_m}{100}\right) \times A_f \qquad (F.5)$$

where

B_m is the volume fraction of oxygen-containing contents in the test fuel, in percent;

A_f is the volume fraction of aromatic hydrocarbons in the fuel, which is indicated by the ratio of aromatic hydrocarbons volume to the fuel volume, excluding the oxygen-containing contents, in percent.

If the oxygen-containing contents are included in the test fuel, the oxygen mass fraction in the test fuel, R_O, shall be calculated by Equation (F.6):

$$R_O = R'_O \times \frac{B_m}{100} \qquad (F.6)$$

where R'_O is the oxygen mass fraction in the oxygen-containing contents, in percent.

Annex G
(normative)

Fuel consumption for two-stroke engines

The mixing ratio of lubrication oil and fuel is defined by Equation (G.1):

$$a = \frac{(1/F_O)}{(1/F_C)} = \frac{F_C}{F_O} \tag{G.1}$$

In the case where the mixing ratio, a, is maintained at constant, the fuel consumption shall be determined by Equation (G.2):

$$F_C = \frac{\left[\rho_f / \left(12{,}01 + 1{,}008 R_{HC,f} + 16{,}00 R_{OC,f}\right)\right] + \left[a\rho_f / \left(12{,}01 + 1{,}008 R_{HC,o} + 16{,}00 R_{OC,o}\right)\right]}{(m_{CO2}/44{,}01) + (m_{CO}/28{,}01) + \left[m_{THC} / \left(12{,}01 + 1{,}008 R'_{HC,ex} + 16{,}00 R'_{OC,ex}\right)\right]} \tag{G.2}$$

$R'_{HC,ex}$ and $R'_{OC,ex}$ in the case of including lubrication oil shall be determined from the contents analysis of exhaust gas.

If it is not possible to measure $R'_{HC,ex}$ and $R'_{OC,ex}$ values, Equations (G.3) and (G.4) can be applied. These equations are based on the assumption that lubricating oil is completely burned.

$$R'_{HC,ex} = \frac{1{,}008}{12{,}01}$$
$$\times \frac{\left(12{,}01 + 1{,}008 R_{HC,o} + 16{,}00 R_{OC,o}\right) R_{HC,f} \times \rho_f + \left(12{,}01 + 1{,}008 R_{HC,f} + 16{,}00 R_{OC,f}\right) a \times R_{OC,f} \times \rho_o}{\left(12{,}01 + 1{,}008 R_{HC,o} + 16{,}00 R_{OC,o}\right) \times \rho_f + \left(12{,}01 + 1{,}008 R_{HC,o} + 16{,}00 R_{OC,o}\right) a \times \rho_o} \tag{G.3}$$

$$R'_{OC,ex} = \frac{1{,}008}{12{,}01}$$
$$\times \frac{\left(12{,}01 + 1{,}008 R_{HC,o} + 16{,}00 R_{OC,o}\right) R_{OC,f} \times \rho_f + \left(12{,}01 + 1{,}008 R_{HC,f} + 16{,}00 R_{OC,f}\right) a \times R_{OC,f} \times \rho_o}{\left(12{,}01 + 1{,}008 R_{HC,o} + 16{,}00 R_{OC,o}\right) \times \rho_f + \left(12{,}01 + 1{,}008 R_{HC,f} + 16{,}00 R_{OC,f}\right) a \times \rho_o} \tag{G.4}$$

$R_{HC,f}$ and $R_{OC,f}$ shall be determined from the contents analysis of fuel. The simplified determination method specified in Annex F can be applied for gasoline. If it is not possible to determine the $R_{HC,f}$ and $R_{OC,f}$ values, the $R_{HC,f}$ value may be 1,85 for gasoline and 2,64 for LPG, and $R_{OC,f}$ may be zero.

For two-stroke engines fuelled gasoline, the fuel consumption shall be calculated by Equation (G.5):

$$F_C = \frac{\left[\rho_f / (12{,}01 + 1{,}008 \times 1{,}85)\right] + \left[a\rho_o / \left(12{,}01 + 1{,}008 R_{HC,o} + 16{,}00 R_{OC,o}\right)\right]}{(m_{CO2}/44{,}01) + (m_{CO}/28{.}01) + \left[m_{THC} / \left(12{,}01 + 1{,}008 R'_{HC,ex} + 16{,}00 R'_{OC,ex}\right)\right]} \tag{G.5}$$

For two-stroke engines fuelled LPG, the fuel consumption shall be calculated by Equation (G.6):

$$F_C = \frac{\left[\rho_f / (12{,}01 + 1{,}008 \times 2{,}64)\right] + \left[a\rho_o / \left(12{,}01 + 1{,}008 R_{HC,o} + 16{,}00 R_{OC,o}\right)\right]}{(m_{CO2}/44{,}01) + (m_{CO}/28{,}01) + \left[m_{THC} / \left(12{,}01 + 1{,}008 R'_{HC,ex} + 16{,}00 R'_{OC,ex}\right)\right]} \tag{G.6}$$

Annex H
(informative)

Criteria of the statistical accuracy for the fuel consumption measurements

Four measurements shall be conducted. The accuracy of measurement, A, shall be calculated by Equation (H.1):

$$A = K \times \frac{s}{\sqrt{n}} \times \frac{100}{\bar{C}} \tag{H.1}$$

where

K is the coefficient given in Table H.1;

n is the number of measurements;

s is the standard deviation given by Equation (H.2);

$$s = \sqrt{\frac{\sum\limits_{i=1}^{n}\left(\bar{C} - C_i\right)^2}{n-1}} \tag{H.2}$$

where

C_i is the amount of fuel consumed during ith measurement;

$\bar{C}$ is the arithmetic means of n values of C.

Table H.1 — Value of K

n	K	$\dfrac{K}{\sqrt{n}}$
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

If an accuracy of measurements is 5 % or less of the mean value of the three measurements, the mean value shall be adopted as the result of the fuel consumption measurement.

If the difference between the extreme measurements is more than 5 % of the mean value of the three measurements, further measurements shall immediately be made to obtain a degree of accuracy of measurements at least equal to 5 %.

If an accuracy of measurement at least equal to 5 % is not obtained after 10 measurements, the test shall be carried out with another moped of the same type.

When a degree of accuracy of measurements within 5 % is satisfied by measurements, the fuel consumption shall be the mean value of the result of all measurements.

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