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Working guidelines

- Use draft proposal of gtr
- Classification of working status by colour
 - No colour / black&white: raw text not yet proven / checked
 - Draft proposal of gtr o.k. => mark text green
 - Draft proposal of gtr not o.k.
 - First: comparison of legislation of US/ECE and Japan
 - Group can find a harmonized proposal => mark text yellow fill in quotation
 - Group cannot find a harmonized proposal => mark text red copy&paste relevant part into the document, fill open issue list
 - to be reviewed: mark text blue
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ECE/TRANS/xxx

27 July 2010

GLOBAL REGISTRY

Created on 18 November 2004, pursuant to Article 6 of the
AGREEMENT CONCERNING THE ESTABLISHING OF GLOBAL TECHNICAL
REGULATIONS FOR WHEELED VEHICLES, EQUIPMENT AND PARTS WHICH CAN BE
FITTED AND/OR BE USED ON WHEELED VEHICLES
(ECE/TRANS/132 and Corr.1)
Done at Geneva on 25 June 1998

Addendum

Global technical regulation No. WLTP-DTP

TEST PROCEDURE FOR LIGHT-DUTY ON-ROAD VEHICLES FUELED BY LIQUID,
GASEOUS, AND ELECTRIC SOURCES WITH REGARD TO THE EMISSION OF
POLLUTANTS

(Established in the Global Registry on 15 November 2006)



UNITED NATIONS

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A. STATEMENT OF TECHNICAL RATIONALE AND JUSTIFICATION

1. TECHNICAL AND ECONOMIC FEASIBILITY

The objective of this proposal is to establish a harmonized global technical regulation (gtr) covering the type-approval procedure for light-duty engine exhaust emissions. The basis will be the test procedure developed by the WLTP informal group of GRPE (see the informal document No. x distributed during the (add reference) GRPE session).

Regulations governing the exhaust emissions from light-duty engines have been in existence for many years but the test cycles and methods of emissions measurement vary significantly. To be able to correctly determine the impact of a light-duty vehicle on the environment in terms of its exhaust pollutant emissions, a laboratory test procedure, and consequently the gtr, needs to be adequately representative of real-world vehicle operation.

The proposed regulation is based on new research into the world-wide pattern of real light-duty vehicle use. From the collected data, two representative test cycles, a transient test cycle (WHTC) with both cold and hot start requirements and a hot start steady state test cycle (WHSC), have been created covering typical driving conditions in the European Union (EU), the United States of America, Japan and Australia. Alternative emission measurement procedures have been developed by an expert committee in ISO and have been published in ISO 16183. This standard reflects exhaust emissions measurement technology with the potential for accurately measuring the pollutant emissions from future low emission engines. This work has been the basis for future Japanese and the EU emission legislation. In parallel, substantial work has been undertaken on a different basis in the last several years in the United States of America to make major improvements to the emissions measurement procedures, testing protocols, and regulatory structure for both highway light-duty and non-road light-duty engines. This work is documented in the rulemaking of the United States of America and was published on 13 July 2005. Some of those new testing protocols are already reflected in this gtr.

Commentaire [MR01]: Add DHC text here.

Commentaire [MR02]: USEPA 1065

Commentaire [MR03]: Correct from USA standpoint. Actively working to create light-duty equivalent.

It is recognized by the Contracting Parties to the 1998 Agreement that a long-term goal for highway light-duty diesel engine testing and non-road diesel engine testing would be gtrs which are similar in structure and substance with respect to measurement equipment, procedures and requirements. Therefore, the Contracting Parties recognize there will be a need in the future to amend this gtr in order to have as much commonality as is possible between the highway light-duty diesel gtr and the non-road diesel gtr currently under development. As discussed below, this gtr does not contain emission limit values. At this stage, the limit values shall be developed by the Contracting Parties according to their own rules of procedure.

Commentaire [MR04]: Not applicable. Equivalent LD statement required.

The WLTP test procedure reflects world-wide on-road light-duty vehicle operation, as closely as possible, and provide a marked improvement in the realism of the test procedure for measuring the emission performance of existing and future light-duty vehicles. In summary, the test procedure was developed so that it would be:

- (a) representative of world-wide on-road vehicle operations,
- (b) able to provide the highest possible level of efficiency in controlling on-road emissions,
- (c) corresponding to state-of-the-art testing, sampling and measurement technology,
- (d) applicable in practice to existing and foreseeable future exhaust emissions abatement technologies, and
- (e) capable of providing a reliable ranking of exhaust emission levels from different vehicle types.

At this stage, the gtr is being presented without limit values. In this way, the test procedure can be given a legal status, based on which the Contracting Parties are required to start the process of implementing it into their national law. The gtr contains several options, whose adoption is left to the discretion of the Contracting Parties. **However,** these aspects have to be fully harmonized when common limit values are established.

Commentaire [MRO5]: List options here, if any.

When implementing the test procedure contained in this gtr as part of their national legislation or regulation, Contracting Parties are invited to use limit values which represent at least the same level of severity as their existing regulations, pending the development of harmonized limit values by the Executive Committee (AC.3) under the 1998 Agreement administered by the World Forum for Harmonization of Vehicle Regulations (WP.29). The performance levels (emissions test results) to be achieved in the gtr will, therefore, be discussed on the basis of the most recently agreed legislation in the Contracting Parties, as required by the 1998 Agreement.

2. ANTICIPATED BENEFITS

Light-duty vehicles and their powertrains are increasingly produced for the world market. It is economically inefficient for manufacturers to have to prepare substantially different models in order to meet different emission regulations and methods of measuring emissions, which, in principle, aim at achieving the same objective. To enable manufacturers to develop new models more effectively and within a shorter time, it is desirable that a gtr should be developed. These savings will accrue not only to the manufacturer, but more importantly, to the consumer as well.

However, developing a test procedure just to address the economic question does not completely address the mandate given when work on this gtr was first started. The test procedure must also improve the state of testing light-duty vehicles, and better reflect how light-duty vehicles are used today. Compared to the measurement methods defined in existing legislation of the Contracting Parties to the 1998 Agreement, the testing methods defined in this gtr are much more representative of in-use driving behaviour of light-duty vehicles world-wide. It should be noted that the requirements of this gtr should be complemented by the requirements relating to the control of the Off-Cycle Emissions (OCE) and OBD systems.

As a consequence, it can be expected that the application of this gtr for emissions legislation within the Contracting Parties to the 1998 Agreement will result in a higher control of in-use emissions due to the improved correlation of the test methods with in-use driving behaviour.

3. POTENTIAL COST EFFECTIVENESS

Specific cost effectiveness values for this gtr have not been calculated. The decision by the Executive Committee (AC.3) to the 1998 Agreement to move forward with this gtr without limit values is the key reason why this analysis has not been completed. This common agreement has been made knowing that specific cost effectiveness values are not immediately available. However, it is fully expected that this information will be developed, generally, in response to the adoption of this regulation in national requirements and also in support of developing harmonized limit values for the next step in this gtr's development. For example, each Contracting Party adopting this gtr into its national law will be expected to determine the appropriate level of stringency associated with using these new test procedures, with these new values being at least as stringent as comparable existing requirements. Also, experience will be gained by the light-duty vehicle industry as to any costs and cost savings associated with using this test procedure. The cost and emissions performance data can then be analyzed as part of the next step in this gtr development to determine the cost effectiveness values of the test procedures being adopted today along with the application of harmonized limit values in the future. While there are no values on calculated costs per ton, the belief of the GRPE experts is that there are clear benefits associated with this regulation.

B. TEXT OF REGULATION

1. PURPOSE

This regulation aims at providing a world-wide harmonized method for the determination of the levels of pollutant emissions from light-duty vehicles in a manner which is representative of real world vehicle operation. The results can be the basis for the regulation of pollutant emissions within regional type-approval and certification procedures.

2. SCOPE

This regulation applies to the measurement of the emission of gaseous and particulate pollutants from positive-ignition (spark) engines, compression-ignition engines and positive-ignition engines fuelled with natural gas (NG), liquefied petroleum gas (LPG) or hydrogen (H₂), in addition to vehicles with supplement or primary propulsion coming from electricity, used for propelling motor vehicles of categories n and n, having a design speed exceeding xx km/h and having a maximum mass less than 3.5 tonnes (USA < 8,500 lbs GVW).

3. DEFINITIONS, SYMBOLS AND ABBREVIATIONS

3.1. Definitions

*** The definitions included below are identical to GTR 4 and have not been modified. It is the responsibility of the WLTP-DTP subgroups to confirm that their associated definitions are properly documented in this section.***

For the purpose of this regulation,

- 3.1.1. "continuous regeneration" see periodic regeneration ~~means the regeneration process of an exhaust after treatment system that occurs either permanently or at least once per WHTC hot start test. Such a regeneration process will not require a special test procedure.~~
- 3.1.2. "delay time" means the difference in time between the change of the component to be measured at the reference point and a system response of 10 per cent of the final reading (t_{10}) with the sampling probe being defined as the reference point. For the gaseous components, this is the transport time of the measured component from the sampling probe to the detector.
- 3.1.3. "deNO_x system" means an exhaust after-treatment system designed to reduce emissions of oxides of nitrogen (NO_x) (e.g. passive and active lean NO_x catalysts, NO_x adsorbers and selective catalytic reduction (SCR) systems).
- 3.1.4. "diesel engine" means an engine which works on the compression-ignition principle.

- 3.1.5. "engine family" means a manufacturers grouping of engines which, through their design as defined in paragraph 5.2. of this gtr, have similar exhaust emission characteristics; all members of the family must comply with the applicable emission limit values.
- 3.1.6. "engine system" means the engine, the emission control system and the communication interface (hardware and messages) between the engine system electronic control unit(s) (ECU) and any other powertrain or vehicle control unit.
- 3.1.7. "engine type" means a category of engines which do not differ in essential engine characteristics.
- ECE R 83-06: 2.6. "Exhaust emissions" means emissions of gaseous and particulate pollutants;**
- 3.1.8. "exhaust after-treatment system" means a catalyst (oxidation or 3-way), particulate filter, deNOx system, combined deNOx particulate filter or any other emission-reducing device that is installed downstream of the engine. This definition excludes exhaust gas recirculation (EGR), which is considered an integral part of the engine.
- 3.1.9. "full flow dilution method" means the process of mixing the total exhaust flow with dilution air prior to separating a fraction of the diluted exhaust stream for analysis.
- 3.1.11. "gaseous pollutants" means carbon monoxide, volatile organic compounds (e.g. hydrocarbons, non-methane hydrocarbons, methane) (assuming a ratio of $\text{CH}_{4,85}$ for diesel, $\text{CH}_{2,525}$ for LPG and $\text{CH}_{2,93}$ for NG, and an assumed molecule $\text{CH}_3\text{O}_{0,5}$ for ethanol, an assumed molecule CH_4O for methanol fuelled diesel engines), methane (assuming a ratio of CH_4 for NG) and oxides of nitrogen (expressed in nitrogen dioxide (NO_2) equivalent), carbon dioxide and additional gaseous compounds
- 3.1.12. non oxidized hydrocarbons (HC): compounds that consist of hydrogen and carbon only
 non-methane hydrocarbons (NMHC): non-oxidized hydrocarbons minus methane
 total hydrocarbons (THC): compounds determined by FID
 volatile organic carbon (VOC);
- 3.1.12. "high speed (n_{H})" means the highest engine speed where 70 per cent of the declared maximum power occurs.
- 3.1.13. "low speed (n_{L})" means the lowest engine speed where 55 per cent of the declared maximum power occurs.
- 3.1.14. "maximum power (P_{max})" means the maximum power in kW as specified by the manufacturer.
- 3.1.15. "maximum torque speed" means the engine speed at which the maximum torque is obtained from the engine, as specified by the manufacturer.

- 3.1.16. "parent engine" means an engine selected from an engine family in such a way that its emissions characteristics are representative for that engine family.
- 3.1.17. "particulate after-treatment device" means an exhaust after-treatment system designed to reduce emissions of particulate pollutants (PM) through a mechanical, aerodynamic, diffusional or inertial separation.
- 3.1.18. "partial flow dilution method" means the process of separating a part from the total exhaust flow, then mixing it with an appropriate amount of dilution air prior to the particulate sampling filter (potentially also for gaseous compounds – BMD).
- 3.1.19. "particulate matter (PM)" means any material collected on a specified filter medium after diluting exhaust with clean filtered air to a temperature between 315 K (42 °C) and 325 K (52 °C), as measured at a point immediately upstream of the filter; this is primarily carbon, condensed hydrocarbons, and sulphates with associated water.

ECE R83-06: "Particulate pollutants" means components of the exhaust gas which are removed from the diluted exhaust gas at a maximum temperature of 325 K (52 °C) by means of the filters described in Annex 4;

- 3.1.20. ~~"per cent load" means the fraction of the maximum available torque at an engine speed.~~

3.1.21. "periodic regeneration" means an anti-pollution device (e.g. catalytic converter, particulate trap) that requires a periodical regeneration process in less than 4,000 km of normal vehicle operation. During cycles where regeneration occurs, emission standards can be exceeded. If a regeneration of an anti-pollution device occurs at least once per Type I test and that has already regenerated at least once during vehicle preparation cycle, it will be considered as a continuously regenerating system which does not require a special test procedure. Annex 13 does not apply to continuously regenerating systems.

At the request of the manufacturer, the test procedure specific to periodically regenerating systems will not apply to a regenerative device if the manufacturer provides data to the type approval authority that, during cycles where regeneration occurs, emissions remain below the standards given in paragraph 5.3.1.4. applied for the concerned vehicle category after agreement of the technical service. ~~means the regeneration process of an exhaust after treatment system that occurs periodically in typically less than 100 hours of normal engine operation. During cycles where regeneration occurs, emission standards may be exceeded.~~

- 3.1.22. ~~"ramped steady state test cycle" means a test cycle with a sequence of steady state engine test modes with defined speed and torque criteria at each mode and defined ramps between these modes (WHSC).~~

- 3.1.23. ~~"rated speed" means the maximum full load speed allowed by the governor as specified by the manufacturer in his sales and service literature, or, if such a governor is not present, the speed at which the maximum power is obtained from the engine, as specified by the manufacturer in his sales and service literature.~~

- 3.1.24. "response time" means the difference in time between the change of the component to be measured at the reference point and a system response of 90 per cent of the final reading (t_{90}) with the sampling probe being defined as the reference point, whereby the change of the measured component is at least 60 per cent full scale (FS) and takes place in less than 0.1 second. The system response time consists of the delay time to the system and of the rise time of the system.
- 3.1.25. "rise time" means the difference in time the 10 per cent and 90 per cent response of the final reading ($t_{90} - t_{10}$).
- 3.1.26. "specific emissions" means the mass emissions expressed in g/kWh.
- 3.1.27. "test cycle" means a sequence of test points each with a defined speed and torque to be followed by the engine under steady state (WHSC) or transient operating conditions (WHTC).
- 3.1.28. "transformation time" means the difference in time between the change of the component to be measured at the reference point and a system response of 50 per cent of the final reading (t_{50}) with the sampling probe being defined as the reference point. The transformation time is used for the signal alignment of different measurement instruments.
- 3.1.29. "transient test cycle" means a test cycle with a sequence of normalized speed and torque values that vary relatively quickly with time (WHTC).
- 3.1.30. "useful life" means the relevant period of distance and/or time over which compliance with the relevant gaseous and particulate emission limits has to be assured.

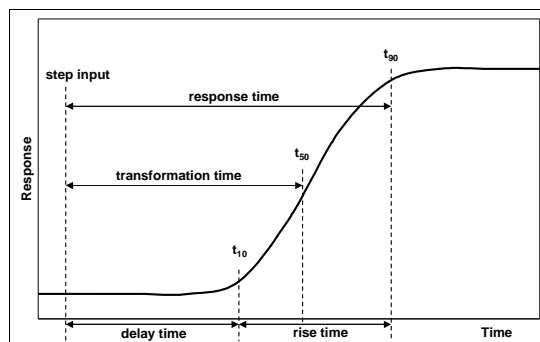


Figure 1:
Definitions of system response (move to delay/response/rise and transformation time)

3.2. General symbols

Draft Proposal – Raw Version after Workshop 03.-06.08.2010 in Ingolstadt

**** The symbols included below are identical to GTR 4 and have not been modified. It is the responsibility of the WLTP-DTP subgroups to confirm that their associated symbols are properly documented in this section.****

Symbol	Unit	Term
A/F_{st}	-	Stoichiometric air to fuel ratio
c	ppm/Vol per cent	Concentration
e_d	ppm/Vol per cent	Concentration on dry basis
e_w	ppm/Vol per cent	Concentration on wet basis
c_b	ppm/Vol per cent	Background concentration
c_i	ppm/Vol per cent	intake air concentration
C_d	-	Discharge coefficient of SSV
d	m	Diameter
d_V	m	Throat diameter of venturi
D_0	m ³ /s	PDP calibration intercept
DF	-	Dilution factor
Δt	s	Time interval
e_{gas}	g/kWh	Specific emission of gaseous components
e_{PM}	g/kWh	Specific emission of particulates
e_p	g/kWh	Specific emission during regeneration
e_w	g/kWh	Weighted specific emission
E_{CO2}	per cent	CO ₂ quench of NO _x analyzer
E_E	per cent	Ethane efficiency
E_{H2O}	per cent	Water quench of NO _x analyzer
E_M	per cent	Methane efficiency
E_{NOx}	per cent	Efficiency of NO _x converter
f	Hz	Data sampling rate
f_a	-	Laboratory atmospheric factor
F_s	-	Stoichiometric factor
H_a	g/kg	Absolute humidity of the intake air
H_d	g/kg	Absolute humidity of the dilution air
i	-	Subscript denoting an instantaneous measurement (e.g. 1 Hz)
k_f	-	Fuel specific factor
$k_{h,D}$	-	Humidity correction factor for NO _x for CI engines
$k_{h,G}$	-	Humidity correction factor for NO _x for PI engines
k_r	-	Regeneration factor
$k_{w,a}$	-	Dry to wet correction factor for the intake air
$k_{w,d}$	-	Dry to wet correction factor for the dilution air
$k_{w,e}$	-	Dry to wet correction factor for the diluted exhaust gas
$k_{w,f}$	-	Dry to wet correction factor for the raw exhaust gas
K_V	-	CFV calibration function
λ	-	Excess air ratio
m_d	kg	Mass of the dilution air sample passed through the particulate sampling filters

Symbol	Unit	Term
\dot{m}_{ed}	kg	Total diluted exhaust mass over the cycle
\dot{m}_{edf}	kg	Mass of equivalent diluted exhaust gas over the test cycle
\dot{m}_{ew}	kg	Total exhaust mass over the cycle
\dot{m}_f	mg	Particulate sample mass collected
\dot{m}_{fd}	mg	Particulate sample mass of the dilution air collected
\dot{m}_{gas}	g	Mass of gaseous emissions over the test cycle
\dot{m}_{PM}	g	Mass of particulate emissions over the test cycle
\dot{m}_{se}	kg	Exhaust sample mass over the test cycle
\dot{m}_{sed}	kg	Mass of diluted exhaust gas passing the dilution tunnel
\dot{m}_{sep}	kg	Mass of diluted exhaust gas passing the particulate collection filters
\dot{m}_{sd}	kg	Mass of secondary dilution air
		replace all masses by standard volumetric conditions
M_a	g/mol	Molar mass of the intake air
M_e	g/mol	Molar mass of the exhaust
M_{gas}	g/mol	Molar mass of gaseous components
		replace all molar masses by density
n	-	Number of measurements
n_r	-	Number of measurements during regeneration
n	min ⁻¹	Engine rotational speed
n_{hi}	min ⁻¹	High engine speed
n_{lo}	min ⁻¹	Low engine speed
n_{pref}	min ⁻¹	Preferred engine speed
n_p	r/s	PDP pump speed
p_a	kPa	Saturation vapour pressure of engine intake air
p_b	kPa	Total atmospheric pressure
p_d	kPa	Saturation vapour pressure of the dilution air
p_p	kPa	Absolute pressure
p_t	kPa	Water vapour pressure after cooling bath
p_s	kPa	Dry atmospheric pressure
\dot{q}_{mad}	kg/s	Intake air mass flow rate on dry basis
\dot{q}_{maw}	kg/s	Intake air mass flow rate on wet basis
\dot{q}_{mCe}	kg/s	Carbon mass flow rate in the raw exhaust gas
\dot{q}_{mCf}	kg/s	Carbon mass flow rate into the engine
\dot{q}_{mCp}	kg/s	Carbon mass flow rate in the partial flow dilution system
\dot{q}_{mdew}	kg/s	Diluted exhaust gas mass flow rate on wet basis
\dot{q}_{mdw}	kg/s	Dilution air mass flow rate on wet basis
\dot{q}_{medf}	kg/s	Equivalent diluted exhaust gas mass flow rate on wet basis
\dot{q}_{mew}	kg/s	Exhaust gas mass flow rate on wet basis
\dot{q}_{mex}	kg/s	Sample mass flow rate extracted from dilution tunnel
\dot{q}_{mf}	kg/s	Fuel mass flow rate
\dot{q}_{mp}	kg/s	Sample flow of exhaust gas into partial flow dilution system
		replace all masses by standard volumetric conditions

Symbol	Unit	Term
q_{vCVS}	m^3/s	CVS volume rate
q_{vs}	dm^3/min	System flow rate of exhaust analyzer system
q_{vt}	cm^3/min	Tracer gas flow rate
r_d	-	Dilution ratio
r_D	-	Diameter ratio of SSV
r_h	-	Hydrocarbon response factor of the FID
r_m	-	Methanol response factor of the FID
r_e	-	Ethanol response factor of the FID
r_p	-	Pressure ratio of SSV
r_s	-	Average sample ratio
ρ	kg/m^3	Density
ρ_e	kg/m^3	Exhaust gas density
σ	-	Standard deviation
T	K	Absolute temperature
T_a	K	Absolute temperature of the intake air
t	s	Time
t_{10}	s	Time between step input and 10 per cent of final reading
t_{50}	s	Time between step input and 50 per cent of final reading
t_{90}	s	Time between step input and 90 per cent of final reading
$\#$	-	Ratio between densities of gas component and exhaust gas
V_0	m^3/r	PDP gas volume pumped per revolution
V_s	dm^3	System volume of exhaust analyzer bench
W_{act}	kWh	Actual cycle work of the test cycle
W_{ref}	kWh	Reference cycle work of the test cycle
X_0	m^3/r	PDP calibration function

3.3. Symbols and abbreviations for the fuel composition

**** The symbols included below are identical to GTR 4 and have not been modified. It is the responsibility of the WLTP-DTP subgroups to confirm that their associated symbols are properly documented in this section. ****

w_{ALF}	hydrogen content of fuel, per cent mass
w_{BET}	carbon content of fuel, per cent mass
w_{GAM}	sulphur content of fuel, per cent mass
w_{DEL}	nitrogen content of fuel, per cent mass
w_{EPS}	oxygen content of fuel, per cent mass
α	molar hydrogen ratio (H/C)
γ	molar sulphur ratio (S/C)
δ	molar nitrogen ratio (N/C)
ε	molar oxygen ratio (O/C)
referring to a fuel $CH_{\alpha}O_{\varepsilon}N_{\delta}S_{\gamma}$	

3.4. Symbols and abbreviations for the chemical components

**** The symbols included below are identical to GTR 4 and have not been modified. It is the responsibility of the WLTP-DTP subgroups to confirm that their associated symbols are properly documented in this section. ****

C1	Carbon 1 equivalent hydrocarbon
CH ₄	Methane
C ₂ H ₆	Ethane
C ₃ H ₈	Propane
CO	Carbon monoxide
CO ₂	Carbon dioxide
DOP	Di-octylphthalate
THC	total Hydrocarbons
H ₂ O	Water
NMHC	Non-methane hydrocarbons
NO _x	Oxides of nitrogen
NO	Nitric oxide
NO ₂	Nitrogen dioxide
PM	Particulate matter
add	additional
compounds here	

3.5. Abbreviations

**** The abbreviations included below are identical to GTR 4 and have not been modified. It is the responsibility of the WLTP-DTP subgroups to confirm that their associated abbreviations are properly documented in this section. ****

CFV	Critical Flow Venturi
CLD	Chemiluminescent Detector
CVS	Constant Volume Sampling

deNO _x	NO _x after-treatment system
EGR	Exhaust gas recirculation
FID	Flame Ionization Detector
GC	Gas Chromatograph
HCLD	Heated Chemiluminescent Detector
HFID	Heated Flame Ionization Detector
LPG	Liquefied Petroleum Gas
NDIR	Non-Dispersive Infrared (Analyzer)
NG	Natural Gas
NMC	Non-Methane Cutter
PDP	Positive Displacement Pump
Per cent FS	Per cent of full scale
PFS	Partial Flow System
SSV	Subsonic Venturi
VGT	Variable Geometry Turbine

4. GENERAL REQUIREMENTS

The vehicle shall be so designed, constructed and assembled as to enable the vehicle in normal use to comply with the provisions of this gtr during its useful life, as defined by the Contracting Party.

5. PERFORMANCE REQUIREMENTS

When implementing the test procedure contained in this gtr as part of their national legislation, Contracting Parties to the 1998 Agreement are encouraged to use limit values which represent at least the same level of severity as their existing regulations; pending the development of harmonized limit values, by the Executive Committee (AC.3) of the 1998 Agreement, for inclusion in the gtr at a later date.

5.1. Emission of gaseous and particulate pollutants

The emissions of gaseous and particulate pollutants by the light-duty vehicle shall be determined on the WLTP-DHC test cycles, as described in paragraph x. The measurement systems shall meet the linearity requirements in paragraph 9.2. and the specifications in paragraph 9.3. (gaseous emissions measurement), paragraph 9.4. (particulate measurement) and in Annex 3.

Other systems or analyzers may be approved by the type approval or certification authority, if it is found that they yield equivalent results in accordance with paragraph 5.1.1.

Commentaire [MRO6]: Requires modification to reflect the final formatting.

5.1.1. Equivalency

The determination of system equivalency shall be based on a seven-sample pair (or larger) correlation study between the system under consideration and one of the systems of this gtr.

"Results" refer to the output of the device in question. ~~specific cycle weighted emissions value.~~ The correlation testing is to be performed at the same laboratory, test cell, and on the same vehicle, and is preferred to be run simultaneously. Should it not be possible to run it simultaneously it should at least be conducted concurrently. The equivalency of the sample pair averages shall be determined by *F*-test and *t*-test statistics as described in Annex 4 obtained under the laboratory test cell and the vehicle conditions described above. Outliers shall be determined in accordance with ISO 5725 and excluded from the database. The systems to be used for correlation testing shall be subject to the approval by the type approval or certification authority.

draft proposal for approval of modification of existing GTR procedures

equivalency of	to be used	examples	may be handled by
minor changes	locally	sensors/instruments, e.g. direct determination of NO+NO ₂ vs. NO _x determination with converter	technical service local authority
	globally	sensors/instruments, e.g. direct determination of NO+NO ₂ vs. NO _x determination with converter	GRPE
major changes	specific application, locally	measurement principle, e.g. for auxiliary power unit, fuel based heater	technical service local authority
	universal application	measurement principle, e.g. for auxiliary power unit, fuel based heater	GRPE
	specific application, locally	procedures, e.g. cooling fan position for specific vehicle	technical service local authority
	globally	overall measurement principle, e.g. direct mass measurement	GRPE
	universal application, globally	procedures, e.g. ???	GRPE

5.2. Test Group Determination

From USEPA Part 86 definitions:

“Test group means the basic classification unit within a durability group used for the purpose of demonstrating compliance with exhaust emission standards. The test group is also used as a classification unit for the gathering of in-use data for the In-Use Verification Procedure (IUV).”

Proposal: Insert definition from USEPA Part 86.1827-01, 1828-01, and 1828-10 here. Maintain the following details to guide the manufacturers in their determination of Test Groups.

5.2.1. General

An engine family is characterized by design parameters. These shall be common to all engines within the family. The engine manufacturer may decide, which engines belong to an engine family, as long as the membership criteria listed in paragraph 5.2.3. are respected. The engine family shall be approved by the type approval or certification authority. The manufacturer shall provide to the type approval or certification authority the appropriate information relating to the emission levels of the members of the engine family.

5.2.2. Special cases

In some cases there may be interaction between parameters. This shall be taken into consideration to ensure that only engines with similar exhaust emission characteristics are included within the same engine family. These cases shall be identified by the manufacturer and notified to the type approval or certification authority. It shall then be taken into account as a criterion for creating a new engine family.

In case of devices or features, which are not listed in paragraph 5.2.3. and which have a strong influence on the level of emissions, this equipment shall be identified by the manufacturer on the basis of good engineering practice, and shall be notified to the type approval or certification authority. It shall then be taken into account as a criterion for creating a new engine family.

In addition to the parameters listed in paragraph 5.2.3., the manufacturer may introduce additional criteria allowing the definition of families of more restricted size. These parameters are not necessarily parameters that have an influence on the level of emissions.

5.2.3. Parameters defining the engine family

5.2.3.1. Combustion cycle

- (a) 2-stroke cycle
- (b) 4-stroke cycle
- (c) Rotary engine
- (d) Others

5.2.3.2. Configuration of the cylinders

5.2.3.2.1. Position of the cylinders in the block

- (a) V
- (b) In line
- (c) Radial
- (d) Others (F, W, etc.)

5.2.3.2.2. Relative position of the cylinders

Engines with the same block may belong to the same family as long as their bore center-to-center dimensions are the same.

5.2.3.3. Main cooling medium

- (a) air
- (b) water
- (c) oil

5.2.3.4. Individual cylinder displacement

5.2.3.4.1. Engine with a unit cylinder displacement $\geq 0.75 \text{ dm}^3$

In order for engines with a unit cylinder displacement of $\geq 0.75 \text{ dm}^3$ to be considered to belong to the same engine family, the spread of their individual cylinder displacements shall not exceed 15 per cent of the largest individual cylinder displacement within the family.

5.2.3.4.2. Engine with a unit cylinder displacement $< 0.75 \text{ dm}^3$

In order for engines with a unit cylinder displacement of $< 0.75 \text{ dm}^3$ to be considered to belong to the same engine family, the spread of their individual cylinder displacements shall not exceed 30 per cent of the largest individual cylinder displacement within the family.

5.2.3.4.3. Engine with other unit cylinder displacement limits

Engines with an individual cylinder displacement that exceeds the limits defined in paragraphs 5.2.3.4.1. and 5.2.3.4.2. may be considered to belong to the same family with the approval of the type approval or certification authority. The approval shall be based on technical elements (calculations, simulations, experimental results etc.) showing that exceeding the limits does not have a significant influence on the exhaust emissions.

5.2.3.5. Method of air aspiration

- (a) naturally aspirated
- (b) pressure charged

- (c) pressure charged with charge cooler

5.2.3.6. Fuel type

- (a) Diesel
- (b) Natural gas (NG)
- (c) Liquefied petroleum gas (LPG)
- (d) Ethanol

5.2.3.7. Combustion chamber type

- (a) Open chamber
- (b) Divided chamber
- (c) Other types

5.2.3.8. Ignition Type

- (a) Positive ignition
- (b) Compression ignition

5.2.3.9. Valves and porting

- (a) Configuration
- (b) Number of valves per cylinder

5.2.3.10. Fuel supply type

- (a) Liquid fuel supply type
 - (i) Pump and (high pressure) line and injector
 - (ii) In-line or distributor pump
 - (iii) Unit pump or unit injector
 - (iv) Common rail
 - (v) Carburettor(s)
 - (vi) Others
- (b) Gas fuel supply type
 - (i) Gaseous
 - (ii) Liquid
 - (iii) Mixing units
 - (iv) Others
- (c) Other types

5.2.3.11. Miscellaneous devices

- (a) Exhaust gas recirculation (EGR)
- (b) Water injection
- (c) Air injection
- (d) Others

5.2.3.12. Electronic control strategy

The presence or absence of an electronic control unit (ECU) on the engine is regarded as a basic parameter of the family.

In the case of electronically controlled engines, the manufacturer shall present the technical elements explaining the grouping of these engines in the same family, i.e. the reasons why these engines can be expected to satisfy the same emission requirements.

These elements can be calculations, simulations, estimations, description of injection parameters, experimental results, etc.

Examples of controlled features are:

- (a) Timing
- (b) Injection pressure
- (c) Multiple injections
- (d) Boost pressure
- (e) VGT
- (f) EGR

5.2.3.13. Exhaust after-treatment systems

The function and combination of the following devices are regarded as membership criteria for an engine family:

- (a) Oxidation catalyst
- (b) Three-way catalyst
- (c) DeNO_x system with selective reduction of NO_x (addition of reducing agent)
- (d) Other DeNO_x systems
- (e) Particulate trap with passive regeneration
- (f) Particulate trap with active regeneration
- (g) Other particulate traps
- (h) Other devices

When an engine has been certified without after-treatment system, whether as parent engine or as member of the family, then this engine, when equipped with an oxidation catalyst, may be included in the same engine family, if it does not require different fuel characteristics.

If it requires specific fuel characteristics (e.g. particulate traps requiring special additives in the fuel to ensure the regeneration process), the decision to include it in the same family shall be based on technical elements provided by the manufacturer. These elements shall indicate that the expected emission level of the equipped engine complies with the same limit value as the non-equipped engine.

When an engine has been certified with after-treatment system, whether as parent engine or as member of a family, whose parent engine is equipped with the same after-treatment system, then this engine, when equipped without after-treatment system, must not be added to the same engine family.

5.2.4. Choice of the parent engine

5.2.4.1. Compression ignition engines

Once the engine family has been agreed by the type approval or certification authority, the parent engine of the family shall be selected using the primary criterion of the highest fuel delivery per stroke at the declared maximum torque speed. In the event that two or more engines share this primary criterion, the parent engine shall be selected using the secondary criterion of highest fuel delivery per stroke at rated speed.

5.2.4.2. Positive ignition engines

Once the engine family has been agreed by the type approval or certification authority, the parent engine of the family shall be selected using the primary criterion of the largest displacement. In the event that two or more engines share this primary criterion, the parent engine shall be selected using the secondary criterion in the following order of priority:

- (a) the highest fuel delivery per stroke at the speed of declared rated power;
- (b) the most advanced spark timing;
- (c) the lowest EGR rate.

5.2.4.3. Remarks on the choice of the parent engine

The type approval or certification authority may conclude that the worst-case emission of the family can best be characterized by testing additional engines. In this case, the engine manufacturer shall submit the appropriate information to determine the engines within the family likely to have the highest emissions level.

If engines within the family incorporate other features which may be considered to affect exhaust emissions, these features shall also be identified and taken into account in the selection of the parent engine.

If engines within the family meet the same emission values over different useful life periods, this shall be taken into account in the selection of the parent engine.

6. TEST CONDITIONS

6.1. Test room and soak area

6.1.1. Test room

The test room with the chassis dynamometer and the gas sample collection device, shall have a temperature of $298 \text{ K} \pm 5 \text{ K}$ ($25 \text{ °C} \pm 5 \text{ °C}$). The room temperature shall be measured twice in the vicinity of vehicle cooling blower (fan), both before and after ambient condition the Type I test.

The absolute humidity (H) of either the air in the test cell or the intake air of the engine shall be such that:

$$5.5 \leq H \leq 12.2 (\text{g H}_2\text{O/kg dry air})$$

JAPAN: 30% to 75% for humidity (lower level than for EC)

ECE R 83-06: The atmospheric pressure shall be measured.

6.1.2. Soak area

The soak area shall have a temperature of $298\text{ K} \pm 5\text{ K}$ ($25\text{ °C} \pm 5\text{ °C}$) and be able to park the test vehicle (vehicle) to be preconditioned in accordance with paragraph 7.2.4.

6.2. Test vehicle (Light-Duty Vehicle)

6.2.1. General

The test vehicle shall conform in all its components with the production series, or, if the vehicle is different from the production series, a full description shall be given in the test report. In selecting the test vehicle, the manufacturer and test authority shall agree which light-duty vehicle test model is representative for a related Test Group of vehicles.

6.2.2. Run-in

The vehicle must be presented in good mechanical condition. It must have been run-in and driven between 3000 km and 15 000 km at least xxx km before the test. The engine, transmission and vehicle shall be properly run-in, in accordance with the manufacturer's requirements.
No requirement for JAPAN.

6.2.3. Adjustments

Vehicle dyno mode can be activated on manufacturer's request for safety reasons.

~~The vehicle shall be adjusted in accordance with the manufacturer's requirements, e.g. the viscosity of the oils, or, if the vehicle is different from the production series, a full description shall be given in the test report.~~

3.2.2 The exhaust device shall not exhibit any leak likely to reduce the quantity of gas collected, which quantity shall be that emerging from the engine.

3.2.3. The tightness of the intake system may be checked to ensure that carburation is not affected by an accidental intake of air.

3.2.4. The settings of the engine and of the vehicle's controls shall be those prescribed by the manufacturer. This requirement also applies, in particular, to the settings for idling (rotation speed and carbon monoxide content of the exhaust gases), for the cold start device and for the exhaust gas cleaning system.

3.2.5. The vehicle to be tested, or an equivalent vehicle, shall be fitted, if necessary, with a device to permit the measurement of the characteristic parameters

necessary for chassis dynamometer setting, in conformity with paragraph 5. of this annex.

3.2.6. The technical service responsible for the tests may verify that the vehicle's performance conforms to that stated by the manufacturer, that it can be used for normal driving and, more particularly, that it is capable of starting when cold and when hot.

6.2.4. Tires

The tires shall be of a type specified as original equipment by the vehicle manufacturer. The tyre pressure may be increased by up to 50 per cent from the manufacturer's recommended setting. ~~in the case of a two-roller dynamometer.~~ The actual pressure used shall be recorded in the test report.

~~The tire pressures shall be adjusted to the specifications of the manufacturer or to those where the speed of the vehicle during the road test and the vehicle speed obtained on the chassis dynamometer are equalized. The tire pressure shall be indicated in the test report.~~

6.3 Specification of the reference fuel

ECE R 83-06: 3.3.1. The appropriate reference fuel as defined in Annex XX to this Regulation shall be used for testing.

3.3.2. Vehicles that are fuelled either with petrol or with LPG or NG/biomethane shall be tested according to Annex XY with the appropriate reference fuel(s) as defined in Annex XZ.

The use of one standardized reference fuel has always been considered as an ideal condition for ensuring the reproducibility of regulatory emission testing, and Contracting Parties are encouraged to use such fuel in their compliance testing. However, until performance requirements (i.e. limit values) have been introduced into this gtr, Contracting Parties to the 1998 Agreement are allowed to define their own reference fuel for their national legislation, to address the actual situation of market fuel for vehicles in use.

The appropriate diesel reference fuels of the European Union, the United States of America and Japan listed in Annex 2 are recommended to be used for testing. Since fuel characteristics influence the engine exhaust gas emission, the characteristics of the fuel used for the test shall be determined, recorded and declared with the results of the test.

No CNG and LPG reference fuels are listed due to the significant differences in local fuel qualities.

The fuel temperature shall be in accordance with the manufacturers recommendations.

6.5. Type I tests Ambient condition test

Commentaire [MRO7]: MRO to fix numbering

The following section 6.5 is extracted from GTR 2. It is meant to offer some initial guidelines in this GTR structure, recognizing that the text is specifically addressing vehicle testing. The DTP subgroups shall modify the text to reflect their needs and technical requirements.

6.5.1. Rider

~~The rider shall have a mass of $75\text{ kg} \pm 5\text{ kg}$.~~

6.5.2. Test bench specifications and settings

6.5.2.1. The dynamometer shall consist of a single or twin roller ($\geq 500\text{mm}$) configuration. If a twin roller configuration is applied it should be permanently coupled. The dynamometer shall meet the following EPA performance requirements: States Environmental United Protection Agency, Attachment A, RFP C100081T1, Specifications for Electric Chassis Dynamometers, 1991 have a single roller with a diameter of at least 0.400 m .

6.5.2.2. ~~The dynamometer shall be equipped with a roller revolution counter for measuring actual distance travelled.~~

6.5.2.3. ~~Flywheels of dynamometer or other means shall be used to simulate the inertia specified in paragraph 7.2.2.~~

6.5.2.4. ~~The dynamometer rollers shall be clean, dry and free from anything, which might cause the tyre to slip.~~

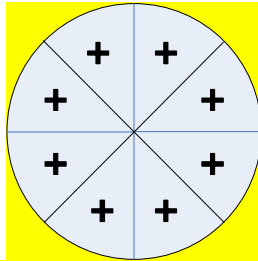
6.5.2.5. Cooling fan specifications as follows:

A current of air of variable speed shall be blown over the vehicle. The blower speed shall be, within the operating range of 10 km/h to at least 50 km/h , or as an alternative, at the request of the manufacturer within the operating range of 10 km/h to at least the maximum speed of the test cycle being used. The linear velocity of the air at the blower outlet shall be within $\pm 5\text{ km/h}$ of the corresponding roller speed within the range of 10 km/h to 50 km/h . At the range over 50 km/h , the linear velocity of the air shall be within $\pm 10\text{ km/h}$ of the corresponding roller speed. At roller speeds of less than 10 km/h , air velocity may be zero.

The above mentioned air velocity shall be determined as an averaged value of a number of measuring points which:

(a) For blowers with rectangular outlets are located at the centre of each rectangle dividing the whole of the blower outlet into 9 areas (dividing both horizontal and vertical sides of the blower outlet into 3 equal parts).

(b) For circular blower outlets, the outlet shall be divided into 8 equal arcs by vertical, horizontal and 45° lines. The measurement points lie on the radial centre line of each arc (22.5°) at a radius of two thirds of the total (as shown in the diagram below).



These measurements shall be made with no vehicle or other obstruction in front of the fan. Each value at those points shall be within 10 per cent of the averaged value of themselves.

The device used to measure the linear velocity of the air shall be located at between 0 and 20 cm from the air outlet.

The final selection of the blower shall have the following characteristics:

- (i) Area: at least 0.2 m²;
 - (ii) Height of the lower edge above ground: approximately 0.2 m;
 - (iii) Distance from the front of the vehicle: approximately 0.3 m. (depending on the size of the fan)
- As an alternative, at the request of the manufacturer the blower speed shall be fixed at an air speed of at least 6 m/s (21.6 km/h).

The height and lateral position of the cooling fan can also be modified at the request of the manufacturer

6.5.2.5.1. Variable speed fan

Proportional to roller speed within operating range of 10km/h to at least 50 km/h

Tolerance: +/- 10km/h or +/-15%, whichever is larger

minimum outlet area: 0.2 m²

minimum width: 0.8 m

Position: approx. 30cm of vehicle, adjust height to meet vehicle air inlet position (grille position)

to be operated with engine compartment closed

additional fans on manufacturer's request if required for typical vehicle operation

alternative on manufacturer's request

fixed speed fan(s) : $v > 21.6$ km/h

operated with engine compartment in open position.

6.5.2.6 General test cell equipment

The following temperatures shall be measured with an accuracy of ± 1.5 K:

- (a) Test cell ambient air
- (b) Intake air to the engine
- (c) Dilution and sampling system temperatures as required for emissions measurement systems defined in Appendices 2 to 5 of this annex.

The atmospheric pressure shall be measurable to within ± 0.1 kPa.

The absolute humidity (H) shall be measurable to within ± 5 per cent.

~~Throughout the test, a variable speed cooling blower (fan) shall be positioned in front of the vehicle, so as to direct the cooling air to the vehicle 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 the range of over 50 km/h, the linear velocity of the air shall be within ± 10 per cent. At roller speeds of less than 10 km/h, air velocity may be zero.~~

~~6.5.2.5.2. The above mentioned air velocity shall be determined as an averaged value of 9 measuring points which are located at the centre of each rectangle dividing the whole of the blower outlet into 9 areas (dividing both of horizontal and vertical sides of the blower outlet into 3 equal parts). Each value at those 9 points shall be within 10 per cent of the averaged value of themselves.~~

~~6.5.2.5.3. The blower outlet shall have a cross section area of at least 0.4 m^2 and the bottom of the blower outlet shall be between 5 and 20 cm above floor level. The blower outlet shall be perpendicular to the longitudinal axis of the vehicle between 30 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 and 20 cm from the air outlet.~~

6.5.3. Exhaust gas measurement system

6.5.3.1. use R83 text, annex4a, appendix 2, page 208ff

Appendix 2

EXHAUST DILUTION SYSTEM

1. SYSTEM SPECIFICATION

1.1. System Overview

A full-flow exhaust dilution system shall be used. This requires that the vehicle exhaust be continuously diluted with ambient air under controlled conditions. The total volume of the mixture of exhaust and dilution air shall be measured and a continuously proportional sample of the volume shall be collected for analysis. The quantities of pollutants are determined from the sample concentrations, corrected for the pollutant content of the ambient air and the totalised flow over the test period.

The exhaust dilution system shall consist of a transfer tube, a mixing chamber and dilution tunnel, a dilution air conditioning, a suction device and a flow measurement device. Sampling probes shall be fitted in the dilution tunnel as specified in Appendices 3, 4 and 5.

The mixing chamber described above will be a vessel, such as those illustrated in Figures 6 and 7, in which vehicle exhaust gases and the dilution air are combined so as to produce a homogeneous mixture at the chamber outlet.

1.2. General Requirements

1.2.1. The vehicle exhaust gases shall be diluted with a sufficient amount of ambient air to prevent any water condensation in the sampling and measuring system at all conditions which may occur during a test.

1.2.2. The mixture of air and exhaust gases shall be homogeneous at the point where the sampling probe is located (see paragraph 1.3.3. below). The sampling probe shall extract a representative sample of the diluted exhaust gas.

1.2.3. The system shall enable the total volume of the diluted exhaust gases to be measured.

1.2.4. The sampling system shall be gas-tight. The design of the variable-dilution sampling system and the materials that go to make it up shall be such that they do not affect the pollutant concentration in the diluted exhaust gases. Should any component in the system (heat exchanger, cyclone separator, blower, etc.) change the concentration of any of the pollutants in the diluted exhaust gases and the fault cannot be corrected, then sampling for that pollutant shall be carried out upstream from that component.

1.2.5. All parts of the dilution system that are in contact with raw and diluted exhaust gas, shall be designed to minimise deposition or alteration of the particulates or particles. All parts shall be made of electrically conductive materials that do not react with exhaust gas components, and shall be electrically grounded to prevent electrostatic effects.

1.2.6. If the vehicle being tested is equipped with an exhaust pipe comprising several branches, the connecting tubes shall be connected as near as possible to the vehicle without adversely affecting its operation.

1.2.7. The variable-dilution system shall be so designed as to enable the exhaust gases to be sampled without appreciably changing the back-pressure at the exhaust pipe outlet.

1.2.8. The connecting tube between the vehicle and dilution system shall be designed so as to minimize heat loss.

1.3. Specific Requirements

1.3.1. Connection to Vehicle Exhaust

The connecting tube between the vehicle exhaust outlets and the dilution system shall be as short as possible; and satisfy the following requirements:

- (a) Be less than 3.6 m long, or less than 6.1 m long if heat insulated. Its internal diameter may not exceed 105 mm; the insulating materials shall have a thickness of at least 25mm and thermal conductivity not exceeding 0.1W/m*K at 400°C (Japanese regulation)
- (b) Shall not cause the static pressure at the exhaust outlets on the vehicle being tested to; differ by more than ± 0.75 kPa at 50 km/h, or more than ± 1.25 kPa for the whole duration of the test from the static pressures recorded when nothing is connected to the vehicle exhaust outlets. The pressure shall be measured in the exhaust outlet or in an extension having the same diameter, as near as possible to the end of the pipe. Sampling systems capable of maintaining the static pressure to within ± 0.25 kPa may be used if a written request from a manufacturer to the Technical Service substantiates the need for the closer tolerance; (conflict to Japanese regulation 0.1kPa @ 70km/h)
- (c) Shall not change the nature of the exhaust gas;
- (d) Any elastomer connectors employed shall be as thermally stable as possible and have minimum exposure to the exhaust gases.

1.3.2. Dilution Air Conditioning

The dilution air used for the primary dilution of the exhaust in the CVS tunnel shall be passed through a medium capable of reducing particles in the most penetrating particle size of the filter material by ≥ 99.95 per cent, or through a filter of at least class H13 of EN 1822:1998. This represents the specification of High Efficiency Particulate Air (HEPA) filters. The dilution air may optionally be charcoal scrubbed before being passed to the HEPA filter. It is recommended that an additional coarse particle filter is situated before the HEPA filter and after the charcoal scrubber, if used.

At the vehicle manufacturer's request, the dilution air may be sampled according to good engineering practice to determine the tunnel contribution to background particulate mass levels, which can then be subtracted from the values measured in the diluted exhaust.

1.3.3. Dilution Tunnel

Provision shall be made for the vehicle exhaust gases and the dilution air to be mixed. A mixing orifice may be used.

In order to minimise the effects on the conditions at the exhaust outlet and to limit the drop in pressure inside the dilution-air conditioning device, if any, the pressure at the mixing point shall not differ by more than ± 0.25 kPa from atmospheric pressure.

The homogeneity of the mixture in any cross-section at the location of the sampling probe shall not vary by more than ± 2 per cent from the average of the values obtained for at least five points located at equal intervals on the diameter of the gas stream.

For particulate and particle emissions sampling, a dilution tunnel shall be used which:

- (a) Shall consist of a straight tube of electrically-conductive material, which shall be earthed;
- (b) Shall be small enough in diameter to cause turbulent flow (Reynolds number ≥ 4000) and of sufficient length to cause complete mixing of the exhaust and dilution air;
- (c) Shall be at least 200 mm in diameter;
- (d) May be insulated.

1.3.4. Suction Device

This device may have a range of fixed speeds to ensure sufficient flow to prevent any water condensation. This result is generally obtained if the flow is either:

- (a) Twice as high as the maximum flow of exhaust gas produced by accelerations of the driving cycle; or
- (b) Sufficient to ensure that the CO₂ concentration in the dilute-exhaust sample bag is less than 3 per cent by volume for petrol and diesel, less than 2.2 per cent by volume for LPG and less than 1.5 per cent by volume for NG/biomethane.

1.3.5. Volume Measurement in the Primary Dilution System

The method of measuring total dilute exhaust volume incorporated in the constant volume sampler shall be such that measurement is accurate to ± 2 per cent under all operating conditions. If the device cannot compensate for variations in the temperature of the mixture of exhaust gases and dilution air at the measuring point, a heat exchanger shall be used to maintain the temperature to within ± 6 K of the specified operating temperature.

If necessary, some form of protection for the volume measuring device may be used e.g. a cyclone separator, bulk stream filter, etc.

A temperature sensor shall be installed immediately before the volume measuring device. This temperature sensor shall have an accuracy and a precision of ± 1 K and a response time of 0.1 s at 62 per cent of a given temperature variation (value measured in silicone oil).

The measurement of the pressure difference from atmospheric pressure shall be taken upstream from and, if necessary, downstream from the volume measuring device.

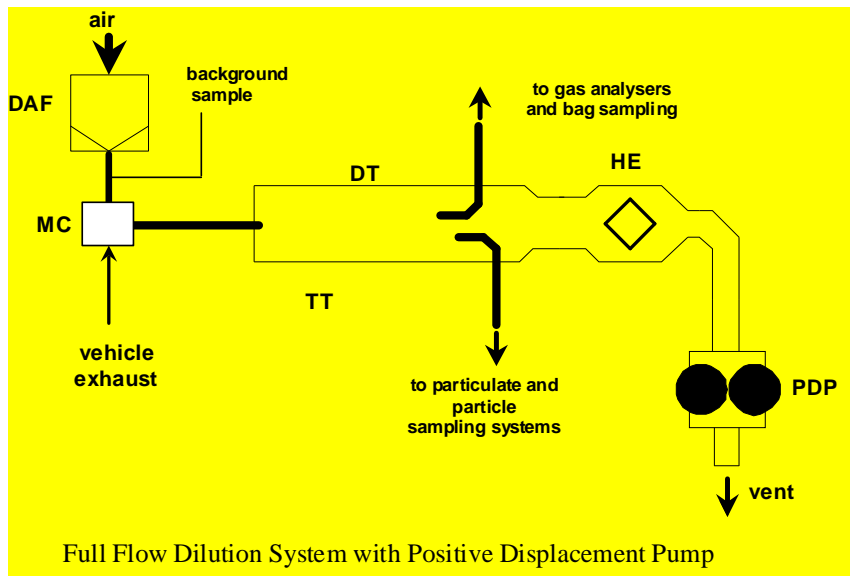
The pressure measurements shall have a precision and an accuracy of ± 0.4 kPa during the test.

1.4. Recommended System Descriptions

Figures 6 and 7 are schematic drawings of two types of recommended exhaust dilution systems that meet the requirements of this annex.

Since various configurations can produce accurate results, exact conformity with these figures is not essential. Additional components such as instruments, valves, solenoids and switches may be used to provide additional information and co-ordinate the functions of the component system.

1.4.1. Figure 6: Positive Displacement Pump Dilution System



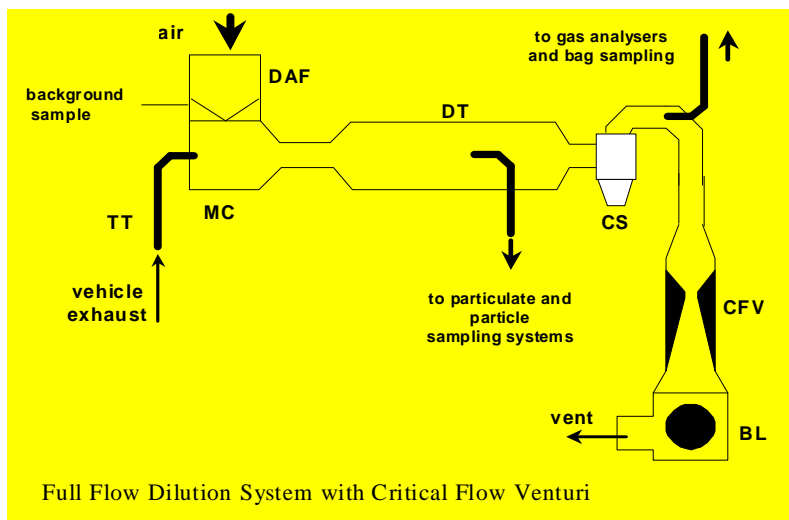
The positive displacement pump (PDP) full flow dilution system satisfies the requirements of this annex by metering the flow of gas through the pump at constant temperature and pressure. The total volume is measured by counting the revolutions made by the calibrated positive displacement pump. The proportional sample is achieved by sampling with pump, flow-meter and flow control valve at a constant flow rate. The collecting equipment consists of:

- 1.4.1.1. A filter (DAF) for the dilution air, which can be preheated if necessary. This filter shall consist of the following filters in sequence: an optional activated charcoal filter (inlet side), and a high efficiency particulate air (HEPA) filter (outlet side). It is recommended that an additional coarse particle filter is situated before the HEPA filter and after the charcoal filter, if used. The purpose of the charcoal filter is to reduce and stabilize the hydrocarbon concentrations of ambient emissions in the dilution air;
- 1.4.1.2. A transfer tube (TT) by which vehicle exhaust is admitted into a dilution tunnel (DT) in which the exhaust gas and dilution air are mixed homogeneously;
- 1.4.1.3. The positive displacement pump (PDP), producing a constant-volume flow of the air/exhaust-gas mixture. The PDP revolutions, together with associated temperature and pressure measurement are used to determine the flowrate;
- 1.4.1.4. A heat exchanger (HE) of a capacity sufficient to ensure that throughout the test the temperature of the air/exhaust-gas mixture measured at a point immediately upstream of the positive displacement pump is within 6 K of the average operating temperature

during the test. This device shall not affect the pollutant concentrations of diluted gases taken off after for analysis.

- 1.4.1.5. A mixing chamber (MC) in which exhaust gas and air are mixed homogeneously, and which may be located close to the vehicle so that the length of the transfer tube (TT) is minimized.

1.4.2. Figure 7: Critical-Flow Venturi Dilution System



The use of a critical-flow venturi (CFV) for the full-flow dilution system is based on the principles of flow mechanics for critical flow. The variable mixture flow rate of dilution and exhaust gas is maintained at sonic velocity which is directly proportional to the square root of the gas temperature. Flow is continually monitored, computed and integrated throughout the test.

The use of an additional critical-flow sampling venturi ensures the proportionality of the gas samples taken from the dilution tunnel. As both pressure and temperature are equal at the two venturi inlets the volume of the gas flow diverted for sampling is proportional to the total volume of diluted exhaust-gas mixture produced, and thus the requirements of this annex are met. The collecting equipment consists of:

- 1.4.2.1. A filter (DAF) for the dilution air, which can be preheated if necessary. This filter shall consist of the following filters in sequence: an optional activated charcoal filter (inlet side), and a high efficiency particulate air (HEPA) filter (outlet side). It is recommended that an additional coarse particle filter is situated before the HEPA filter and after the charcoal filter, if used. The purpose of the charcoal filter is to reduce and stabilize the hydrocarbon concentrations of ambient emissions in the dilution air;

- 1.4.2.2. A mixing chamber (MC) in which exhaust gas and air are mixed homogeneously, and which may be located close to the vehicle so that the length of the transfer tube (TT) is minimized;
- 1.4.2.3. A dilution tunnel (DT) from which particulates and particles are sampled;
- 1.4.2.4. Some form of protection for the measurement system may be used e.g. a cyclone separator, bulk stream filter, etc.;
- 1.4.2.5. A measuring critical-flow venturi tube (CFV), to measure the flow volume of the diluted exhaust gas;
- 1.4.2.6. A blower (BL), of sufficient capacity to handle the total volume of diluted exhaust gas.

2. CVS CALIBRATION PROCEDURE

2.1. General Requirements

The CVS system shall be calibrated by using an accurate flow-meter and a restricting device. The flow through the system shall be measured at various pressure readings and the control parameters of the system measured and related to the flows. The flow-metering device shall be dynamic and suitable for the high flow-rate encountered in constant volume sampler testing. The device shall be of certified accuracy traceable to an approved national or international standard.

- 2.1.1. Various types of flow-meter may be used, e.g. calibrated venturi, laminar flow-meter, calibrated turbine-meter, provided that they are dynamic measurement systems and can meet the requirements of paragraph 1.3.5. of this appendix.

- 2.1.2. The following paragraphs give details of methods of calibrating PDP and CFV units, using a laminar flow-meter, which gives the required accuracy, together with a statistical check on the calibration validity.

2.2. Calibration of the positive displacement pump (PDP)

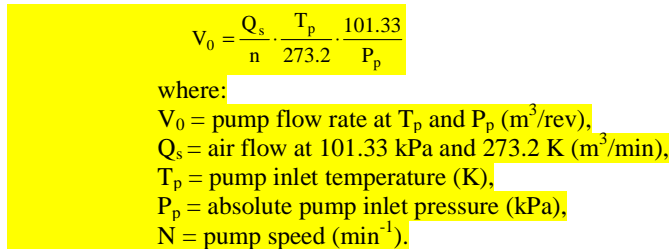
- 2.2.1. The following calibration procedure outlines the equipment, the test configuration and the various parameters that are measured to establish the flow-rate of the CVS pump. All the parameters related to the pump are simultaneously measured with the parameters related to the flow-meter which is connected in series with the pump. The calculated flow-rate (given in m³/min at pump inlet, absolute pressure and temperature) can then be plotted versus a correlation function that is the value of a specific combination of pump parameters. The linear equation that relates the pump flow and the correlation function is then determined. In the event that a CVS has a multiple speed drive, a calibration for each range used shall be performed.

- 2.2.2. This calibration procedure is based on the measurement of the absolute values of the pump and flow-meter parameters that relate the flow rate at each point. Three

conditions shall be maintained to ensure the accuracy and integrity of the calibration curve:

- 2.2.2.1. The pump pressures shall be measured at tappings on the pump rather than at the external piping on the pump inlet and outlet. Pressure taps that are mounted at the top centre and bottom centre of the pump drive headplate are exposed to the actual pump cavity pressures, and therefore reflect the absolute pressure differentials;
- 2.2.2.2. Temperature stability shall be maintained during the calibration. The laminar flow-meter is sensitive to inlet temperature oscillations which cause the data points to be scattered. Gradual changes of ± 1 K in temperature are acceptable as long as they occur over a period of several minutes;
- 2.2.2.3. All connections between the flow-meter and the CVS pump shall be free of any leakage.
- 2.2.3. During an exhaust emission test, the measurement of these same pump parameters enables the user to calculate the flow rate from the calibration equation.
- 2.2.4. Figure 8 of this appendix shows one possible test set-up. Variations are permissible, provided that the Technical Service approves them as being of comparable accuracy. If the set-up shown in Figure 8 is used, the following data shall be found within the limits of precision given:

Barometric pressure (corrected)(P_b)	± 0.03 kPa
Ambient temperature (T)	± 0.2 K
Air temperature at LFE (ETI)	± 0.15 K
Pressure depression upstream of LFE (EPI)	± 0.01 kPa
Pressure drop across the LFE matrix (EDP)	± 0.0015 kPa
Air temperature at CVS pump inlet (PTI)	± 0.2 K
Air temperature at CVS pump outlet (PTO)	± 0.2 K
Pressure depression at CVS pump inlet (PPI)	± 0.22 kPa
Pressure head at CVS pump outlet (PPO)	± 0.22 kPa
Pump revolutions during test period (n)	± 1 min ⁻¹
Elapsed time for period (minimum 250 s) (t)	± 0.1 s



2.2.9. To compensate for the interaction of pump speed pressure variations at the pump and the pump slip rate, the correlation function (x_0) between the pump speed (n), the pressure differential from pump inlet to pump outlet and the absolute pump outlet pressure is then calculated as follows:

$$x_0 = \frac{1}{n} \sqrt{\frac{\Delta P_p}{P_e}}$$

where:

x_0 = correlation function,

ΔP_p = pressure differential from pump inlet to pump outlet (kPa),

P_e = absolute outlet pressure ($PPO + P_b$) (kPa).

A linear least-square fit is performed to generate the calibration equations which have the formula:

$$V_0 = D_0 - M (x_0)$$

$$n = A - B (\Delta P_p)$$

D_0 , M , A and B are the slope-intercept constants describing the lines.

2.2.10. A CVS system that has multiple speeds shall be calibrated on each speed used. The calibration curves generated for the ranges shall be approximately parallel and the intercept values (D_0) shall increase as the pump flow range decreases.

2.2.11. If the calibration has been performed carefully, the calculated values from the equation will be within 0.5 per cent of the measured value of V_0 . Values of M will vary from one pump to another. Calibration is performed at pump start-up and after major maintenance.

2.3. Calibration of the critical-flow venturi (CFV)

2.3.1. Calibration of the CFV is based upon the flow equation for a critical venturi:

$$Q_s = \frac{K_v P}{\sqrt{T}}$$

where:

Q_s = flow,

K_v = calibration coefficient,

P = absolute pressure (kPa),

T = absolute temperature (K).

Gas flow is a function of inlet pressure and temperature.

The calibration procedure described below establishes the value of the calibration coefficient at measured values of pressure, temperature and air flow.

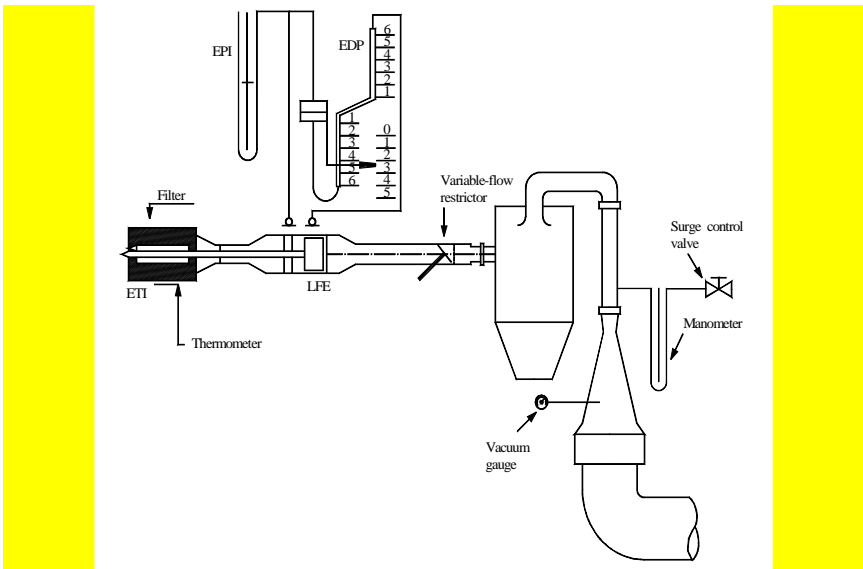
2.3.2. The manufacturer's recommended procedure shall be followed for calibrating electronic portions of the CFV.

2.3.3. Measurements for flow calibration of the critical flow venturi are required and the following data shall be found within the limits of precision given:

Barometric pressure (corrected) (P_b)	± 0.03 kPa,
LFE air temperature, flow-meter (ETI)	± 0.15 K,
Pressure depression upstream of LFE (EPI)	± 0.01 kPa,
Pressure drop across (EDP) LFE matrix	± 0.0015 kPa,
Air flow (Q_s)	± 0.5 per cent,
CFV inlet depression (PPI)	± 0.02 kPa,
Temperature at venturi inlet (T_v)	± 0.2 K.

2.3.4. The equipment shall be set up as shown in Figure 9 of this appendix and checked for leaks. Any leaks between the flow-measuring device and the critical-flow venturi will seriously affect the accuracy of the calibration.

Figure 9: CFV Calibration Configuration



2.3.5. The variable-flow restrictor shall be set to the open position, the blower shall be started and the system stabilized. Data from all instruments shall be recorded.

2.3.6. The flow restrictor shall be varied and at least eight readings across the critical flow range of the venturi shall be made.

2.3.7. The data recorded during the calibration shall be used in the following calculations. The air flow-rate (Q_s) at each test point is calculated from the flow-meter data using the manufacturer's prescribed method.

Calculate values of the calibration coefficient for each test point:

$$K_v = \frac{Q_s \sqrt{T_v}}{P_v}$$

where:

Q_s = flow-rate in m³/min at 273.2 K and 101.33 kPa,

T_v = temperature at the venturi inlet (K),

P_v = absolute pressure at the venturi inlet (kPa).

Plot K_v as a function of venturi inlet pressure. For sonic flow, K_v will have a relatively constant value. As pressure decreases (vacuum increases) the venturi becomes unchoked and K_v decreases. The resultant K_v changes are not permissible.

For a minimum of eight points in the critical region, calculate an average K_v and the standard deviation.

If the standard deviation exceeds 0.3 per cent of the average K_v , take corrective action.

3. SYSTEM VERIFICATION PROCEDURE

3.1. General Requirements

The total accuracy of the CVS sampling system and analytical system shall be determined by introducing a known mass of a pollutant gas into the system whilst it is being operated as if during a normal test and then analysing and calculating the pollutant mass according to the formula in paragraph 6.6. of Annex 4a except that the density of propane shall be taken as 1.967 grams per litre at standard conditions. The following two techniques are known to give sufficient accuracy.

The maximum permissible deviation between the quantity of gas introduced and the quantity of gas measured is ≤ 2 per cent.

3.2. CFO Method

3.2.1. Metering a constant flow of pure gas (CO , CO_2 , or C_3H_8) using a critical flow orifice device.

3.2.2. A known quantity of pure gas (CO , CO_2 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 ≤ 2 per cent occur, the cause of the malfunction shall be determined and corrected. The CVS system is operated as

in an exhaust emission test for about 5 to 10 minutes. The gas collected in the sampling bag is analysed by the usual equipment and the results compared to the concentration of the gas samples which was known beforehand.

3.3. Gravimetric Method

3.3.1. Metering a limited quantity of pure gas (CO, CO₂, or C₃H₈) by means of a gravimetric technique.

3.3.2. 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 minutes, the CVS system is operated as in a normal 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.

~~The gas collection device shall be a closed type device that can collect all exhaust gases at the vehicle exhaust outlet(s) on condition that it satisfies the backpressure condition of ± 1.25 kPa H₂O. 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 that nature of exhaust gases at the test temperature. The system of gas collection device is shown in Figure 6-2, for example.~~

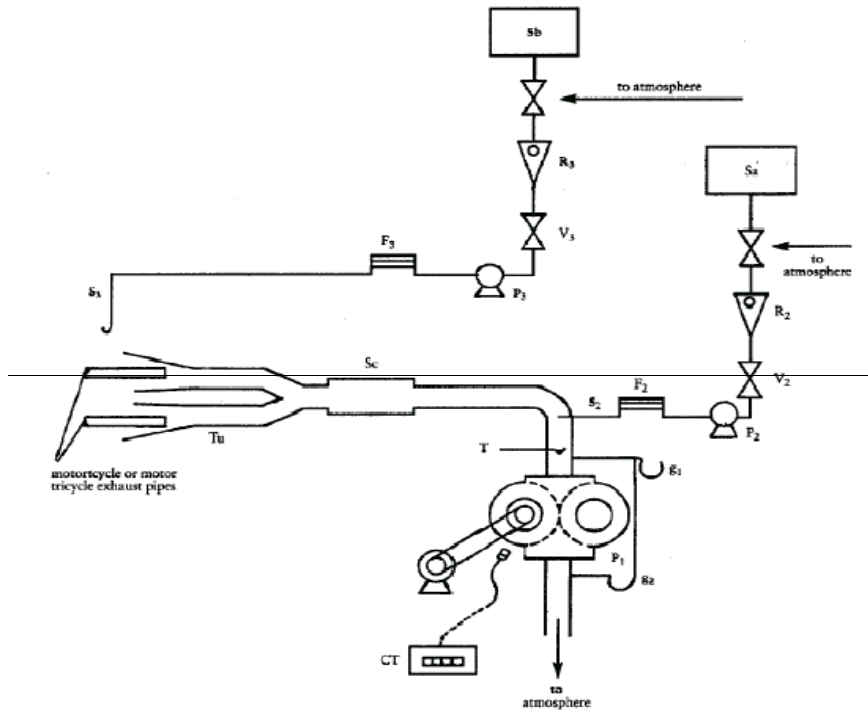


Figure 6 2: Equipment for sampling the gases and measuring their volume

- 6.5.3.2. 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.
- 6.5.3.3. A heat exchanger capable of limiting the temperature variation of the diluted gases in the pump intake to $\pm 5^{\circ}\text{C}$ throughout the test. This exchanger shall be equipped with a preheating system able to bring the exchanger to its operating temperature (with the tolerance of $\pm 5^{\circ}\text{C}$) before the test begins.
- 6.5.3.4. A positive displacement pump 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 the exhaust gases. A device using a critical flow venture (CFV) may also be used.
- 6.5.3.5. A device (T) to allow continuous recording of the temperature of the diluted exhaust mixture entering the pump.

- ~~6.5.3.6. Two gauges; the first to ensure the pressure depression of the dilute exhaust mixture entering the pump, relative to atmospheric pressure, the other to measure the dynamic pressure variation of the positive displacement pump.~~
- ~~6.5.3.7. A probe located near to, but outside the gas collecting device, to collect, through a pump, a filter and a flow meter, samples of the dilution air stream, at constant flow rates throughout the test.~~
- ~~6.5.3.8. A sample probe pointed upstream into the dilute exhaust mixture flow, upstream of the positive displacement pump to collect, through a pump, a filter and a flow meter, samples of the dilute exhaust mixture, at constant flow rates, throughout the test. The minimum sample flow rate in the two sampling devices described above and in paragraph 6.5.3.7. shall be at least 150 litre/hour.~~
- ~~6.5.3.9. Three way valves on the sampling system described in paragraph 6.5.3.7. and paragraph 6.5.3.8. to direct the samples either to their respective bags or to the outside throughout the test.~~
- ~~6.5.3.10. Gas tight collection bags~~
- ~~6.5.3.10.1. For dilution air and dilute exhaust mixture of sufficient capacity so as not to impede normal sample flow and which will not change the nature of the pollutants concerned.~~
- ~~6.5.3.10.2. 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.~~
- ~~6.5.3.11. A revolution counter to count the revolutions of the positive displacement pump throughout the test.~~

Note 2 ~~Good care shall be taken on 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 becomes 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 3 ~~Open type devices have risks of incomplete gas collection and gas leakage into the test cell. It is necessary to make sure there is no leakage throughout the sampling period.~~

Note 4 ~~If a constant CVS flow rate is used throughout the test cycle that includes low and high speeds all in one (i.e. part 1, 2 and 3 cycles) special attention should be paid because of higher risk of water condensation in high speed range.~~

6.5.4. **Driving schedules**

These items will have to be reviewed with the new cycle.

Commentaire [MRO8]: DHC input required here.

ECE R 83-06: 6.1. Test cycle

The operating cycle, made up of a Part One (urban cycle) and Part Two (extra-urban cycle), is illustrated in Figure 1. During the complete test the elementary urban cycle is run four times followed, by Part Two.

6.1.3. Use of the gearbox

6.1.3.1. If the maximum speed which can be attained in first gear is below 15 km/h, the second, third and fourth gears shall be used for the urban cycle (Part One) and the second, third, fourth and fifth gears for the extra-urban cycle (Part Two). The second, third and fourth gears may also be used for the urban cycle (Part One) and the second, third, fourth and fifth gears for the extra-urban cycle (Part Two) when the manufacturer's instructions recommend starting in second gear on level ground, or when first gear is therein defined as a gear reserved for cross-country driving, crawling or towing.

Vehicles which do not attain the acceleration and maximum speed values required in the operating cycle shall be operated with the accelerator control fully depressed until they once again reach the required operating curve. Deviations from the operating cycle shall be recorded in the test report.

Vehicles equipped with semi-automatic-shift gearboxes shall be tested by using the gears normally employed for driving, and the gear shift is used in accordance with the manufacturer's instructions.

6.1.3.2. Vehicles equipped with automatic-shift gearboxes shall be tested with the highest gear ("Drive") engaged. The accelerator shall be used in such a way as to obtain the steadiest acceleration possible, enabling the various gears to be engaged in the normal order. Furthermore, the gear-change points shown in Tables 1 and 2 of this annex shall not apply; acceleration shall continue throughout the period represented by the straight line connecting the end of each period of idling with the beginning of the next following period of steady speed. The tolerances given in paragraphs 6.1.3.4. and 6.1.3.5. below shall apply.

6.1.3.3. Vehicles equipped with an overdrive that the driver can actuate shall be tested with the overdrive out of action for the urban cycle (Part One) and with the overdrive in action for the extra-urban cycle (Part Two).

6.1.3.4. A tolerance of ~~$\pm 2 \text{ km/h}$~~ $\pm 3 \text{ km/h}$ shall be allowed between the indicated speed and the theoretical speed during acceleration, during steady speed, and during deceleration when the vehicle's brakes are used. If the vehicle decelerates more rapidly without the use of the brakes, only the provisions of paragraph 6.4.4.3. below shall apply. Speed tolerances greater than those prescribed shall be accepted during phase changes provided that the tolerances are never exceeded for more than 0.5 s on any one occasion.

USA Additional driving cycle requirements to be added: 86.128-00 § d, 86.115-78

6.1.3.5. The time tolerances shall be $\pm 1.0 \text{ s}$. The above tolerances shall apply equally at the beginning and at the end of each gear-changing period for the urban cycle (Part One) and for the

operations Nos. 3, 5 and 7 of the extra-urban cycle (Part Two). It should be noted that the time of two seconds allowed includes the time for changing gear and, if necessary, a certain amount of latitude to catch up with the cycle

JAPAN/ iii. In cases where the engine revolution speed of the motor vehicle concerned exceeds 90% of the engine speed at which the engine produces the maximum output during the Standard mode
Lower limit
allowable line
Reference point
±1.0 second
±2.0 km/h
Upper limit
allowable line
33

11-1-4-42

operation of the test motor vehicle, it is permissible to use the shift gear 1 position higher than the shift gear that is being used at this time. In this case, the vehicle speed at which the gear-changing operation is performed shall be the vehicle speed at which the engine revolution speed is 90% of the engine speed at the time when the engine produces the maximum output.

Use of Multi-mode gearboxes

USE OF GSI IF EQUIPPED

6.5.6. Dynamometer settings

A full description of the chassis dynamometer and instruments shall be provided in accordance with Annex 6. [measurement equipment group to review] Measurements shall be made to the accuracies as specified in section X.X of Annex 9 paragraph 6.5.7. The running resistance force for the chassis dynamometer settings shall can be derived in accordance with Annex 9 either from on road coast down measurements or from a running resistance table (see Annex 3).

~~6.5.6.1. Chassis dynamometer setting derived from on road coast down measurements~~

~~————— To use this alternative on road coast down measurements have to be carried out as specified in Annex 7.~~

~~6.5.6.1.1. Requirements for the equipment~~

~~————— The instrumentation for the speed and time measurement shall have the accuracies as specified in paragraph 6.5.7.~~

6.5.6.1.2. Inertia mass setting

6.5.6.1.2.1. ~~The equivalent inertia mass for the chassis dynamometer shall be the flywheel equivalent inertia mass, m_{fi} , closest to the actual mass of the vehicle, m_a . The actual mass, m_a , is obtained by adding the rotating mass of the front wheel, m_{rf} , to the total mass of the vehicle, rider and instruments measured during the road test. Alternatively, the equivalent inertia mass m_i can be derived from Annex 3. The value of m_{rf} , in kilograms, may be measured or calculated as appropriate, or may be estimated as 3 per cent of m .~~

6.5.6.1.2.2. ~~If the actual mass m_a cannot be equalized to the flywheel equivalent inertia mass m_i , to make the target running resistance force F^{sk} equal to the running resistance force F_E (which is to be set to the chassis dynamometer), the corrected coast down time ΔT_E may be adjusted in accordance with the total mass ratio of the target coast down time ΔT_{road} in the following sequence:~~

$$\Delta T_{\text{road}} = \frac{1}{3.6} (m_a + m_{r1}) \frac{2\Delta v}{F^*} \quad \text{Equation 6-4}$$

$$\Delta T_E = \frac{1}{3.6} (m_i + m_{r1}) \frac{2\Delta v}{F_E} \quad \text{Equation 6-5}$$

$$F_E = F^* \quad \text{Equation 6-6}$$

$$\Delta T_E = \Delta T_{\text{road}} \times \frac{m_i + m_{r1}}{m_a + m_{r1}} \quad \text{Equation 6-7}$$

$$\text{with } 0.95 < \frac{m_i + m_{r1}}{m_a + m_{r1}} < 1.05$$

~~where:~~

~~m_{r1} may be measured or calculated, in kilograms, as appropriate. As an alternative, m_{r1} may be estimated as 4 per cent of m .~~

6.5.6.2. Running resistance force derived from a running resistance table

6.5.6.2.1. The chassis dynamometer can be set by the use of the running resistance table instead of the running resistance force obtained by the coast down method. In this table method, the chassis dynamometer shall be set by the mass in running order regardless of particular vehicle/motorcycle characteristics.

~~Note 6~~ Cares should be taken for the application of this method to vehicles having extraordinary characteristics.

~~6.5.6.2.2.~~ The flywheel equivalent inertia mass m_f shall be the equivalent inertia mass m_i specified in Annex 3. The chassis dynamometer shall be set by the rolling resistance of the front wheel a and the aero drag coefficient b as specified in Annex 3.

~~6.5.6.2.3.~~ The running resistance force on the chassis dynamometer F_E shall be determined from the following equation:

$$F_E = F_T = a + b \times v^2 \quad \text{Equation 6-8}$$

~~6.5.6.2.4.~~ The target running resistance force F^* shall be equal to the running resistance force obtained from the running resistance table F_T because the correction for the standard ambient conditions is not necessary.

~~6.5.7.~~ Measurement accuracies

~~Measurements have to be carried out using equipment that fulfil the accuracy requirements as described in table 6-1 below:~~

~~Table 6-1: Required accuracy of measurements~~

Measurement Items	At measured value	Resolution
a) Running resistance force, F	+ 2 per cent	-
b) Vehicle speed (v_1, v_2)	± 1 per cent	0.2 km/h
c) Coast down speed interval ($2\Delta v = v_1 - v_2$)	± 1 per cent	0.1 km/h
d) Coast down time (Δt)	± 0.5 per cent	0.01 s
e) Total vehicle mass ($m_k + m_{rid}$)	± 0.5 per cent	1.0 kg
f) Wind speed	± 10 per cent	0.1 m/s
g) Wind direction	-	5 deg.
h) Temperatures	± 1 °C	1 °C
i) Barometric pressure	-	0.2 kPa
j) Distance	± 0.1 per cent	1 m
k) Time	± 0.1 s	0.1 s

The following section 7.0 is extracted from GTR 2. It is meant to offer some initial guidelines in this GTR structure, recognizing that the text is specifically addressing vehicle testing. The DTP subgroups shall modify the text to reflect their needs and technical requirements.

7. Test procedures

7.1. Description of tests.

The test vehicle (~~motorcycle~~) shall be subjected, according to its category, to ambient condition test tests of two types, I and II, as as specified below.

7.1.1. Ambient condition test ~~Type I test~~ (verifying the average emission of gaseous and particulate pollutants, CO₂ emissions and fuel consumption in a characteristic driving cycle).

7.1.1.1. The test shall be carried out by the method described in paragraph 7.2. to this regulation. The gases and particulates shall be collected and analysed by the prescribed methods.

7.1.1.2. Number of tests

The number of tests shall be determined as shown in figure 7-1. R_{i1} to R_{i3} describe the final measurement results for the first (No.1) test to the third (No.3) test and the gaseous and particulate pollutant, the carbon dioxide emission or fuel consumption as defined in paragraph 8.1.1.6. L is the limit value as defined in paragraph 5.

Harmonised concept: 1 or 3 tests?

7.1.1.2.2. In each test, the mass of the carbon monoxide, the mass of the hydrocarbons, the mass of the nitrogen oxides, the mass of carbon dioxide and the mass of the fuel, consumed during the test shall be determined.

7.1.2. Type II test (test of carbon monoxide at idling speed) and emissions data required for roadworthiness testing.

The carbon monoxide content of the exhaust gases emitted shall be checked by a test with the engine at normal idling speed and at "high idle" speed (i.e. $> 2.000 \text{ min}^{-1}$) carried out by the method described in paragraph 7.3. to this regulation.

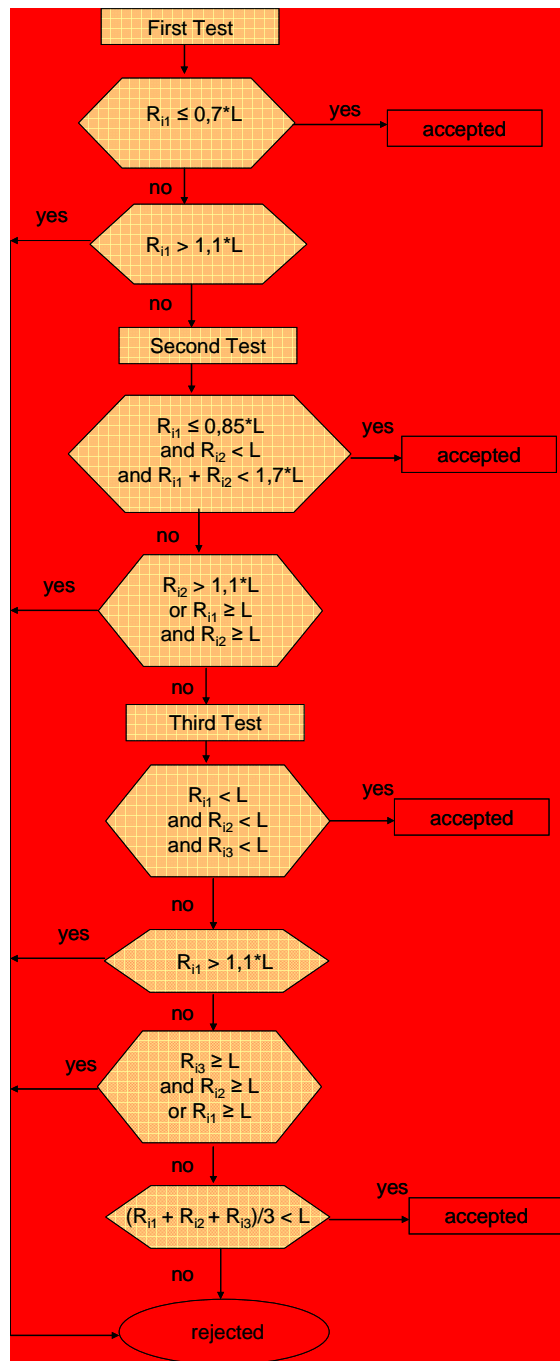


Figure 7-1: Flowchart for the **number** of **Ambient condition** Type I test

7.2. **Ambient condition test** Type I tests

7.2.1. Overview

7.2.1.1. **Ambient condition test** The Type I test consists of prescribed sequences of dynamometer preparation, fuelling, **soaking parking**, and operating conditions.

7.2.1.2. The test is designed to determine **gaseous, particulates emissions** ~~hydrocarbon, carbon monoxide, oxides of nitrogen, carbon dioxide mass emissions~~ emissions, and fuel consumption while simulating real world operation. The test consists of engine start-ups and ~~motorcycle~~ vehicle operation on a chassis dynamometer, through a specified driving cycle. A proportional part of the diluted exhaust emissions is collected continuously for subsequent analysis, using a constant volume (variable dilution) sampler (CVS).

Definition of gaseous pollutants and particulates?

Definition of new or alternative equipment?

7.2.1.3. Except in cases of component malfunction or failure, all emission control systems installed on or incorporated in a tested vehicle shall be functioning during all procedures.

7.2.1.4. Background concentrations are measured for all species for which emissions measurements are made. For exhaust testing, this requires sampling and analysis of the dilution air.

Measurement of background concentrations for particles?

6.2.4. Background particulate mass measurement

The particulate background level of the dilution air may be determined by passing filtered dilution air through the particulate filter. This shall be drawn from the same point as the particulate sample. One measurement may be performed prior to or after the test. Particulate mass measurements may be corrected by subtracting the background contribution from the dilution system. The permissible background contribution shall be ≤ 1 mg/km (or equivalent mass on the filter). If the background exceeds this level, the default figure of 1 mg/km (or equivalent mass on the filter) shall be employed. Where subtraction of the background contribution gives a negative result, the particulate mass result shall be considered to be zero.

6.2.5. Background particle number measurements

The subtraction of background particle numbers may be determined by sampling dilution air drawn from a point downstream of the particle and hydrocarbon filters into the particle number measurement system. Background correction of particle number measurements shall not be allowed for type approval, but may be used at the manufacturer's request for conformity of production and in service conformity where there are indications that tunnel contribution is significant.

Measurement of background concentrations for particles?

7.2.2. Dynamometer settings and verification

7.2.2.1. Test vehicle (motorcycle) preparation

ECE R 83-06: 3.4.1. The vehicle shall be approximately horizontal during the test so as to avoid any abnormal distribution of the fuel.

7.2.2.1.1. **If necessary**, the manufacturer shall provide additional fittings and adapters, as required to accommodate a fuel drain at the lowest point possible in the tank(s) as installed on the vehicle, and to provide for exhaust sample collection.

7.2.2.1.2. **The tyres shall be of a type specified as original equipment by the vehicle manufacturer. The tyre pressure may be increased by up to 50 per cent from the manufacturer's recommended setting. in the case of a two roller dynamometer. The actual pressure used shall be recorded in the test report.**

~~The tyre pressures shall be adjusted to the specifications of the manufacturer or to those at which the speed of the motorcycle during the road test and the motorcycle speed obtained on the chassis dynamometer are equal.~~

7.2.2.1.3. **The test vehicle shall be warmed up on the chassis dynamometer to the same condition as it was during the road test.**

7.2.2.2. Dynamometer preparation, if settings are derived from on-road coast down measurements. Before the test, the chassis dynamometer shall be appropriately warmed up to the stabilized frictional force F_f . The load on the chassis dynamometer F_E is, in view of its construction, composed of the total friction loss F_f which is the sum of the chassis dynamometer rotating frictional resistance, the tyre rolling resistance, the frictional resistance of the rotating parts in the driving system of the vehicle and the braking force of the power absorbing unit (pau) F_{pau} , as shown in the following equation:

$$F_E = F_f + F_{pau} \quad \text{Equation 7-1}$$

The target running resistance force F^* derived from paragraph 6.3 of Annex 7 shall be reproduced on the chassis dynamometer in accordance with the vehicle speed. Namely:

$$F_E(v_i) = F^*(v_i) \quad \text{Equation 7-2}$$

The total friction loss F_f on the chassis dynamometer shall be measured by the method in paragraph 7.2.2.2.1. or paragraph 7.2.2.2.2.

7.2.2.2.1. Motoring by chassis dynamometer

This method applies only to chassis dynamometers capable of driving a vehicle. The vehicle shall be driven by the chassis dynamometer steadily at the reference speed v_0 with the transmission engaged and the clutch disengaged. The total friction loss $F_f(v_0)$ at the reference speed v_0 is given by the chassis dynamometer force.

7.2.2.2.2. Coast down without absorption

The method of measuring the coast down time is the coast down method for the measurement of the total friction loss F_f . The vehicle coast down shall be performed on the chassis dynamometer by the procedure described in paragraph 5 of Annex 7 with zero chassis dynamometer absorption, and the coast down time Δt_i corresponding to the reference speed v_0 shall be measured. The measurement shall be carried out at least three times, and the mean coast down time $\overline{\Delta t}$ shall be calculated by the following equation:

$$\overline{\Delta t} = \frac{1}{n} \sum_{i=1}^n \Delta t_i \quad \text{Equation 7-3}$$

7.2.2.2.3. Total friction loss

The total friction loss $F_f(v_0)$ at the reference speed v_0 is calculated by the following equation:

$$F_f(v_0) = \frac{1}{3.6} (m_i + m_{r1}) \frac{2\Delta v}{\Delta t} \quad \text{Equation 7-4}$$

7.2.2.2.4. Calculation of power absorption unit force

The force $F_{pau}(v_0)$ to be absorbed by the chassis dynamometer at the reference speed v_0 is calculated by subtracting $F_f(v_0)$ from the target running resistance force $F^*(v_0)$ as shown in the following equation:

$$F_{pau}(v_0) = F^*(v_0) - F_f(v_0) \quad \text{Equation 7-5}$$

7.2.2.2.5. Chassis dynamometer setting

According to its type, the chassis dynamometer shall be set by one of the methods described in paragraphs 7.2.2.2.5.1. to 7.2.2.2.5.4. The chosen setting shall be applied to the pollutant emissions measurements as well as to the CO₂ emission measurements.

7.2.2.2.5.1. Chassis dynamometer with polygonal function

In the case of a chassis dynamometer with polygonal function, in which the absorption characteristics are determined by load values at several speed points, at least three specified speeds, including the reference speed, shall be chosen as the setting points. At each setting point, the chassis dynamometer shall be set to the value $F_{pau}(v_j)$ obtained in paragraph 7.2.2.2.4.

7.2.2.2.5.2. Chassis dynamometer with coefficient control

In the case of a chassis dynamometer with coefficient control, in which the absorption characteristics are determined by given coefficients of a polynomial function, the value of $F_{pau}(v_j)$ at each specified speed should be calculated by the procedure in paragraph 7.2.2.2.

Assuming the load characteristics to be:

$$F_{pau}(v) = a \times v^2 + b \times v + c \quad \text{Equation 7-6}$$

where:

the coefficients a, b and c shall be determined by the polynomial regression method.

The chassis dynamometer shall be set to the coefficients a, b and c obtained by the polynomial regression method.

7.2.2.2.5.3. Chassis dynamometer with F^* polygonal digital setter

In the case of a chassis dynamometer with a polygonal digital setter, where a central processor unit (CPU) is incorporated in the system, F^* is input directly, and Δt_i , F_f and F_{pau} are automatically measured and calculated to set the chassis dynamometer to the target running resistance force $F^* = f^* + f_{\text{r}}^* \times v^2$.

In this case, several points in succession are directly input digitally from the data set of F^*_j and v_j , the coast down is performed and the coast down time Δt_j is measured. After the coast down test has been repeated several times, F_{pau} is automatically calculated and set at vehicle speed intervals of 0.1 km/h, in the following sequence:

$$F^* + F_f = \frac{1}{3.6} (m_i + m_{r1}) \frac{2\Delta v}{\Delta t_i} \quad \text{Equation 7-7}$$

$$F_f = \frac{1}{3.6} (m_i + m_{r1}) \frac{2\Delta v}{\Delta t_i} - F^* \quad \text{Equation 7-8}$$

$$F_{pau} = F^* - F_f \quad \text{Equation 7-9}$$

7.2.2.2.5.4. Chassis dynamometer with f_0^* , f_2^* coefficient digital setter

In the case of a chassis dynamometer with a coefficient digital setter, where a CPU (central processor unit) is incorporated in the system, the target running resistance force $F^* = f_0^* + f_2^* \times v^2$ is automatically set on the chassis dynamometer.

In this case, the coefficients f_0^* and f_2^* are directly input digitally; the coast down is performed and the coast down time Δt_i is measured. F_{pau} is automatically calculated and set at vehicle speed intervals of 0.06 km/h, in the following sequence:

$$F^* + F_f = \frac{1}{3.6} (m_i + m_{r1}) \frac{2\Delta v}{\Delta t_i} \quad \text{Equation 7-10}$$

$$F_f = \frac{1}{3.6} (m_i + m_{r1}) \frac{2\Delta v}{\Delta t_i} - F^* \quad \text{Equation 7-11}$$

$$F_{pau} = F^* - F_f \quad \text{Equation 7-12}$$

7.2.2.2.6. Dynamometer settings verification

7.2.2.2.6.1. Verification test

Immediately after the initial setting, the coast down time Δt_E on the chassis dynamometer corresponding to the reference speed (v_0), shall be measured by the same procedure as in paragraph 5 of Annex 7. The measurement shall be carried out at least three times, and the mean coast down time Δt_E shall be calculated from the results. The set running resistance force at the reference speed, $F_E(v_0)$ on the chassis dynamometer is calculated by the following equation:

$$F_E(v_0) = \frac{1}{3.6} (m_i + m_{r1}) \frac{2\Delta v}{\Delta t_E} \quad \text{Equation 7-13}$$

7.2.2.2.6.2. Calculation of setting error

The setting error ε is calculated by the following equation:

$$\varepsilon = \frac{|F_E(v_0) - F^*(v_0)|}{F^*(v_0)} \times 100 \quad \text{Equation 7-14}$$

The chassis dynamometer shall be readjusted if the setting error does not satisfy the following criteria:

- $\varepsilon \leq 2$ per cent for $v_0 \geq 50$ km/h
- $\varepsilon \leq 3$ per cent for $30 \text{ km/h} \leq v_0 < 50 \text{ km/h}$
- $\varepsilon \leq 10$ per cent for $v_0 < 30 \text{ km/h}$

The procedure in paragraphs 7.2.2.2.6.1. to 7.2.2.2.6.2. shall be repeated until the setting error satisfies the criteria. The chassis dynamometer setting and the observed errors shall be recorded. The examples of the record forms are given in Annex 9.

7.2.2.3. Dynamometer preparation, if settings are derived from a running resistance table

What sub-group??

7.2.2.3.1. The specified speed for the chassis dynamometer

The running resistance on the chassis dynamometer shall be verified at the specified speed v . At least four specified speeds should be verified. The range of specified speed points (the interval between the maximum and minimum points) shall extend either side of the reference speed or the reference speed range, if there is more than one reference speed, by at least Δv , as defined in paragraph 4. of Annex 7. The specified speed points, including the reference speed point(s), shall be no greater than 20 km/h apart and the interval of specified speeds should be the same.

7.2.2.3.2. Verification of chassis dynamometer

7.2.2.3.2.1. Immediately after the initial setting, the coast down time on the chassis dynamometer corresponding to the specified speed shall be measured. The vehicle shall not be set up on the chassis dynamometer during the coast down time measurement. When the chassis dynamometer speed exceeds the maximum speed of the test cycle, the coast down time measurement shall start.

7.2.2.3.2.2. The measurement shall be carried out at least three times, and the mean coast down time Δt_E shall be calculated from the results.

7.2.2.3.2.3. The set running resistance force $F_E(v_j)$ at the specified speed on the chassis dynamometer is calculated by the following equation:

$$F_E(v_j) = \frac{1}{3.6} \times m_i \times \frac{2\Delta v}{\Delta t_E} \quad \text{Equation 7-15}$$

7.2.2.3.2.4. The setting error ε at the specified speed is calculated by the following equation:

$$\varepsilon = \frac{|F_E(v_j) - F_T|}{F_T} \times 100 \quad \text{Equation 7-16}$$

7.2.2.3.2.5. The chassis dynamometer shall be readjusted if the setting error does not satisfy the following criteria:

- $\varepsilon \leq 2$ per cent for $v \geq 50$ km/h
- $\varepsilon \leq 3$ per cent for $30 \text{ km/h} \leq v < 50 \text{ km/h}$
- $\varepsilon \leq 10$ per cent for $v < 30 \text{ km/h}$

7.2.2.3.2.6. The procedure described above shall be repeated until the setting error satisfies the criteria. The chassis dynamometer setting and the observed errors shall be recorded. An example of the record form is given in Annex 10.

6.5. Post-test procedures

6.5.1. Gas analyser check

Zero and span gas reading of the analysers used for continuous measurement shall be checked. The test shall be considered acceptable if the difference between the pre-test and post-test results is less than 2 per cent of the span gas value.

6.5.2. Particulate filter weighing

Reference filters shall be weighed within 8 hours of the test filter weighing. The contaminated particulate test filter shall be taken to the weighing chamber within one hour following the analyses of the exhaust gases. The test filter shall be conditioned for at least 2 hours and not more than 80 hours and then weighed.

6.5.3. Bag analysis

6.5.3.1. The exhaust gases contained in the bag shall be analysed as soon as possible and in any event not later than 20 minutes after the end of the test cycle.

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

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

6.5.3.4. The analysers' zero settings shall then be rechecked: if any reading differs by more than 2 per cent of the range from that set in paragraph 6.5.3.2. above, the procedure shall be repeated for that analyser.

6.5.3.5. The samples shall then be analysed.

6.5.3.6. After the analysis, zero and span points shall be rechecked using the same gases. If these rechecks are within ± 2 per cent of those in paragraph 6.5.3.3. above, the analysis shall be considered acceptable.

6.5.3.7. At all points in this paragraph, the flow-rates and pressures of the various gases shall be the same as those used during calibration of the analysers.

6.5.3.8. The figure adopted for the content of the gases in each of the pollutants measured shall be that read off after stabilisation of the measuring device. Hydrocarbon mass emissions of compression-ignition engines shall be calculated from the integrated

HFID reading, corrected for varying flow if necessary, as shown in paragraph 6.6.6. below.

7.2.3. Calibration of analysers
use R83, annex 4a, appendix 3

GASEOUS EMISSIONS MEASUREMENT EQUIPMENT

1. SPECIFICATION

1.1. System Overview

A continuously proportional sample of the diluted exhaust gases and the dilution air shall be collected for analysis.

Mass gaseous emissions shall be determined from the proportional sample concentrations and the total volume measured during the test. The sample concentrations shall be corrected to take account of the pollutant content of the ambient air.

1.2. Sampling System Requirements

1.2.1. The sample of dilute exhaust gases shall be taken upstream from the suction device but downstream from the conditioning devices (if any).

1.2.2. The flow rate shall not deviate from the average by more than ± 2 per cent.

1.2.3. The sampling rate shall not fall below 5 litres per minute and shall not exceed 0.2 per cent of the flow rate of the dilute exhaust gases. An equivalent limit shall apply to constant-mass sampling systems.

1.2.4. A sample of the dilution air shall be taken at a constant flow rate near the ambient air-inlet (after the filter if one is fitted).

1.2.5. The dilution air sample shall not be contaminated by exhaust gases from the mixing area.

1.2.6. The sampling rate for the dilution air shall be comparable to that used in the case of the dilute exhaust gases.

1.2.7. The materials used for the sampling operations shall be such as not to change the pollutant concentration.

1.2.8. Filters may be used in order to extract the solid particles from the sample.

1.2.9. The various valves used to direct the exhaust gases shall be of a quick-adjustment, quick-acting type.

1.2.10. Quick-fastening gas-tight connections may be used between the three-way valves and the sampling bags, the connections sealing themselves automatically on the bag side. Other systems may be used for conveying the samples to the analyser (three-way stop valves, for example).

1.2.11. Storage of the sample

The gas samples shall be collected in sampling bags of sufficient capacity not to impede the sample flow; the bag material shall be such as to affect neither the measurements themselves nor the chemical composition of the gas samples by more than ± 2 per cent after 20 minutes (for instance: laminated polyethylene/polyamide films, or fluorinated polyhydrocarbons).

1.2.12. Hydrocarbon Sampling System – Diesel Engines

1.2.12.1. The hydrocarbon sampling system shall consist of a heated sampling probe, line, filter and pump. The sampling probe shall be installed at the same distance from the exhaust gas inlet as the particulate sampling probe, in such a way that neither interferes with samples taken by the other. It shall have a minimum internal diameter of 4 mm.

1.2.12.2. All heated parts shall be maintained at a temperature of $463\text{ K } (190\text{ }^{\circ}\text{C}) \pm 10\text{ K}$ by the heating system.

1.2.12.3. The average concentration of the measured hydrocarbons shall be determined by integration.

1.2.12.4. The heated sampling line shall be fitted with a heated filter (F_H) 99 per cent efficient with particles $\geq 0.3\text{ }\mu\text{m}$, to extract any solid particles from the continuous flow of gas required for analysis.

1.2.12.5. The sampling system response time (from the probe to the analyser inlet) shall be no more than four seconds.

1.2.12.6. The HFID shall be used with a constant flow (heat exchanger) system to ensure a representative sample, unless compensation for varying CFV or CFO flow is made.

possibly continuous NO measurement provisions for determination of NO₂ from NO/NO_x ratio should be inserted here

1.3. Gas Analysis Requirements

Use only analyzers which are appropriate for testing at the given emission standard. The analyzers need to fulfill the following requirements (Text and Table added to reflect ideas of EPA §1065)

Table 1 of §1065.205—Recommended performance specifications for measurement instruments

Measurement Instrument	Measured quantity symbol	Complete System Rise time ($t_{0.90}$) and Fall time ($t_{0.10}$) ^a	Recording update frequency	Accuracy ^b	Repeatability ^b	Noise ^b
Batch gas analyzer	x	N/A	N/A	2.0 % of pt. or 2.0 % of meas.	1.0 % of pt. or 1.0 % of meas.	1.0 % of max.

^a Accuracy, repeatability, and noise are all determined with the same collected data, as described in §1065.305, and based on absolute values. "pt." refers to the overall flow-weighted mean value expected at the standard; "max." refers to the peak value expected at the standard over any test interval, not the maximum of the instrument's range; "meas" refers to the actual flow-weighted mean measured over any test interval.

1.3.1. Carbon monoxide (CO) and carbon dioxide (CO₂) analyses:

Analysers shall be of the non-dispersive infra-red (NDIR) absorption type.

1.3.2. Hydrocarbons (HC) analysis - spark-ignition engines:

The analyser shall be of the flame ionisation (FID) type calibrated with propane gas expressed equivalent to carbon atoms (C₁).

1.3.3. Hydrocarbons (HC) analysis - compression-ignition engines:

The analyser shall be of the flame ionisation type with detector, valves, pipework, etc., heated to 463 K (190 °C) ±10 K (HFID). It shall be calibrated with propane gas expressed equivalent to carbon atoms (C₁).

1.3.4. Nitrogen oxide (NO_x) analysis:

The analyser shall be either of the chemi-luminescent (CLA) or of the non-dispersive ultra-violet resonance absorption (NDUVR) type, both with NO_x-NO converters.

1.3.5. The analysers shall have a measuring range compatible with the accuracy required to measure the concentrations of the exhaust gas sample pollutants.

1.3.6. Measurement error shall not exceed ±2 per cent (intrinsic error of analyser) disregarding the true value for the calibration gases.

1.3.7. For concentrations of less than 100 ppm, the measurement error shall not exceed ±2 ppm.

1.3.8. The ambient air sample shall be measured on the same analyser with an appropriate range.

1.3.9. No gas drying device shall be used before the analysers unless shown to have no effect on the pollutant content of the gas stream.

1.4. Recommended System Descriptions

Figure 10 is a schematic drawing of the system for gaseous emissions sampling.

1.4.8. Bags (B), for collecting samples of the diluted exhaust gas and of the dilution air during the test;

1.4.9. A sampling critical-flow venturi (SV), to take proportional samples of the diluted exhaust gas at sampling probe S₂ A(CFV-CVS only);

1.4.10. A scrubber (PS), in the sampling line (CFV-CVS only);

1.4.11. Components for hydrocarbon sampling using HFID:

F_h is a heated filter,

S₃ is a sampling point close to the mixing chamber,

V_h is a heated multi-way valve,

Q is a quick connector to allow the ambient air sample BA to be analysed on the HFID,

FID is a heated flame ionisation analyser,

R and I are a means of integrating and recording the instantaneous hydrocarbon concentrations,

L_h is a heated sample line.

2. CALIBRATION PROCEDURES

2.1. Analyser Calibration Procedure

2.1.1. Each analyser shall be calibrated as often as necessary and in any case in the month before type approval testing and at least once every six months for verifying conformity of production.

2.1.2. Each normally used operating range shall be calibrated by the following procedure:

2.1.2.1. The analyser calibration curve is established by at least five calibration points spaced as uniformly as possible. The nominal concentration of the calibration gas of the highest concentration shall be not less than 80 per cent of the full scale.

2.1.2.2. The calibration gas concentration required may be obtained by means of a gas divider, diluting with purified N₂ or with purified synthetic air. The accuracy of the mixing device shall be such that the concentrations of the diluted calibration gases may be determined to within ± 2 per cent.

2.1.2.3. The calibration curve is calculated by the least squares method. If the resulting polynomial degree is greater than 3, the number of calibration points shall be at least equal to this polynomial degree plus 2.

2.1.2.4. The calibration curve shall not differ by more than ± 2 per cent from the nominal value of each calibration gas.

2.1.3. Trace of the calibration curve

From the trace of the calibration curve and the calibration points, it is possible to verify that the calibration has been carried out correctly. The different characteristic parameters of the analyser shall be indicated, particularly:

- The scale;
- The sensitivity;
- The zero point;
- The date of carrying out the calibration.

2.1.4. If it can be shown to the satisfaction of the technical service that alternative technology (e.g. computer, electronically controlled range switch, etc.) can give equivalent accuracy, then these alternatives may be used.

2.2. Analyser Verification Procedure

2.2.1. Each normally used operating range shall be checked prior to each analysis in accordance with the following:

2.2.2. The calibration shall be checked by use of a zero gas and by use of a span gas that has a nominal value within 80-95 per cent of the supposed value to be analysed.

2.2.3. If, for the two points considered, the value found does not differ by more than ± 5 per cent of the full scale from the theoretical value, the adjustment parameters may be modified. Should this not be the case, a new calibration curve shall be established in accordance with paragraph 1. of this appendix.

2.2.4. After testing, zero gas and the same span gas are used for re-checking. The analysis is considered acceptable if the difference between the two measuring results is less than 2 per cent.

2.3. FID Hydrocarbon Response Check Procedure

2.3.1. Detector response optimisation

The FID shall be adjusted, as specified by the instrument manufacturer. Propane in air should be used, to optimise the response, on the most common operating range.

2.3.2. Calibration of the HC analyser

The analyser should be calibrated using propane in air and purified synthetic air (see paragraph 3 of this appendix).

Establish a calibration curve as described in paragraph 2.1. of this appendix.

2.3.3. Response factors of different hydrocarbons and recommended limits

The response factor (Rf), for a particular hydrocarbon species is the ratio of the FID C_1 reading to the gas cylinder concentration, expressed as ppm C_1 .

The concentration of the test gas shall be at a level to give a response of approximately 80 per cent of full-scale deflection, for the operating range. The concentration shall be known, to an accuracy of ± 2 per cent in reference to a gravimetric standard expressed in volume. In addition, the gas cylinder shall be pre-conditioned for 24 hours at a temperature between 293 K and 303 K (20 and 30 °C).

Response factors should be determined when introducing an analyser into service and thereafter at major service intervals. The test gases to be used and the recommended response factors are:

Methane and purified air: $1.00 < R_f < 1.15$

~~or $1.00 < R_f < 1.05$ for NG/biomethane fuelled vehicles~~

argumentation: FID cannot meet this requirement if other response factors need to be within tolerance, too.

solutions: a) calibrate with methane, when testing CNG vehicles
or b) apply the CH₄ response factor

Propylene and purified air: $0.90 < R_f < 1.00$

Toluene and purified air: $0.90 < R_f < 1.00$

These are relative to a response factor (R_f) of 1.00 for propane and purified air.

2.3.4. ~~Oxygen interference check and recommended limits~~

~~The response factor shall be determined as described in paragraph 2.3.3. above. The test gas to be used and recommended response factor range is:~~

~~Propane and nitrogen: $0.95 < R_f < 1.05$~~

In practice neither with bag analysis nor with continuous HC sampling oxygen contents below 15% Vol. will be encountered

2.4. NO_x Converter Efficiency Test Procedure

The efficiency of the converter used for the conversion of NO₂ into NO is tested as follows:

Using the test set up as shown in Figure 11 and the procedure described below, the efficiency of converters can be tested by means of an ozonator.

2.4.1. Calibrate the analyzer in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which shall amount to about 80 per cent of the operating range and the NO₂ concentration of the gas mixture shall be less than 5 per cent of the NO concentration). The NO_x analyser

shall be in the NO mode so that the span gas does not pass through the converter. Record the indicated concentration.

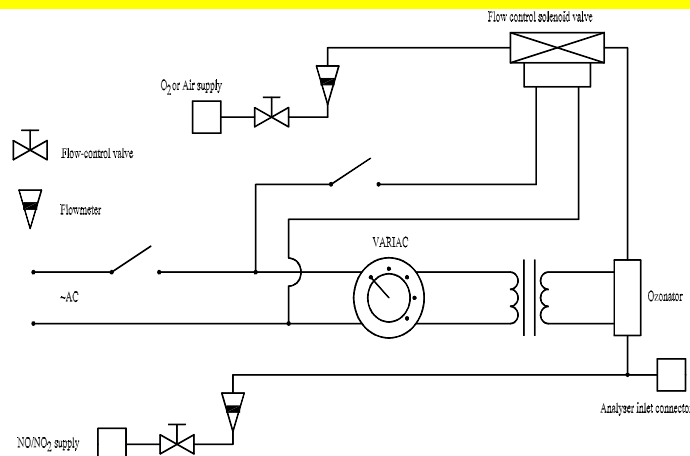
2.4.2. Via a T-fitting, oxygen or synthetic air is added continuously to the span gas flow until the concentration indicated is about 10 per cent less than the indicated calibration concentration given in paragraph 2.4.1. above. Record the indicated concentration (C). The ozonator is kept deactivated throughout this process.

2.4.3. The ozonator is now activated to generate enough ozone to bring the NO concentration down to 20 per cent (minimum 10 per cent) of the calibration concentration given in paragraph 2.4.1. above. Record the indicated concentration (d).

2.4.4. The NO_x analyser is then switched to the NO_x mode, which means that the gas mixture (consisting of NO, NO₂, O₂ and N₂) now passes through the converter. Record the indicated concentration (a).

2.4.5. The ozonator is now deactivated. The mixture of gases described in paragraph 2.4.2. above passes through the converter into the detector. Record the indicated concentration (b).

Figure 11: NO_x Converter Efficiency Test Configuration



2.4.6. With the ozonator deactivated, the flow of oxygen or synthetic air is also shut off. The NO₂ reading of the analyser shall then be no more than 5 per cent above the figure given in paragraph 2.4.1. above.

2.4.7. The efficiency of the NO_x converter is calculated as follows:

$$\text{Efficiency (per cent)} = \left(1 + \frac{a-b}{c-d} \right) \cdot 100$$

2.4.8. The efficiency of the converter shall not be less than 95 per cent. (EPA §86 requirement was 90%)

2.4.9. The efficiency of the converter shall be tested at least once a week. (EPA §1065.341 requires less frequent check, 35days)

3. REFERENCE GASES

3.1. Pure gases

The following pure gases shall be available, if necessary, for calibration and operation:

Purified nitrogen: (purity: ≤1 ppm C, ≤1 ppm CO, ≤400 ppm CO₂, ≤0.1 ppm NO);

Purified synthetic air: (purity: ≤1 ppm C, ≤1 ppm CO, ≤400 ppm CO₂, ≤0.1 ppm NO); oxygen content between 18 and 21 per cent volume;

Purified oxygen: (purity > 99.5 per cent vol. O₂);

Purified hydrogen (and mixture containing helium): (purity ≤1 ppm C, ≤400 ppm CO₂);

Carbon monoxide: (minimum purity 99.5 per cent);

Propane: (minimum purity 99.5 per cent).

3.2. Calibration and span gases

Mixtures of gases having the following chemical compositions shall be available:

- (a) C₃H₈ and purified synthetic air (see paragraph 3.1. above);
- (b) CO and purified nitrogen;
- (c) CO₂ and purified nitrogen.
- (d) CH₄ and purified synthetic air (new text)

NO and purified nitrogen (the amount of NO₂ contained in this calibration gas shall not exceed 5 per cent of the NO content).

The true concentration of a calibration gas shall be within ±21 per cent of the stated figure.

additional pollutants will need higher tolerances (strict requirement taken over from §1065)

conflict to §1065 in terms of reference gases

argumentation: gas suppliers find it very hard to supply gases at these tight limits,
gases become very expensive
pure gases that clean are only needed if BMD technique is used, otherwise less strict
Japanese/European requirements are sufficient

- 7.2.3.1. ~~The quantity of gas at the indicated pressure compatible with the correct functioning of the equipment shall be injected into the analyser with the aid of the flow metre and the pressure reducing valve mounted on each gas cylinder. The apparatus shall be adjusted to indicate as a stabilized value the value inserted on the standard gas cylinder. Starting from the setting obtained with the gas cylinder of greatest capacity, a curve shall be drawn of the deviations of the apparatus according to the content of the various standard cylinders used. The flame ionisation analyser shall be recalibrated periodically, at intervals of not more than one month, using air/propane or air/hexane mixtures with nominal hydrocarbon concentrations equal to 50 per cent and 90 per cent of full scale.~~
- 7.2.3.2. ~~Non dispersive infrared absorption analysers shall be checked at the same intervals using nitrogen/CO and nitrogen/CO₂ mixtures in nominal concentrations equal to 10, 40, 60, 85 and 90 per cent of full scale.~~
- 7.2.3.3. ~~To calibrate the NO_x chemiluminescence analyser, nitrogen/nitrogen oxide (NO) mixtures with nominal concentrations equal to 50 per cent and 90 per cent of full scale shall be used. The calibration of all three types of analysers shall be checked before each series of tests, using mixtures of the gases, which are measured in a concentration equal to 80 per cent of full scale. A dilution device can be applied for diluting a 100 per cent calibration gas to required concentration.~~
- 7.2.4. Test vehicle (~~motoreycle~~) preconditioning
- 7.2.4.1. The test vehicle shall be moved to the test area and the following operations performed:
- The fuel tank(s) shall be drained through the provided fuel tank(s) drain(s) and charged with the test fuel as specified in paragraph 6.4. ~~to half the tank(s) capacity.~~
 - The test vehicle shall be placed, either by being driven or pushed, on a dynamometer ~~without operating engine~~ and operated through the cycles as specified in paragraph 6.5.4. The vehicle need not be cold, and may be used to set dynamometer power.
- 7.2.4.2. ~~Practice runs over the prescribed driving schedule may be performed at test points, provided an emission sample is not taken, for the purpose of finding the minimum throttle action to maintain the proper speed time relationship, or to permit sampling system adjustments.~~

6.2.2. Preliminary testing cycles

Preliminary testing cycles should be carried out if necessary to determine how best to actuate the accelerator and brake controls so as to achieve a cycle approximating to the theoretical cycle within the prescribed limits under which the cycle is carried out.

~~7.2.4.3. Within 5 minutes of completion of preconditioning, the test vehicle shall be removed from the dynamometer and may be driven or pushed to the soak area to be parked. The vehicle shall be stored for not less than 6 hours and not more than 36 hours prior to the cold start Type I test or until the engine oil temperature T^{Θ} or the coolant temperature T^C or the sparkplug seat/gasket temperature T^P (only for air cooled engine) equals the air temperature of the soak area.~~

ECE R 83-06 preconditioning: 6.3.1. For the purpose of measuring particulates, at most 36 hours and at least 6 hours before testing, the Part Two cycle described in paragraph 6.1. of this annex shall be used for vehicle pre-conditioning. Three consecutive cycles shall be driven. The dynamometer setting shall be indicated as in paragraph 6.2.1. above.

At the request of the manufacturer, vehicles fitted with indirect injection positive-ignition engines may be preconditioned with one Part One and two Part Two driving cycles.

In a test facility in which there may be possible contamination of a low particulate emitting vehicle test with residue from a previous test on a high particulate emitting vehicle, it is recommended, for the purpose of sampling equipment pre-conditioning, that a 120 km/h steady state drive cycle of 20 minutes duration followed by three consecutive Part Two cycles be driven by a low particulate emitting vehicle.

After this preconditioning, and before testing, vehicles shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20 °C and 30 °C). This conditioning shall be carried out for at least six hours and continue until the engine oil temperature and coolant, if any, are within ± 2 K of the temperature of the room.

EPA recommendation: at least 12 hours and maximum 36 hours.

At the request of the manufacturer, forced cooling down could be used.

If the manufacturer so requests, the test shall be carried out not later than 30 hours after the vehicle has been run at its normal temperature.

6.3.3. For positive-ignition engines fuelled with LPG or NG/biomethane or so equipped that they can be fuelled with either petrol or LPG or NG/biomethane, between the tests on the first gaseous reference fuel and the second gaseous reference fuel, the vehicle shall be preconditioned before the test on the second reference fuel. This preconditioning is done on the second reference fuel by driving a preconditioning cycle consisting of one Part One (urban part) and two times Part Two (extra-urban part) of the test cycle described in Appendix 1 to this annex. On the manufacturer's request and with the agreement of the technical service this

preconditioning may be extended. The dynamometer setting shall be the one indicated in paragraph

7.2.5. Emissions tests

6.4. Test procedure: ECE R 83-06

6.4.1. Starting-up the engine

6.4.1.1. The engine shall be started up by means of the devices provided for this purpose according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles.

6.4.1.2. The first cycle starts on the initiation of the engine start-up procedure.

6.4.1.3. In cases where LPG or **NG/biomethane** is used as a fuel it is permissible that the engine is started on petrol and switched to LPG or **NG/biomethane** after a predetermined period of time which cannot be changed by the driver.

6.4.2. Idling

6.4.2.1. Manual-shift or semi-automatic gearbox, see Tables 1 and 2.

6.4.2.2. Automatic-shift gearbox

After initial engagement the selector shall not be operated at any time during the test except in the case specified in paragraph 6.4.3.3. below or if the selector can actuate the overdrive, if any.

6.4.3. Accelerations

6.4.3.1. Accelerations shall be so performed that the rate of acceleration is as constant as possible throughout the operation.

6.4.3.2. If an acceleration cannot be carried out in the prescribed time, the extra time required shall be deducted from the time allowed for changing gear, if possible, but otherwise from the subsequent steady-speed period.

6.4.3.3. Automatic-shift gearboxes

If acceleration cannot be carried out in the prescribed time, the gear selector shall operate in accordance with requirements for manual-shift gearboxes.

6.4.4. Decelerations

6.4.4.1. All decelerations of the elementary urban cycle (Part One) shall be effected by removing the foot completely from the accelerator with the clutch remaining engaged. The clutch shall be disengaged, without use of the gear lever, at the higher

of the following speeds: 10 km/h or the speed corresponding to the engine idle speed.

All decelerations of the extra-urban cycle (Part Two) shall be effected by removing the foot completely from the accelerator, the clutch remaining engaged. The clutch shall be disengaged, without use of the gear lever, at a speed of 50 km/h for the last deceleration.

6.4.4.2. If the period of deceleration is longer than that prescribed for the corresponding phase, the vehicle's brakes shall be used to enable compliance with the timing of the cycle.

6.4.4.3. If the period of deceleration is shorter than that prescribed for the corresponding phase, the timing of the theoretical cycle shall be restored by constant speed or an idling period merging into the following operation.

6.4.4.4. At the end of the deceleration period (halt of the vehicle on the rollers) of the elementary urban cycle (Part One), the gears shall be placed in neutral and the clutch engaged.

6.4.5. Steady speeds

6.4.5.1. "Pumping" or the closing of the throttle shall be avoided when passing from acceleration to the following steady speed.

6.4.5.2. Periods of constant speed shall be achieved by keeping the accelerator position fixed.

6.4.6. Sampling

Sampling shall begin (BS) before or at the initiation of the engine start up procedure and end on conclusion of the final idling period in the extra-urban cycle (Part Two, end of sampling (ES)) or, in the case of test Type VI, on conclusion of the final idling period of the last elementary urban cycle (Part One).

6.4.7. During the test the speed is recorded against time or collected by the data-acquisition system so that the correctness of the cycles performed can be assessed.

6.4.8. Particles shall be measured continuously in the particle sampling system. The average concentrations shall be determined by integrating the analyser signals over the test cycle.

7.2.5.1. Engine starting and restarting

7.2.5.1.1. ~~The engine shall be started according to the manufacturer's recommended starting~~ (a)

Otto-cycle vehicles. Paragraph (a)

of this section applies to Otto-cycle vehicle procedures. ~~The test cycle run shall begin when the engine starts.~~

(1) The engine shall be started according to the manufacturer's recommended starting procedures in the owner's manual. The initial 20-second idle period shall begin when the engine starts.

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(2) *Choke operation:* (i) Vehicles equipped with automatic chokes shall be operated according to the manufacturer's operating instructions in the owner's manual, including choke setting and "kick-down" from cold fast idle.

(ii) Vehicles equipped with manual chokes shall be operated according to the manufacturer's operating instructions in the owner's manual.

(3) The transmission shall be placed in gear 15 seconds after the engine is started. If necessary, braking may be employed to keep the drive wheels from turning.

(4) The operator may use the choke, accelerator pedal, etc., where necessary to keep the engine running.

(5) If the manufacturer's operating instructions in the owner's manual do not specify a warm engine starting procedure, the engine (automatic and manual-choke engines) shall be started by depressing the accelerator pedal about half way and cranking the engine until it starts.

(b) *Diesel vehicles.* The engine shall be started according to the manufacturers recommended starting procedures in the owners manual. The initial 20-second idle period shall begin when the engine starts. The transmission shall be placed in gear 15 seconds after the engine is started. If necessary, braking may be employed to keep the drive wheels from turning.

(c) If the vehicle does not start after the manufacturer's recommended cranking time (or 10 continuous seconds in the absence of a manufacturer's recommendation), cranking shall cease for the period recommended by the manufacturer (or 10 seconds in the absence of a manufacturer's recommendation). This may be repeated for up to three start attempts. If the vehicle does not start after three attempts, the reason for failure to start shall be determined. The gas flow

measuring device on the constant volume sampler (usually a revolution counter) or CFV (and the hydrocarbon integrator and particulate sampling system when testing petroleum-fueled diesel vehicles and the particulate sampling system when testing methanol-fueled diesel vehicles, see § 86.137) shall be turned off and the sampler selector valves, including the methanol sampler, placed in the "standby" position during this diagnostic period. In addition, either the CVS should be turned off, or the exhaust tube disconnected from the tailpipe during the diagnostic period. If failure to start is an operational error, the vehicle shall be rescheduled for testing from a cold start.

(d) If the engine "false starts" the operator shall repeat the recommended starting procedure (such as resetting the choke, etc.).

(e) *Stalling.* (1) If the engine stalls during an idle period, the engine shall be restarted immediately and the test continued. If the engine cannot be started soon enough to allow the vehicle to follow the next acceleration as prescribed, the driving schedule indicator shall be stopped. When the vehicle restarts, the driving schedule indicator shall be reactivated.

(2) If the engine stalls during some operating mode other than idle, the driving schedule indicator shall be stopped, the vehicle shall then be restarted and accelerated to the speed required at that point in the driving schedule and the test continued. During acceleration to this point, shifting shall be performed in accordance with § 86.128.

(3) If the vehicle will not restart within one minute, the test shall be voided, the vehicle removed from the dynamometer, corrective action taken, and the vehicle rescheduled for test. The reason for the malfunction (if determined) and the corrective action taken shall be reported to the Administrator.

~~7.2.5.1.2. Test vehicles equipped with automatic chokes shall be operated according to the instructions in the manufacturer's operating instructions or owner's manual including choke setting and "kick down" from cold fast idle. The transmission shall be placed in gear 15 seconds after the engine is started. If necessary, braking may be employed to keep the drive wheels from turning.~~

~~7.2.5.1.3. Test vehicles equipped with manual chokes shall be operated according to the manufacturer's operating instructions or owner's manual. Where times are provided in the instructions, the point for operation may be specified, within 15 seconds of the recommended time.~~

~~7.2.5.1.4. The operator may use the choke, throttle etc. where necessary to keep the engine running.~~

~~7.2.5.1.5. If the manufacturer's operating instructions or owner's manual do not specify a warm engine starting procedure, the engine (automatic and manual choke engines) shall be started by opening the throttle about half way and cranking the engine until it starts.~~

~~7.2.5.1.6. If, during the cold start, the test vehicle does not start after 10 seconds of cranking, or ten cycles of the manual starting mechanism, cranking shall cease and the reason for failure to start determined. The revolution counter on the constant volume sampler shall be turned off and the sample solenoid valves placed in the "standby" position during this diagnostic period. In addition, either the CVS blower shall be turned off or the exhaust tube disconnected from the tailpipe during the diagnostic period.~~

~~7.2.5.1.7. If failure to start is an operational error, the test vehicle shall be rescheduled for testing from a cold start. If failure to start is caused by vehicle malfunction, corrective action (following the unscheduled maintenance provisions) of less than 30 minutes duration may be taken and the test continued. The sampling system shall be reactivated at the same time cranking is started. When the engine starts, the driving schedule timing sequence shall begin. If failure to start is caused by vehicle malfunction and the vehicle cannot be started, the test shall be voided, the vehicle removed from the dynamometer, corrective action taken (following the unscheduled maintenance provisions), and the vehicle rescheduled for test. The reason for the malfunction (if determined) and the corrective action taken shall be reported.~~

~~7.2.5.1.8. If the test vehicle does not start during the hot start after ten seconds of cranking, or ten cycles of the manual starting mechanism, cranking shall cease, the test shall be voided, the vehicle removed from the dynamometer, corrective action taken and the vehicle rescheduled for test. The reason for the malfunction (if determined) and the corrective action taken shall be reported.~~

~~7.2.5.1.9. If the engine "false starts", the operator shall repeat the recommended starting procedure (such as resetting the choke, etc.)~~

~~7.2.5.2. Stalling~~

~~7.2.5.2.1. If the engine stalls during an idle period, the engine shall be restarted immediately and the test continued. If the engine cannot be started soon enough to allow the vehicle to follow the next acceleration as prescribed, the driving schedule indicator shall be stopped. When the vehicle restarts, the driving schedule indicator shall be reactivated.~~

~~7.2.5.2.2. If the engine stalls during some operating mode other than idle, the driving schedule indicator shall be stopped, the test vehicle shall then be restarted and accelerated to the speed required at that point in the driving schedule and the test continued. During acceleration to this point, shifting shall be performed in accordance with paragraph 6.5.5.~~

~~7.2.5.2.3. If the test vehicle will not restart within one minute, the test shall be voided, the vehicle removed from the dynamometer, corrective action taken, and the vehicle rescheduled for test. The reason for the malfunction (if determined) and the corrective action taken shall be reported.~~

~~7.2.6. Drive instructions~~

~~7.2.6.1. The test vehicle shall be driven with minimum throttle movement to maintain the desired speed. No simultaneous use of brake and throttle shall be permitted.~~

~~7.2.6.2. If the test vehicle cannot accelerate at the specified rate, it shall be operated with the throttle fully opened until the roller speed reaches the value prescribed for that time in the driving schedule.~~

ECE R 83-06: 6.2.6. Particulate mass filter selection

A single particulate filter without back-up shall be employed for both urban and extra-urban phases of the cycle combined.

Twin particulate filters, one for the urban, one for the extra-urban phase, may be used without back-up filters, only where the pressure-drop increase across the sample filter between the beginning and the end of the emissions test is otherwise expected to exceed 25 kPa.

6.2.7. Particulate mass filter preparation

6.2.7.1. Particulate mass sampling filters shall be conditioned (as regards temperature and humidity) in an open dish that has been protected against dust ingress for at least 2 and for not more than 80 hours before the test in an air-conditioned chamber. After this conditioning, the uncontaminated filters will be weighed and stored until they are used. If the filters are not used within one hour of their removal from the weighing chamber, they shall be re-weighed.

6.2.7.2. The one hour limit may be replaced by an eight-hour limit if one or both of the following conditions are met:

6.2.7.2.1. A stabilized filter is placed and kept in a sealed filter holder assembly with the ends plugged, or;

6.2.7.2.2. A stabilized filter is placed in a sealed filter holder assembly which is then immediately placed in a sample line through which there is no flow.

§ 86.139–90 Particulate filter handling and weighing.

(a) At least 8 hours, but not more than 56 hours before the test, place each filter in an open, but protected, petri dish and place in the weighing chamber which meets the humidity and temperature specifications of § 86.112.

(b) At the end of the 8 to 56 hour stabilization period, weigh the filter on a

balance having a precision of one microgram. Record this weight. This reading is the tare weight.

(c) The filter shall then be stored in a covered petri dish which shall remain in the weighing chamber until needed for testing.

(d)(1) If the filter is not used within one hour of its removal from the weighing chamber, it shall be reweighed.

(2) The one hour limit may be replaced by an eight-hour limit if one or both of the following conditions are met:

(i) A stabilized filter is placed and kept in a sealed filter holder assembly with the ends plugged, or

(ii) A stabilized filter is placed in a sealed filter holder assembly, which is then immediately placed in a sample line through which there is no flow.

JAPAN:

2-12-2-1 Before collection of PM and PMb

(1) The collecting filter shall be soaked in the weighing room for at least 24 hours.

(2) After completion of the soaking according to Item (1), the weight of the collecting filter shall be measured in the weighing room.

Then, the collecting filter for which the measurement of the weight has been conducted shall be used immediately for collecting PM and PMb.

6.2.7.3. The particulate sampling system shall be started and prepared for sampling.

6.2.8. Particle number measurement preparation

6.2.8.1. The particle specific dilution system and measurement equipment shall be started and readied for sampling.

6.2.8.2. Prior to the test(s) the correct function of the particle counter and volatile particle remover elements of the particle sampling system shall be confirmed according to Appendix 5, paragraphs 2.3.1. and 2.3.3.:

The particle counter response shall be tested at near zero prior to each test and, on a daily basis, at high particle concentrations using ambient air.

When the inlet is equipped with a HEPA filter, it shall be demonstrated that the entire particle sampling system is free from any leaks.

6.2.9. Checking the gas analysers

The emissions analysers for the gases shall be set at zero and spanned. The sample bags shall be evacuated.

7.2.7. Dynamometer test runs

7.2.7.1. The complete dynamometer test consists of consecutive parts as described in paragraph 6.5.4.

7.2.7.2. The following steps shall be taken for each test:

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(1) Place drive wheels of vehicle on dynamometer without starting engine.

(2) Open the vehicle engine compartment

Cover (fully opened) and position the cooling

fan. At the request of the manufacturer, if a proportional speed cooling fan is used, the engine compartment cover shall be closed.

(3) For all vehicles, with the sample selector valves in the "standby" position, connect evacuated sample collection bags to the dilute exhaust and dilution air sample collection systems.

(4) For methanol-fueled vehicles,

with the sample selector valves in the

"standby" position, insert fresh sample

collection impingers into the methanol

sample collection system, the formaldehyde

sample collection system and

fresh impingers (or capsules for formaldehyde)

into the dilution air sample

collection systems for methanol and

formaldehyde (may be omitted for 1990

through 1994 model years).

Additional Pollutants sampling should be included

Sampling and analysing equipment shall be set to operational mode.

(5) Start the CVS (if not already on), the sample pumps (except the diesel particulate sample pump, if applicable), the temperature recorder, the vehicle cooling fan, and the heated hydrocarbon analysis recorder (diesels only). (The heat exchanger of the constant volume sampler, if used, petroleum-fueled diesel hydrocarbon analyzer continuous sample line and filter, methanol-fueled vehicle hydrocarbon, methanol and formaldehyde sample lines, if applicable, should be preheated to their respective operating temperatures before the test begins.)

(6) Adjust the sample flow rates to the desired flow rate and set the gas flow measuring devices to zero.

(i) For gaseous bag samples (except hydrocarbon samples), the minimum flow rate is 0.17 cfm (0.08 l/sec).

(ii) For hydrocarbon samples, the minimum FID (or HFID in the case of diesel and methanol-fueled Otto cycle vehicles) flow rate is 0.066 cfm (0.031 l/sec).

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(iii) For methanol samples, the minimum flow rate is 0.14 cfm (0.067 l/sec).

(iv) For formaldehyde samples, the minimum flow rate is 0.036 cfm (0.017 l/s) with capsule collector and 0.14 cfm (0.067 l/s) with impinger.

NOTE: CFV sample flow rate is fixed by the venturi design.

(7) Attach the exhaust tube to the vehicle tailpipe(s).

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(8) Carefully install a particulate sample filter into each of the filter holders for diesel vehicle tests. The filters must be handled only with forceps or tongs. Rough or abrasive filter handling will result in erroneous weight determination.

(9) Start the gas flow measuring device, position the sample selector valves to direct the sample flow into the "transient" exhaust sample bag, the "transient" methanol exhaust sample, the "transient" formaldehyde exhaust sample, the "transient" dilution air sample bag, the "transient" methanol dilution air sample and the "transient" formaldehyde dilution air sample (turn on the petroleum-fueled diesel hydrocarbon analyzer system integrator, mark the recorder chart, start particulate sample pump No. 1, and record both gas meter or flow measurement instrument readings, if applicable), turn the key on, and start cranking the engine.

- ~~(a) Place drive wheel of vehicle on dynamometer without starting engine.~~
- ~~(b) Activate vehicle cooling fan.~~
- ~~(c) For all test vehicles, with the sample selector valves in the "standby" position connect evacuated sample collection bags to the dilute exhaust and dilution air sample collection systems.~~
- ~~(d) Start the CVS (if not already on), the sample pumps and the temperature recorder. (The heat exchanger of the constant volume sampler, if used, and sample lines should be preheated to their respective operating temperatures before the test begins.)~~
- ~~(e) Adjust the sample flow rates to the desired flow rate and set the gas flow measuring devices to zero.~~
 - ~~For gaseous bag samples select sufficient bag fill flow rates to allow satisfactory bag measurement(except hydrocarbon samples), the minimum flow rate is 0.08 litre/second.~~
 - ~~For hydrocarbon samples, the minimum flame ionization detection (FID) (or heated flame ionization detection (HFID) in the case of methanol-fuelled vehicles) flow rate is 0.031 litre/second.~~
- ~~(f) Attach the flexible exhaust tube to the vehicle tailpipe(s).~~
- ~~(g) Start the gas flow measuring device, position the sample selector valves to direct the sample flow into the "transient" exhaust sample bag, the "transient" dilution air sample bag, turn the key on, and start cranking the engine.~~
- ~~(h) Fifteen seconds after the engine starts, place the transmission in gear.~~
- ~~(i) Twenty seconds after the engine starts, begin the initial vehicle acceleration of the driving schedule.~~
- (j) Operate the vehicle according to the driving cycles specified in paragraph 6.5.4.

Depends on WLTP cycle:

- (k) At the end of the part 1 or part 1 reduced speed in cold condition, simultaneously switch the sample flows from the first bags and samples to the second bags and samples, switch off gas flow measuring device No. 1 and start gas flow measuring device No. 2.
- (l) In case of class 3 vehicles, at the end of part 2 simultaneously switch the sample flows from the second bags and samples to the third bags and samples, switch off gas flow measuring device No. 2 and, start gas flow measuring device No. 3.
- (m) Before starting a new part, record the measured roll or shaft revolutions and reset the counter or switch to a second counter. As soon as possible, transfer the exhaust and dilution air samples to the analytical system and process the samples according to paragraph 8.1.1., obtaining a stabilised reading of the exhaust bag sample on all analysers within 20 minutes of the end of the sample collection phase of the test.
- (n) Turn the engine off 2 seconds after the end of the last part of the test.
- (o) Immediately after the end of the sample period, turn off the cooling fan.
- (p) Turn off the constant volume sampler (CVS) or critical flow venturi (CFV) or disconnect the exhaust tube from the tailpipe(s) of the vehicle.
- (q) Disconnect the exhaust tube from the vehicle tailpipe(s) and remove the vehicle from dynamometer.
- (r) ~~For comparison and analysis reasons besides the bag results also second by second data of the emissions (diluted gas) have to be monitored. For the same reasons also the temperatures of the cooling water and the crankcase oil as well as the catalyst temperature shall be recorded.~~

ECE R 83-06: 6.5. Post-test procedures

6.5.1. Gas analyser check

Zero and span gas reading of the analysers used for continuous measurement shall be checked. The test shall be considered acceptable if the difference between the pre-test and post-test results is less than 2 per cent of the span gas value.

6.5.2. Particulate filter weighing

Reference filters shall be weighed within 8 hours of the test filter weighing. The contaminated particulate test filter shall be taken to the weighing chamber within one hour following the analyses of the exhaust gases. The test filter shall be conditioned for at least 2 hours and not more than 80 hours and then weighed.

EPA:

- (e) After the test, and after the sample filter is returned to the weighing room, condition it for at least 1 hour but not more than 56 hours. Then weigh a second time. This latter reading is the gross weight of the filter. Record this weight.
- (f) The net weight (P_0) is the gross

weight minus the tare weight.

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NOTE: Should the sample on the filter contact the petri dish or any other surface, the test is void and must be rerun

JAPAN:

2–12–2–2 After collection of PM and PMb

(1) The collecting filter that has been used for collecting PM and PMb shall be soaked in the weighing room for 1 to 80 hours immediately after the collection of PM and PMb.

(2) After completion of the soaking according to Item (1), the weight of the collecting filter shall be measured in the weighing room.

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6.5.3. Bag analysis

6.5.3.1. The exhaust gases contained in the bag shall be analysed as soon as possible and in any event not later than 20 minutes after the end of the test cycle.

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

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

6.5.3.4. The analysers' zero settings shall then be rechecked: if any reading differs by more than 2 per cent of the range from that set in paragraph 6.5.3.2. above, the procedure shall be repeated for that analyser.

6.5.3.5. The samples shall then be analysed.

6.5.3.6. After the analysis, zero and span points shall be rechecked using the same gases. If these rechecks are within ± 2 per cent of those in paragraph 6.5.3.3. above, the analysis shall be considered acceptable.

6.5.3.7. At all points in this paragraph, the flow-rates and pressures of the various gases shall be the same as those used during calibration of the analysers.

6.5.3.8. The figure adopted for the content of the gases in each of the pollutants measured shall be that read off after stabilisation of the measuring device. Hydrocarbon mass emissions of compression-ignition engines shall be calculated from the integrated HFID reading, corrected for varying flow if necessary, as shown in paragraph 6.6.6. below.

7.3. Type II tests

7.3.1. Conditions of measurement

- 7.3.1.1. The Type II test specified in paragraph 6.6. must be measured immediately after the Type I test with the engine at normal idling speed and at high idle.
- 7.3.1.2. The following parameters must be measured and recorded at normal idling speed and at high idle speed:
- (a) the carbon monoxide content by volume of the exhaust gases emitted,
 - (b) the carbon dioxide content by volume of the exhaust gases emitted,
 - (c) the engine speed during the test, including any tolerances,
 - (d) the engine oil temperature at the time of the test.
- 7.3.2. Sampling of exhaust gases
- 7.3.2.1. The exhaust outlets shall be provided with an air-tight extension, so that the sample probe used to collect exhaust gases may be inserted into the exhaust outlet at least 60 cm, without increasing the back pressure of more than 125 mm H₂O, and without disturbance of the vehicle running. The shape of this extension shall however be chosen in order to avoid, at the location of the sample probe, any appreciable dilution of exhaust gases in the air. Where a vehicle is equipped with an exhaust system having multiple outlets, either these shall be joined to a common pipe or the content of carbon monoxide must be collected from each of them, the result of the measurement being reached from the arithmetical average of these contents.
- 7.3.2.2. The concentrations in CO (C_{CO}) and CO₂ (C_{CO2}) shall be determined from the measuring instrument readings or recordings, by use of appropriate calibration curves. The results have to be corrected according to paragraph 8.2.

8. EMISSION MEASUREMENT AND CALCULATION

The final test result shall be rounded in one step to the number of places to the right of the decimal point indicated by the applicable emission standard plus one additional significant figure, in accordance with ASTM E 29-04. No rounding of intermediate values leading to the final ~~break-specific~~ emission result is permitted. For information not related to standards report use good engineering judgement.

*** The subgroups shall reference the following text, which is extracted from GTR 4, as well as GTR 2, and the EPA Draft Test Procedure. Final Emission Measurement and Calculation results should be appropriate for light-duty vehicles and in following with the established measurement equipment and procedures. ***

Calculations taken over from R83 Annex 4a §6.6 ff.

8.1. Dry/wet correction

~~———— If the emissions are measured on a dry basis, the measured concentration shall be converted to a wet basis according to the following equation:~~

$$c_w = k_w \times c_d \quad (7)$$

where:

c_w is the wet concentration in ppm or per cent volume

c_d is the dry concentration in ppm or per cent volume

k_w is the dry/wet correction factor

8.1.1. Raw exhaust gas

$$k_{w,r} = \left(\frac{1.2442 \times H_a + 111.19 \times w_{ALF} \times \frac{q_{mf,i}}{q_{mad,i}}}{773.4 + 1.2442 \times H_a + \frac{q_{mf,i}}{q_{mad,i}} \times k_f \times 1,000} \right) \times 1.008 \quad (8)$$

or

$$k_{w,r} = \left(\frac{1.2442 \times H_a + 111.19 \times w_{ALF} \times \frac{q_{mf,i}}{q_{mad,i}}}{773.4 + 1.2442 \times H_a + \frac{q_{mf,i}}{q_{mad,i}} \times k_f \times 1,000} \right) \left/ \left(1 - \frac{p_r}{p_b} \right) \right. \quad (9)$$

or

$$k_{w,a} = \left(\frac{1}{1 + \alpha \times 0.005 \times (c_{CO_2} + c_{CO})} \right) k_{w1} \times 1.008 \quad (10)$$

with

$$k_f = 0.055594 \times w_{ALF} + 0.0080021 \times w_{DEL} + 0.0070046 \times w_{EPS} \quad (11)$$

and

$$k_{w1} = \frac{1.608 \times H_a}{1,000 + (1.608 \times H_a)} \quad (12)$$

where:

H_a is the intake air humidity, g water per kg dry air

w_{ALF} is the hydrogen content of the fuel, per cent mass

$q_{mf,i}$ is the instantaneous fuel mass flow rate, kg/s

$q_{mad,i}$ is the instantaneous dry intake air mass flow rate, kg/s

p_r is the water vapour pressure after cooling bath, kPa

p_b is the total atmospheric pressure, kPa

w_{DEL} is the nitrogen content of the fuel, per cent mass

w_{EPS} is the oxygen content of the fuel, per cent mass

α is the molar hydrogen ratio of the fuel

c_{CO_2} is the dry CO₂ concentration, per cent

c_{CO} is the dry CO concentration, per cent

Equations (8) and (9) are principally identical with the factor 1.008 in equations (8) and (10) being an approximation for the more accurate denominator in equation (9).

8.1.2. Diluted exhaust gas

$$k_{w,e} = \left[\left(1 - \frac{\alpha \times c_{CO_2w}}{200} \right) k_{w2} \right] \times 1.008 \quad (13)$$

or

$$k_{w,e} = \left[\left(\frac{(1 - k_{w2})}{1 + \frac{\alpha \times c_{CO_2d}}{200}} \right) \right] \times 1.008 \quad (14)$$

with

$$k_{w2} = \frac{1.608 \times \left[H_d \times \left(1 - \frac{1}{D} \right) + H_a \times \left(\frac{1}{D} \right) \right]}{1,000 + \left\{ 1.608 \times \left[H_d \times \left(1 - \frac{1}{D} \right) + H_a \times \left(\frac{1}{D} \right) \right] \right\}} \quad (15)$$

where:

α is the molar hydrogen ratio of the fuel

c_{CO_2w} is the wet CO₂ concentration, per cent

c_{CO_2d} is the dry CO₂ concentration, per cent

H_d is the dilution air humidity, g water per kg dry air

H_a is the intake air humidity, g water per kg dry air

D is the dilution factor (see paragraph 8.4.2.4.2.)

8.1.3. Dilution air

$$k_{w,d} = (1 - k_{w3}) \times 1.008 \quad (16)$$

with

$$k_{w3} = \frac{1.608 \times H_d}{1,000 + (1.608 \times H_d)} \quad (17)$$

where:

H_d is the dilution air humidity, g water per kg dry air

6.6.1. Determination of volume

6.6.1.1. Calculation of the volume when a variable dilution device with constant flow control by orifice or venturi is used.

Record continuously the parameters showing the volumetric flow, and calculate the total volume for the duration of the test.

6.6.1.2. Calculation of volume when a positive displacement pump is used

The volume of diluted exhaust gas measured in systems comprising a positive displacement pump is calculated with the following formula:

$$V = V_o \cdot N$$

where:

V = volume of the diluted gas expressed in litres per test (prior to correction),

V_o = volume of gas delivered by the positive displacement pump in testing conditions in litres per revolution,

N = number of revolutions per test.

6.6.1.3. Correction of Volume to Standard Conditions

The diluted exhaust-gas volume is corrected by means of the following formula:

$$V_{\text{mix}} = V \cdot K_1 \cdot \left(\frac{P_B - P_1}{T_p} \right) \quad (1)$$

where:

$$K_1 = \frac{273.2 \text{ (K)}}{101.33 \text{ (kPa)}} = 2.6961 \quad (2)$$

P_B = barometric pressure in the test room in kPa,

P_1 = vacuum at the inlet to the positive displacement pump in kPa relative to the ambient barometric pressure,

T_p = average temperature of the diluted exhaust gas entering the positive displacement pump during the test (K).

6.6.2. Total mass of gaseous and particulate pollutants emitted

The mass M of each pollutant emitted by the vehicle during the test shall be determined by obtaining the product of the volumetric concentration and the volume of the gas in question, with due regard for the following densities under above-mentioned reference conditions:

In the case of carbon monoxide (CO): $d = 1.25 \text{ g/l}$

In the case of hydrocarbons:

for petrol (E5) ($C_1H_{1.89}O_{0.016}$) $d = 0.631 \text{ g/l}$
 for diesel (B5) ($C_1H_{1.86}O_{0.005}$) $d = 0.622 \text{ g/l}$
 for LPG ($CH_{2.525}$) $d = 0.649 \text{ g/l}$
 for NG/biomethane (C_1H_4) $d = 0.714 \text{ g/l}$
 for ethanol (E85) ($C_1H_{2.74}O_{0.385}$) $d = 0.932 \text{ g/l}$

In the case of nitrogen oxides (NO_x): $d = 2.05 \text{ g/l}$

6.6.3. Mass emissions of gaseous pollutants shall be calculated by means of the following formula:

$$M_i = \frac{V_{\text{mix}} \cdot Q_i \cdot k_h \cdot C_i \cdot 10^{-6}}{d} \quad (3)$$

where:

M_i = mass emission of the pollutant i in grams per kilometre,
 V_{mix} = volume of the diluted exhaust gas expressed in litres per test and corrected to standard conditions (273.2 K and 101.33 kPa),
 Q_i = density of the pollutant i in grams per litre at normal temperature and pressure (273.2 K and 101.33 kPa),
 k_h = humidity correction factor used for the calculation of the mass emissions of oxides of nitrogen. There is no humidity correction for HC and CO,
 C_i = concentration of the pollutant i in the diluted exhaust gas expressed in ppm and corrected by the amount of the pollutant i contained in the dilution air,
 d = distance corresponding to the operating cycle in kilometres.

6.6.4. Correction for dilution air concentration

The concentration of pollutant in the diluted exhaust gas shall be corrected by the amount of the pollutant in the dilution air as follows:

$$C_i = C_e - C_d \cdot \left(1 - \frac{1}{DF}\right) \quad (4)$$

where:

C_i = concentration of the pollutant i in the diluted exhaust gas, expressed in ppm and corrected by the amount of i contained in the dilution air,
 C_e = measured concentration of pollutant i in the diluted exhaust gas, expressed in ppm,
 C_d = concentration of pollutant i in the air used for dilution, expressed in ppm,
 DF = dilution factor.

The dilution factor is calculated as follows:

$$DF = \frac{13.4}{C_{CO_2} + (C_{HC} + C_{CO}) \cdot 10^{-4}} \quad \text{for petrol (E5)} \quad (5a)$$

$$DF = \frac{13.5}{C_{CO_2} + (C_{HC} + C_{CO}) \cdot 10^{-4}} \quad \text{and diesel (B5)} \quad (5a)$$

$$DF = \frac{11.9}{C_{CO_2} + (C_{HC} + C_{CO}) \cdot 10^{-4}} \quad \text{for LPG} \quad (5b)$$

$$DF = \frac{9.5}{C_{CO_2} + (C_{HC} + C_{CO}) \cdot 10^{-4}} \quad \text{for NG/biomethane} \quad (5c)$$

$$DF = \frac{12.5}{C_{CO_2} + (C_{HC} + C_{CO}) \cdot 10^{-4}} \quad \text{for Ethanol (E85)} \quad (5d)$$

General formula for dilution factor (DF) for each reference fuel with an average composition of $C_xH_yO_z$: Text not originally contained in R83, conflict to Japanese regulation especially for LPG

$$DF = \frac{X}{C_{CO_2} + (C_{HC} + C_{CO}) \times 10^{-4}}$$

$$X = 100 \frac{x}{x + \frac{y}{2} + 3,76 \left(x + \frac{y}{4} - \frac{z}{2} \right)}$$

In these equations:

C_{CO_2} = concentration of CO_2 in the diluted exhaust gas contained in the sampling bag, expressed in per cent volume,

C_{HC} = concentration of HC in the diluted exhaust gas contained in the sampling bag, expressed in ppm carbon equivalent,

C_{CO} = concentration of CO in the diluted exhaust gas contained in the sampling bag, expressed in ppm.

6.6.5. Calculation of the NO humidity correction factor

In order to correct the influence of humidity on the results of oxides of nitrogen, the following calculations are applied:

$$k_h = \frac{1}{1 - 0.0329 \cdot (H - 10.71)} \quad (6)$$

in which:

$$H = \frac{6.211 \cdot R_a \cdot P_d}{P_B - P_d \cdot R_a \cdot 10^{-2}} \quad \text{conflict to current Japanese regulation and US §1065}$$

where:

H = absolute humidity expressed in grams of water per kilogram of dry air,

R_a = relative humidity of the ambient air expressed as a percentage,

P_d = saturation vapour pressure at ambient temperature expressed in kPa,

P_B = atmospheric pressure in the room, expressed in kPa.

6.6.6. Determination of HC for compression-ignition engines

To calculate HC-mass emission for compression-ignition engines, the average HC concentration is calculated as follows:

$$C_e = \frac{\int_{t_1}^{t_2} C_{HC} \cdot dt}{t_2 - t_1} \quad (7)$$

where:

$$\int_{t_1}^{t_2} C_{HC} \cdot dt = \quad \text{integral of the recording of the heated FID over the test (t}_2\text{-t}_1\text{)}$$

C_e = concentration of HC measured in the diluted exhaust in ppm
of C_i is substituted for C_{HC} in all relevant equations.

6.6.7. Determination of particulates

Particulate emission M_p (g/km) is calculated by means of the following equation:

$$M_p = \frac{(V_{mix} + V_{ep}) \cdot P_e}{V_{ep} \cdot d}$$

where exhaust gases are vented outside tunnel;

$$M_p = \frac{V_{mix} \cdot P_e}{V_{ep} \cdot d}$$

where exhaust gases are returned to the tunnel;

where:

V_{mix} = volume of diluted exhaust gases (see paragraph 6.6.1.), under standard conditions,

V_{ep} = volume of exhaust gas flowing through particulate filter under standard conditions,

P_e = particulate mass collected by filter(s),

d = distance corresponding to the operating cycle in km,

M_p = particulate emission in g/km.

Where correction for the particulate background level from the dilution system has been used, this shall be determined in accordance with paragraph 6.2.4. In this case, the particulate mass (g/km) shall be calculated as follows:

$$M_p = \left[\frac{P_e}{V_{ep}} - \left(\frac{P_a}{V_{ap}} \cdot \left(1 - \frac{1}{DF} \right) \right) \right] \cdot \frac{(V_{mix} + V_{ep})}{d}$$

where exhaust gases are vented outside tunnel;

$$M_p = \left[\frac{P_e}{V_{ep}} - \left(\frac{P_a}{V_{ap}} \cdot \left(1 - \frac{1}{DF} \right) \right) \right] \cdot \frac{V_{mix}}{d}$$

where exhaust gases are returned to the tunnel.

Where:

V_{ap} = volume of tunnel air flowing through the background particulate filter under standard conditions,

P_a = particulate mass collected by background filter,

DF = dilution factor as determined in paragraph 6.6.4.

Where application of a background correction results in a negative particulate mass (in g/km) the result shall be considered to be zero g/km particulate mass.

6.6.8. Determination of particle numbers (to be reviewed by PM/PN subgroup)

Number emission of particles shall be calculated by means of the following equation:

$$N = \frac{V \cdot k \cdot \overline{C_s} \cdot \overline{f_r} \cdot 10^3}{d}$$

where:

N = particle number emission expressed in particles per kilometre,

V = volume of the diluted exhaust gas expressed in litres per test and corrected to standard conditions (273.2 K and 101.33 kPa),

k = calibration factor to correct the particle number counter measurements to the level of the reference instrument where this is not applied internally within the particle number counter. Where the calibration factor is applied internally within the particle number counter a value of 1 shall be used for k in the above equation,

\overline{C}_s = corrected concentration of particles from the diluted exhaust gas expressed as the average particles per cubic centimetre figure from the emissions test including the full duration of the drive cycle. If the volumetric mean concentration results (\overline{C}) from the particle number counter are not output at standard conditions (273.2 K and 101.33 kPa), then the concentrations should be corrected to those conditions (\overline{C}_s),

\overline{f}_r = mean particle concentration reduction factor of the volatile particle remover at the dilution setting used for the test,

d = distance corresponding to the operating cycle expressed in kilometres.

\overline{C} shall be calculated from the following equation:

$$\overline{C} = \frac{\sum_{i=1}^{i=n} C_i}{n}$$

where:

C_i = a discrete measurement of particle concentration in the diluted gas exhaust from the particle counter expressed in particles per cubic centimetre and corrected for coincidence,

n = total number of discrete particle concentration measurements made during the operating cycle.

n shall be calculated from the following equation:

$$n = T \cdot f$$

where:

T = time duration of the operating cycle expressed in seconds,

f = data logging frequency of the particle counter expressed in Hz.

8.2. ~~NO_x correction for humidity~~

~~As the NO_x emission depends on ambient air conditions, the NO_x concentration shall be corrected for humidity with the factors given in paragraph 8.2.1. or 8.2.2. The intake air humidity H_a may be derived from relative humidity measurement, dew point measurement, vapour pressure measurement or dry/wet bulb measurement using generally accepted equation.~~

8.2.1. ~~Compression ignition engines~~

$$k_{h,D} = \frac{15.698 \times H_a}{1,000} + 0.832 \quad (18)$$

~~where:~~

~~H_a is the intake air humidity, g water per kg dry air~~

8.2.2. Positive ignition engines

$$k_{h,G} = 0.6272 + 44.030 \times 10^{-3} \times H_a - 0.862 \times 10^{-3} \times H_a^2 \tag{19}$$

where:
 H_a is the intake air humidity, g water per kg dry air

8.3. Partial flow dilution (PFS) and raw gaseous measurement

The instantaneous concentration signals of the gaseous components are used for the calculation of the mass emissions by multiplication with the instantaneous exhaust mass flow rate. The exhaust mass flow rate may be measured directly, or calculated using the methods of intake air and fuel flow measurement, tracer method or intake air and air/fuel ratio measurement. Special attention shall be paid to the response times of the different instruments. These differences shall be accounted for by time aligning the signals. For particulates, the exhaust mass flow rate signals are used for controlling the partial flow dilution system to take a sample proportional to the exhaust mass flow rate. The quality of proportionality shall be checked by applying a regression analysis between sample and exhaust flow in accordance with paragraph 8.3.3.3. The complete test set up is schematically shown in figure 6.

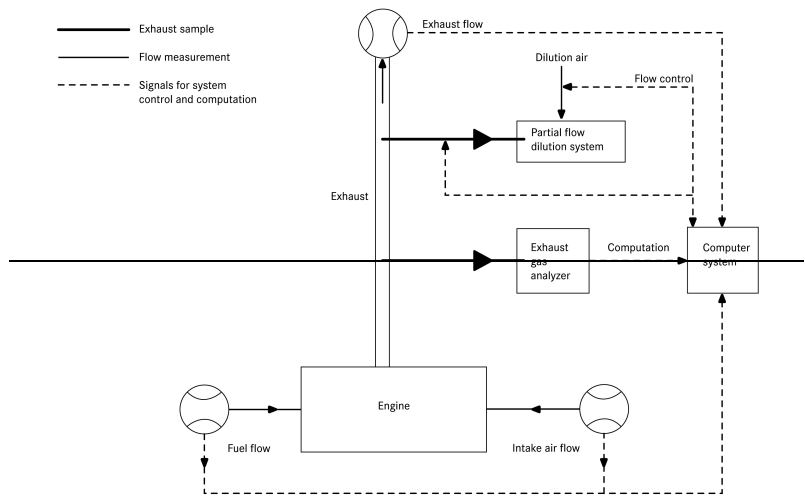


Figure 6:
Scheme of raw/partial flow measurement system

8.3.1. Determination of exhaust gas mass flow

8.3.1.1. Introduction

~~For calculation of the emissions in the raw exhaust gas and for controlling of a partial flow dilution system, it is necessary to know the exhaust gas mass flow rate. For the determination of the exhaust mass flow rate, either of the methods described in paragraphs 8.3.1.3 to 8.3.1.6 may be used.~~

8.3.1.2. ~~Response time~~

~~For the purpose of emissions calculation, the response time of either method described in paragraphs 8.3.1.3 to 8.3.1.6 shall be equal to or less than the analyzer response time of ≤ 10 s, as required in paragraph 9.3.5.~~

~~For the purpose of controlling of a partial flow dilution system, a faster response is required. For partial flow dilution systems with online control, the response time shall be ≤ 0.3 s. For partial flow dilution systems with look ahead control based on a pre-recorded test run, the response time of the exhaust flow measurement system shall be ≤ 5 s with a rise time of ≤ 1 s. The system response time shall be specified by the instrument manufacturer. The combined response time requirements for the exhaust gas flow and partial flow dilution system are indicated in paragraph 8.3.3.3.~~

8.3.1.3. ~~Direct measurement method~~

~~Direct measurement of the instantaneous exhaust flow shall be done by systems, such as:~~

- ~~(a) pressure differential devices, like flow nozzle, (details see ISO 5167)~~
- ~~(b) ultrasonic flowmeter~~
- ~~(c) vortex flowmeter~~

~~Precautions shall be taken to avoid measurement errors which will impact emission value errors. Such precautions include the careful installation of the device in the engine exhaust system according to the instrument manufacturers' recommendations and to good engineering practice. Especially, engine performance and emissions shall not be affected by the installation of the device.~~

~~The flowmeters shall meet the linearity requirements of paragraph 9.2.~~

8.3.1.4. ~~Air and fuel measurement method~~

~~This involves measurement of the airflow and the fuel flow with suitable flowmeters. The calculation of the instantaneous exhaust gas flow shall be as follows:~~

$$\dot{q}_{mew,i} = \dot{q}_{maw,i} + \dot{q}_{mf,i} \quad (20)$$

~~where:~~

~~$\dot{q}_{mew,i}$ is the instantaneous exhaust mass flow rate, kg/s~~

~~$\dot{q}_{maw,i}$ is the instantaneous intake air mass flow rate, kg/s~~

~~$\dot{q}_{mf,i}$ is the instantaneous fuel mass flow rate, kg/s~~

~~The flowmeters shall meet the linearity requirements of paragraph 9.2., but shall be accurate enough to also meet the linearity requirements for the exhaust gas flow.~~

8.3.1.5. ~~Tracer measurement method~~

~~This involves measurement of the concentration of a tracer gas in the exhaust.~~

~~A known amount of an inert gas (e.g. pure helium) shall be injected into the exhaust gas flow as a tracer. The gas is mixed and diluted by the exhaust gas, but shall not react in the exhaust pipe. The concentration of the gas shall then be measured in the exhaust gas sample.~~

~~In order to ensure complete mixing of the tracer gas, the exhaust gas sampling probe shall be located at least 1 m or 30 times the diameter of the exhaust pipe, whichever is larger, downstream of the tracer gas injection point. The sampling probe may be located closer to the injection point if complete mixing is verified by comparing the tracer gas concentration with the reference concentration when the tracer gas is injected upstream of the engine.~~

~~The tracer gas flow rate shall be set so that the tracer gas concentration at engine idle speed after mixing becomes lower than the full scale of the trace gas analyzer.~~

~~The calculation of the exhaust gas flow shall be as follows:~~

$$\del{q_{mew,i} = \frac{q_{vt} \times \rho_e}{60 \times (c_{mix,i} - c_b)}} \quad (21)$$

~~where:~~

~~$q_{mew,i}$ is the instantaneous exhaust mass flow rate, kg/s~~

~~q_{vt} is tracer gas flow rate, cm³/min~~

~~$c_{mix,i}$ is the instantaneous concentration of the tracer gas after mixing, ppm~~

~~ρ_e is the density of the exhaust gas, kg/m³ (cf. table 4)~~

~~c_b is the background concentration of the tracer gas in the intake air, ppm~~

~~The background concentration of the tracer gas (c_b) may be determined by averaging the background concentration measured immediately before the test run and after the test run.~~

~~When the background concentration is less than 1 per cent of the concentration of the tracer gas after mixing ($c_{mix,i}$) at maximum exhaust flow, the background concentration may be neglected.~~

~~The total system shall meet the linearity requirements for the exhaust gas flow of paragraph 9.2.~~

8.3.1.6. ~~Airflow and air to fuel ratio measurement method~~

~~This involves exhaust mass calculation from the airflow and the air to fuel ratio. The calculation of the instantaneous exhaust gas mass flow is as follows:~~

$$\dot{q}_{mew,i} = \dot{q}_{maw,i} \times \left(1 + \frac{1}{A/F_{st} \times \lambda_i} \right) \quad (22)$$

~~with~~

$$A/F_{st} = \frac{138.0 \times \left(1 + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma \right)}{12.011 + 1.00794 \times \alpha + 15.9994 \times \varepsilon + 14.0067 \times \delta + 32.065 \times \gamma} \quad (23)$$

$$\lambda_i = \frac{\left(100 - \frac{c_{COd} \times 10^{-4}}{2} - c_{HCw} \times 10^{-4} \right) + \left(\frac{\alpha}{4} \times \frac{1 - \frac{2 \times c_{COd} \times 10^{-4}}{3.5 \times c_{CO2d}} - \frac{\varepsilon}{2} - \frac{\delta}{2}}{1 + \frac{c_{CO} \times 10^{-4}}{3.5 \times c_{CO2d}}} \right) \times (c_{CO2d} + c_{COd} \times 10^{-4})}{4.764 \times \left(1 + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma \right) \times (c_{CO2d} + c_{COd} \times 10^{-4} + c_{HCw} \times 10^{-4})} \quad (24)$$

~~where:~~

~~$\dot{q}_{mew,i}$ is the instantaneous exhaust mass flow rate, kg/s~~

~~$\dot{q}_{maw,i}$ is the instantaneous intake air mass flow rate, kg/s~~

~~A/F_{st} is the stoichiometric air to fuel ratio, kg/kg~~

~~λ_i is the instantaneous excess air ratio~~

~~c_{CO2d} is the dry CO₂ concentration, per cent~~

~~c_{COd} is the dry CO concentration, ppm~~

~~c_{HCw} is the wet HC concentration, ppm~~

~~Airflowmeter and analyzers shall meet the linearity requirements of paragraph 9.2., and the total system shall meet the linearity requirements for the exhaust gas flow of paragraph 9.2.~~

~~If an air to fuel ratio measurement equipment such as a zirconia type sensor is used for the measurement of the excess air ratio, it shall meet the specifications of paragraph 9.3.2.7.~~

~~8.3.2. Determination of the gaseous components~~

~~8.3.2.1. Introduction~~

~~The gaseous components in the raw exhaust gas emitted by the engine submitted for testing shall be measured with the measurement and sampling systems described in paragraph 9.3. and Annex 3. The data evaluation is described in paragraph 8.3.2.3.~~

~~Two calculation procedures are described in paragraphs 8.3.2.4. and 8.3.2.5., which are equivalent for the reference fuels of Annex 2. The procedure in paragraph 8.3.2.4. is more straightforward, since it uses tabulated μ values for the ratio between component and exhaust gas density. The procedure in paragraph 8.3.2.5. is more accurate for fuel qualities that deviate from the specifications in Annex 2, but requires elementary analysis of the fuel composition.~~

~~8.3.2.2. Sampling for gaseous emissions~~

~~The gaseous emissions sampling probes shall be fitted at least 0.5 m or 3 times the diameter of the exhaust pipe whichever is the larger upstream of the exit of the exhaust gas system but sufficiently close to the engine as to ensure an exhaust gas temperature of at least 343 K (70 °C) at the probe.~~

~~In the case of a multi-cylinder engine with a branched exhaust manifold, the inlet of the probe shall be located sufficiently far downstream so as to ensure that the sample is representative of the average exhaust emissions from all cylinders. In multi-cylinder engines having distinct groups of manifolds, such as in a "Vee" engine configuration, it is recommended to combine the manifolds upstream of the sampling probe. If this is not practical, it is permissible to acquire a sample from the group with the highest CO₂ emission. For exhaust emission calculation the total exhaust mass flow shall be used.~~

~~If the engine is equipped with an exhaust after treatment system, the exhaust sample shall be taken downstream of the exhaust after treatment system.~~

~~8.3.2.3. Data evaluation~~

~~For the evaluation of the gaseous emissions, the raw emission concentrations (HC, CO and NO_x) and the exhaust gas mass flow rate shall be recorded and stored with at least 2 Hz on a computer system. All other data shall be recorded with a sample rate of at least 1 Hz. For analogue analyzers, the response shall be recorded, and the calibration data may be applied online or offline during the data evaluation.~~

~~For calculation of the mass emission of the gaseous components, the traces of the recorded concentrations and the trace of the exhaust gas mass flow rate shall be time aligned by the transformation time as defined in paragraph 3.1.28. Therefore, the response time of each gaseous emissions analyzer and of the exhaust gas mass flow system shall be determined according to paragraphs 8.3.1.2. and 9.3.5., respectively, and recorded.~~

8.3.2.4. Calculation of mass emission based on tabulated values

The mass of the pollutants (g/test) shall be determined by calculating the instantaneous mass emissions from the raw concentrations of the pollutants and the exhaust gas mass flow, aligned for the transformation time as determined in accordance with paragraph 8.3.2.3., integrating the instantaneous values over the cycle, and multiplying the integrated values with the u values from table 4. If measured on a dry basis, the dry/wet correction according to paragraph 8.1. shall be applied to the instantaneous concentration values before any further calculation is done.

For the calculation of NO_x , the mass emission shall be multiplied with the humidity correction factor $k_{h,D}$ or $k_{h,G}$, as determined according to paragraph 8.2.

An example of the calculation procedures is given in Annex 6.

The following equation shall be applied:

$$m_{\text{gas}} = u_{\text{gas}} \times \sum_{i=1}^{i=n} c_{\text{gas},i} \times q_{\text{mew},i} \times \frac{1}{f} \quad (\text{in g/test}) \quad (25)$$

where:

u_{gas} is the ratio between density of exhaust component and density of exhaust gas

$c_{\text{gas},i}$ is the instantaneous concentration of the component in the exhaust gas, ppm

$q_{\text{mew},i}$ is the instantaneous exhaust mass flow, kg/s

f is the data sampling rate, Hz

n is the number of measurements

Fuel	ρ_e	Gas					
		NO _x	CO	HC	CO ₂	O ₂	CH ₄
		ρ_{gas} [kg/m ³]					
		2.053	1.250	^{a)}	1.9636	1.4277	0.716
		u_{gas} ^{b)}					
Diesel	1.2943	0.001586	0.000966	0.000479	0.001517	0.001103	0.000553
Ethanol	1.2757	0.001609	0.000980	0.000805	0.001539	0.001119	0.000561
CNG ^{c)}	1.2661	0.001621	0.000987	0.000558 ^{d)}	0.001551	0.001128	0.000565
Propane	1.2805	0.001603	0.000976	0.000512	0.001533	0.001115	0.000559
Butane	1.2832	0.001600	0.000974	0.000505	0.001530	0.001113	0.000558
LPG ^{e)}	1.2811	0.001602	0.000976	0.000510	0.001533	0.001115	0.000559

a) depending on fuel
b) at $\lambda = 2$, dry air, 273 K, 101.3 kPa
c) μ accurate within 0.2 % for mass composition of: C = 66 – 76 %; H = 22 – 25 %; N = 0 – 12 %
d) NMHC on the basis of CH_{2.93} (for total HC the μ_{gas} coefficient of CH₄ shall be used)
e) μ accurate within 0.2 % for mass composition of: C3 = 70 – 90 %; C4 = 10 – 30 %

Table 4:

Raw exhaust gas u values and component densities

8.3.2.5. Calculation of mass emission based on exact equations

The mass of the pollutants (g/test) shall be determined by calculating the instantaneous mass emissions from the raw concentrations of the pollutants, the u values and the exhaust gas mass flow, aligned for the transformation time as determined in accordance with paragraph 8.3.2.3. and integrating the instantaneous values over the cycle. If measured on a dry basis, the dry/wet correction according to paragraph 8.1. shall be applied to the instantaneous concentration values before any further calculation is done.

For the calculation of NO_x , the mass emission shall be multiplied with the humidity correction factor $k_{h,D}$, or $k_{h,G}$, as determined according to paragraph 8.2.

The following equation shall be applied:

$$m_{\text{gas}} = \sum_{i=1}^{i=n} u_{\text{gas},i} \times c_{\text{gas},i} \times q_{\text{mew},i} \times \frac{1}{f} \quad (\text{in g/test}) \quad (26)$$

where:

$u_{\text{gas},i}$ is the instantaneous density ratio of exhaust component and exhaust gas

$c_{\text{gas},i}$ is the instantaneous concentration of the component in the exhaust gas, ppm

$q_{\text{mew},i}$ is the instantaneous exhaust mass flow, kg/s

f is the data sampling rate, Hz

n is the number of measurements

The instantaneous u values shall be calculated as follows:

$$u_{\text{gas},i} = M_{\text{gas}} / (M_{\text{e},i} \times 1,000) \quad (27)$$

or

$$u_{\text{gas},i} = \rho_{\text{gas}} / (\rho_{\text{e},i} \times 1,000) \quad (28)$$

with

$$\rho_{\text{gas}} = M_{\text{gas}} / 22.414 \quad (29)$$

where:

M_{gas} is the molar mass of the gas component, g/mol (cf. Annex 6)

$M_{\text{e},i}$ is the instantaneous molar mass of the exhaust gas, g/mol

ρ_{gas} is the density of the gas component, kg/m³

$\rho_{\text{e},i}$ is the instantaneous density of the exhaust gas, kg/m³

The molar mass of the exhaust, M_{e} , shall be derived for a general fuel composition $\text{CH}_x\text{O}_y\text{N}_z\text{S}_w$ under the assumption of complete combustion, as follows:

$$M_{e,i} = \frac{1 + \frac{q_{mf,i}}{q_{maw,i}}}{\frac{q_{mf,i}}{q_{maw,i}} \times \frac{\frac{\alpha}{4} + \frac{\varepsilon}{2} + \frac{\delta}{2}}{12.011 + 1.00794 \times \alpha + 15.9994 \times \varepsilon + 14.0067 \times \delta + 32.065 \times \gamma} + \frac{\frac{H_a \times 10^{-3}}{2 \times 1.00794 + 15.9994} + \frac{1}{M_a}}{1 + H_a \times 10^{-3}}} \quad (30)$$

where:

$q_{maw,i}$ is the instantaneous intake air mass flow rate on wet basis, kg/s

$q_{mf,i}$ is the instantaneous fuel mass flow rate, kg/s

H_a is the intake air humidity, g water per kg dry air

M_a is the molar mass of the dry intake air = 28.965 g/mol

The exhaust density $\rho_{e,i}$ shall be derived, as follows:

$$\rho_{e,i} = \frac{1,000 + H_a + 1,000 \times (q_{mf,i}/q_{mad,i})}{773.4 + 1.2434 \times H_a + k_f \times 1,000 \times (q_{mf,i}/q_{mad,i})} \quad (31)$$

where:

$q_{mad,i}$ is the instantaneous intake air mass flow rate on dry basis, kg/s

$q_{mf,i}$ is the instantaneous fuel mass flow rate, kg/s

H_a is the intake air humidity, g water per kg dry air

k_f is the fuel specific factor according to equation 11 in paragraph 8.1.1.

8.3.3. Particulate determination

8.3.3.1. Introduction

The determination of the particulates requires dilution of the sample with filtered ambient air, synthetic air or nitrogen. The partial flow dilution system shall be set to completely eliminate water condensation in the dilution and sampling systems, and maintain the temperature of the diluted exhaust gas between 315 K (42 °C) and 325 K (52 °C) immediately upstream of the filter holders. Dehumidifying the dilution air before entering the dilution system is permitted, and especially useful if dilution air humidity is high. The temperature of the dilution air shall be ≥ 288 K (15 °C) in close proximity to the entrance into the dilution tunnel.

The partial flow dilution system has to be designed to extract a proportional raw exhaust sample from the engine exhaust stream, thus responding to excursions in the exhaust stream flow rate, and introduce dilution air to this sample to achieve a temperature between 315 K (42 °C) and 325 K (52 °C) at the test filter. For this it is essential that the dilution ratio or the sampling ratio r_d or r_s be determined such that the accuracy requirements of paragraph 9.4.4. are fulfilled.

To determine the mass of the particulates, a particulate sampling system, a particulate sampling filter, a microgram balance, and a temperature and humidity

controlled weighing chamber, are required. The details of the system are described in paragraph 9.4.

8.3.3.2. Particulate sampling

In general, the particulate sampling probe shall be installed in close proximity to the gaseous emissions sampling probe, but sufficiently distant as to not cause interference. Therefore, the installation provisions of paragraph 8.3.2.2. also apply to particulate sampling. The sampling line shall conform to the requirements laid down in Annex 3.

In the case of a multi-cylinder engine with a branched exhaust manifold, the inlet of the probe shall be located sufficiently far downstream so as to ensure that the sample is representative of the average exhaust emissions from all cylinders. In multi-cylinder engines having distinct groups of manifolds, such as in a "Vee" engine configuration, it is recommended to combine the manifolds upstream of the sampling probe. If this is not practical, it is permissible to acquire a sample from the group with the highest particulate emission. For exhaust emission calculation the total exhaust mass flow of the manifold shall be used.

8.3.3.3. System response time

For the control of a partial flow dilution system, a fast system response is required. The transformation time for the system shall be determined by the procedure in paragraph 9.4.7.3. If the combined transformation time of the exhaust flow measurement (see paragraph 8.3.1.2.) and the partial flow system is ≤ 0.3 s, online control shall be used. If the transformation time exceeds 0.3 s, look-ahead control based on a pre-recorded test run shall be used. In this case, the combined rise time shall be ≤ 1 s and the combined delay time ≤ 10 s.

The total system response shall be designed as to ensure a representative sample of the particulates, $q_{mp,i}$, proportional to the exhaust mass flow. To determine the proportionality, a regression analysis of $q_{mp,i}$ versus $q_{mew,i}$ shall be conducted on a minimum 5 Hz data acquisition rate, and the following criteria shall be met:

- (a) The coefficient of determination r^2 of the linear regression between $q_{mp,i}$ and $q_{mew,i}$ shall not be less than 0.95.
- (b) The standard error of estimate of $q_{mp,i}$ on $q_{mew,i}$ shall not exceed 5 per cent of q_{mp} maximum.
- (c) q_{mp} intercept of the regression line shall not exceed ± 2 per cent of q_{mp} maximum.

Look-ahead control is required if the combined transformation times of the particulate system, $t_{50,P}$ and of the exhaust mass flow signal, $t_{50,E}$ are > 0.3 s. In this case, a pre-test shall be run, and the exhaust mass flow signal of the pre-test be used for controlling the sample flow into the particulate system. A correct control of the partial dilution system is obtained, if the time trace of $q_{mew,pre}$ of the pre-test, which controls q_{mp} , is shifted by a "look-ahead" time of $t_{50,P} + t_{50,E}$.

For establishing the correlation between $q_{mp,i}$ and $q_{mew,i}$ the data taken during the actual test shall be used, with $q_{mew,i}$ time aligned by $t_{50,P}$ relative to $q_{mp,i}$ (no contribution from $t_{50,P}$ to the time alignment). That is, the time shift between q_{mew} and q_{mp} is the difference in their transformation times that were determined in paragraph 9.4.7.3.

8.3.3.4. Data evaluation

The tare weight of the filter, as determined according to paragraph 7.8.2.2., shall be subtracted from the gross weight of the filter, as determined according to paragraph 7.8.4.5., which results in the particulate sample mass m_t . For the evaluation of the particulate concentration, the total sample mass (m_{sep}) through the filter over the test cycle shall be recorded.

With the prior approval of the type approval or certification authority, the particulate mass may be corrected for the particulate level of the dilution air, as determined in paragraph 7.8.2.5., in line with good engineering practice and the specific design features of the particulate measurement system used.

8.3.3.5. Calculation of mass emission

Depending on system design, the mass of particulates (g/test) shall be calculated by either of the methods in paragraphs 8.3.3.5.1. or 8.3.3.5.2 after buoyancy correction of the particulate sample mass according to paragraph 9.4.3.5. An example of the calculation procedures is given in Annex 6.

8.3.3.5.1. Calculation based on sample ratio

$$m_{PM} = m_t / (r_s \times 1,000) \quad (32)$$

where:

m_t is the particulate mass sampled over the cycle, mg

r_s is the average sample ratio over the test cycle

with

$$r_s = \frac{m_{se}}{m_{ew}} \times \frac{m_{sep}}{m_{sed}} \quad (33)$$

where:

m_{se} is the sample mass over the cycle, kg

m_{ew} is the total exhaust mass flow over the cycle, kg

m_{sep} is the mass of diluted exhaust gas passing the particulate collection filters, kg

m_{sed} is the mass of diluted exhaust gas passing the dilution tunnel, kg

In case of the total sampling type system, m_{sep} and m_{sed} are identical.

8.3.3.5.2. Calculation based on dilution ratio

$$m_{PM} = \frac{m_f}{m_{sep}} \times \frac{m_{edf}}{1,000} \quad (34)$$

where:

m_f is the particulate mass sampled over the cycle, mg

m_{sep} is the mass of diluted exhaust gas passing the particulate collection filters, kg

m_{edf} is the mass of equivalent diluted exhaust gas over the cycle, kg

The total mass of equivalent diluted exhaust gas mass over the cycle shall be determined as follows:

$$m_{edf} = \sum_{i=1}^{i=n} q_{medf,i} \times \frac{1}{f} \quad (35)$$

$$q_{medf,i} = q_{mew,i} \times F_{d,i} \quad (36)$$

$$F_{d,i} = \frac{q_{mdew,i}}{(q_{mdew,i} - q_{mdw,i})} \quad (37)$$

where:

$q_{medf,i}$ is the instantaneous equivalent diluted exhaust mass flow rate, kg/s

$q_{mew,i}$ is the instantaneous exhaust mass flow rate, kg/s

$F_{d,i}$ is the instantaneous dilution ratio

$q_{mdew,i}$ is the instantaneous diluted exhaust mass flow rate, kg/s

$q_{mdw,i}$ is the instantaneous dilution air mass flow rate, kg/s

f is the data sampling rate, Hz

n is the number of measurements

8.4. Full flow dilution measurement (CVS)

The concentration signals, either by integration over the cycle or by bag sampling, of the gaseous components shall be used for the calculation of the mass emissions by multiplication with the diluted exhaust mass flow rate. The exhaust mass flow rate shall be measured with a constant volume sampling (CVS) system, which may use a positive displacement pump (PDP), a critical flow venturi (CFV) or a subsonic venturi (SSV) with or without flow compensation.

For bag sampling and particulate sampling, a proportional sample shall be taken from the diluted exhaust gas of the CVS system. For a system without flow compensation, the ratio of sample flow to CVS flow must not vary by more than ± 2.5 per cent from the set point of the test. For a system with flow compensation, each individual flow rate shall be constant within ± 2.5 per cent of its respective target flow rate.

The complete test set-up is schematically shown in figure 7.

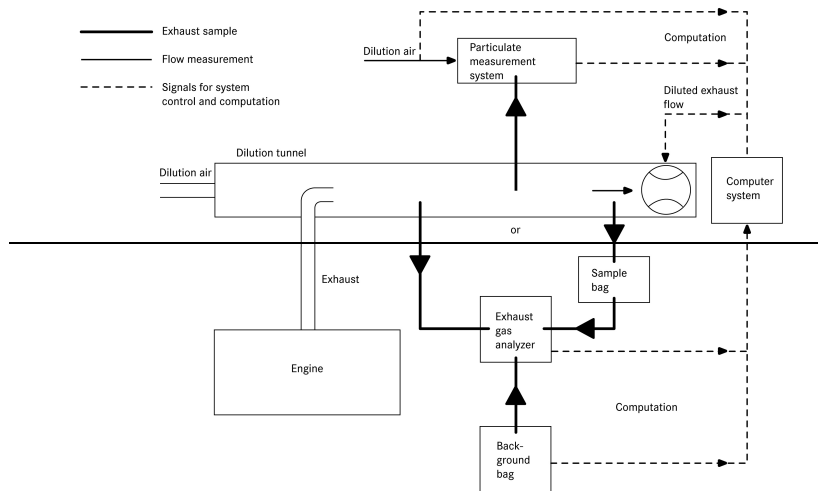


Figure 7:
Scheme of full flow measurement system

8.4.1. Determination of the diluted exhaust gas flow

8.4.1.1. Introduction

For calculation of the emissions in the diluted exhaust gas, it is necessary to know the diluted exhaust gas mass flow rate. The total diluted exhaust gas flow over the cycle (kg/test) shall be calculated from the measurement values over the cycle and the corresponding calibration data of the flow measurement device (V_0 for PDP, K_V for CFV, C_d for SSV) by either of the methods described in paragraphs 8.4.1.2. to 8.4.1.4. If the total sample flow of particulates (m_{sep}) exceeds 0.5 per cent of the total CVS flow (m_{ed}), the CVS flow shall be corrected for m_{sep} or the particulate sample flow shall be returned to the CVS prior to the flow measuring device.

8.4.1.2. PDP CVS system

The calculation of the mass flow over the cycle is as follows, if the temperature of the diluted exhaust is kept within ± 6 K over the cycle by using a heat exchanger:

$$m_{ed} = 1.293 \times V_0 \times n_P \times p_P \times 273 / (101.3 \times T) \quad (38)$$

where:

V_0 is the volume of gas pumped per revolution under test conditions, m³/rev

n_P is the total revolutions of pump per test

p_p is the absolute pressure at pump inlet, kPa

T is the average temperature of the diluted exhaust gas at pump inlet, K

If a system with flow compensation is used (i.e. without heat exchanger), the instantaneous mass emissions shall be calculated and integrated over the cycle. In this case, the instantaneous mass of the diluted exhaust gas shall be calculated as follows:

$$m_{ed,i} = 1.293 \times V_0 \times n_{P,i} \times p_p \times 273 / (101.3 \times T) \quad (39)$$

where:

$n_{P,i}$ is the total revolutions of pump per time interval

8.4.1.3. CFV CVS system

The calculation of the mass flow over the cycle is as follows, if the temperature of the diluted exhaust is kept within ± 11 K over the cycle by using a heat exchanger:

$$m_{ed} = 1.293 \times t \times K_v \times p_p / T^{0.5} \quad (40)$$

where:

t is the cycle time, s

K_v is the calibration coefficient of the critical flow venturi for standard conditions,

p_p is the absolute pressure at venturi inlet, kPa

T is the absolute temperature at venturi inlet, K

If a system with flow compensation is used (i.e. without heat exchanger), the instantaneous mass emissions shall be calculated and integrated over the cycle. In this case, the instantaneous mass of the diluted exhaust gas shall be calculated as follows:

$$m_{ed,i} = 1.293 \times \Delta t_i \times K_v \times p_p / T^{0.5} \quad (41)$$

where:

Δt_i is the time interval, s

8.4.1.4. SSV CVS system

The calculation of the mass flow over the cycle shall be as follows, if the temperature of the diluted exhaust is kept within ± 11 K over the cycle by using a heat exchanger:

$$m_{ed} = 1.293 \times Q_{SSV} \quad (42)$$

with

$$Q_{SSV} = A_0 d_v^2 C_d p_p \sqrt{\left[\frac{1}{T} \left(r_p^{1.4286} - r_p^{1.7143} \right) \left(\frac{1}{1 - r_D^4 r_p^{1.4286}} \right) \right]} \quad (43)$$

where:

A_0 is 0.006111 in SI units of $\left(\frac{m^3}{min} \right) \left(\frac{K^{\frac{1}{2}}}{kPa} \right) \left(\frac{1}{mm^2} \right)$

d_v is the diameter of the SSV throat, m

C_d is the discharge coefficient of the SSV

p_p is the absolute pressure at venturi inlet, kPa

T is the temperature at the venturi inlet, K

r_p is the ratio of the SSV throat to inlet absolute static pressure, $1 - \frac{\Delta p}{p_a}$

r_D is the ratio of the SSV throat diameter, d , to the inlet pipe inner diameter D

If a system with flow compensation is used (i.e. without heat exchanger), the instantaneous mass emissions shall be calculated and integrated over the cycle. In this case, the instantaneous mass of the diluted exhaust gas shall be calculated as follows:

$$m_{ed} = 1.293 \times Q_{SSV} \times \Delta t_i \quad (44)$$

where:

Δt_i is the time interval, s

The real time calculation shall be initialized with either a reasonable value for C_d , such as 0.98, or a reasonable value of Q_{SSV} . If the calculation is initialized with Q_{SSV} , the initial value of Q_{SSV} shall be used to evaluate the Reynolds number.

During all emissions tests, the Reynolds number at the SSV throat shall be in the range of Reynolds numbers used to derive the calibration curve developed in paragraph 9.5.4.

8.4.2. Determination of the gaseous components

8.4.2.1. Introduction

The gaseous components in the diluted exhaust gas emitted by the engine submitted for testing shall be measured by the methods described in Annex 3. Dilution of the exhaust shall be done with filtered ambient air, synthetic air or nitrogen. The flow capacity of the full flow system shall be large enough to completely eliminate water condensation in the dilution and sampling systems. Data evaluation and calculation procedures are described in paragraphs 8.4.2.3. and 8.4.2.4.

~~8.4.2.2. Sampling for gaseous emissions~~

~~The exhaust pipe between the engine and the full flow dilution system shall conform to the requirements laid down in Annex 3. The gaseous emissions sample probe(s) shall be installed in the dilution tunnel at a point where the dilution air and exhaust gas are well mixed, and in close proximity to the particulates sampling probe.~~

~~Sampling can generally be done in two ways:~~

- ~~(a) the emissions are sampled into a sampling bag over the cycle and measured after completion of the test; for HC, the sample bag shall be heated to 464 ± 11 K ($191 \pm 11^\circ\text{C}$), for NO_x , the sample bag temperature shall be above the dew point temperature;~~
- ~~(b) the emissions are sampled continuously and integrated over the cycle.~~

~~The background concentrations shall be sampled upstream of the dilution tunnel into a sampling bag, and shall be subtracted from the emissions concentration according to paragraph 8.4.2.4.2.~~

~~8.4.2.3. Data evaluation~~

~~For continuous sampling, the emission concentrations (HC, CO and NO_x) shall be recorded and stored with at least 1 Hz on a computer system, for bag sampling one mean value per test is required. The diluted exhaust gas mass flow rate and all other data shall be recorded with a sample rate of at least 1 Hz. For analogue analyzers the response will be recorded, and the calibration data may be applied online or offline during the data evaluation.~~

~~8.4.2.4. Calculation of mass emission~~

~~8.4.2.4.1. Systems with constant mass flow~~

~~For systems with heat exchanger, the mass of the pollutants shall be determined from the following equation:~~

$$~~m_{\text{gas}} = n_{\text{gas}} \times c_{\text{gas}} \times m_{\text{ed}} \quad (\text{in g/test}) \quad (45)~~$$

~~where:~~

~~n_{gas} is the ratio between density of exhaust component and density of air~~

~~c_{gas} is the average background corrected concentration of the component, ppm~~

~~m_{ed} is the total diluted exhaust mass over the cycle, kg~~

~~If measured on a dry basis, the dry/wet correction according to paragraph 8.1. shall be applied.~~

~~For the calculation of NO_x , the mass emission shall be multiplied with the humidity correction factor $k_{h,D}$, or $k_{h,G}$, as determined according to paragraph 8.2.~~

The μ values are given in table 5. For calculating the μ_{gas} values, the density of the diluted exhaust gas has been assumed to be equal to air density. Therefore, the μ_{gas} values are identical for single gas components, but different for HC.

Alternatively, the exact equation method described in paragraph 8.3.2.5., equations 27 or 28 may be used.

Fuel	ρ_{de}	Gas					
		NO _x	CO	HC	CO ₂	O ₂	CH ₄
		ρ_{gas} [kg/m ³]					
		2.053	1.250	^{a)}	1.9636	1.4277	0.716
		μ_{gas} ^{b)}					
Diesel	1.293	0.001588	0.000967	0.000480	0.001519	0.001104	0.000553
Ethanol	1.293	0.001588	0.000967	0.000795	0.001519	0.001104	0.000553
CNG ^{c)}	1.293	0.001588	0.000967	0.000584 ^{d)}	0.001519	0.001104	0.000553
Propane	1.293	0.001588	0.000967	0.000507	0.001519	0.001104	0.000553
Butane	1.293	0.001588	0.000967	0.000501	0.001519	0.001104	0.000553
LPG ^{e)}	1.293	0.001588	0.000967	0.000505	0.001519	0.001104	0.000553

a) depending on fuel
b) at $\lambda = 2$, dry air, 273 K, 101.3 kPa
c) μ accurate within 0.2 % for mass composition of: C = 66 – 76 %; H = 22 – 25 %; N = 0 – 12 %
d) NMHC on the basis of CH_{2.02} (for total HC the μ_{gas} coefficient of CH₄ shall be used)
e) μ accurate within 0.2 % for mass composition of: C3 = 70 – 90 %; C4 = 10 – 30 %

Table 5:
Diluted exhaust gas μ values and component densities

8.4.2.4.2. Determination of the background corrected concentrations

The average background concentration of the gaseous pollutants in the dilution air shall be subtracted from measured concentrations to get the net concentrations of the pollutants. The average values of the background concentrations can be determined by the sample bag method or by continuous measurement with integration. The following equation shall be used:

$$c = c_e - c_d \times (1 - (1/D)) \quad (46)$$

where:

c_e is the concentration of the component measured in the diluted exhaust gas, ppm

c_d is the concentration of the component measured in the dilution air, ppm

D is the dilution factor

The dilution factor shall be calculated as follows:

a) for diesel and LPG fueled gas engines

$$D = \frac{F_s}{c_{\text{CO}_2,e} + (c_{\text{HC},e} + c_{\text{CO},e}) \times 10^{-4}} \quad (47)$$

b) for NG fueled gas engines

$$D = \frac{F_s}{c_{\text{CO}_2,e} + (c_{\text{NMHC},e} + c_{\text{CO},e}) \times 10^{-4}} \quad (48)$$

where:

$c_{\text{CO}_2,e}$ is the wet concentration of CO_2 in the diluted exhaust gas, per cent vol

$c_{\text{HC},e}$ is the wet concentration of HC in the diluted exhaust gas, ppm C1

$c_{\text{NMHC},e}$ is the wet concentration of NMHC in the diluted exhaust gas, ppm C1

$c_{\text{CO},e}$ is the wet concentration of CO in the diluted exhaust gas, ppm

F_s is the stoichiometric factor

The stoichiometric factor shall be calculated as follows:

$$F_s = \frac{100 \times 1}{1 + \frac{\alpha}{2} + 3.76 \times \left(1 + \frac{\alpha}{4}\right)} \quad (49)$$

where:

α is the molar hydrogen ratio of the fuel (H/C)

Alternatively, if the fuel composition is not known, the following stoichiometric factors may be used:

F_s (diesel) = 13.4

F_s (LPG) = 11.6

F_s (NG) = 9.5

8.4.2.4.3 Systems with flow compensation

For systems without heat exchanger, the mass of the pollutants (g/test) shall be determined by calculating the instantaneous mass emissions and integrating the instantaneous values over the cycle. Also, the background correction shall be applied directly to the instantaneous concentration value. The following equation shall be applied:

$$m_{\text{gas}} = \sum_{i=1}^n [(m_{\text{ed},i} \times c_e \times u_{\text{gas}})] - [(m_{\text{ed}} \times c_d \times (1 - 1/D) \times u_{\text{gas}})] \quad (50)$$

where:

c_e is the concentration of the component measured in the diluted exhaust gas, ppm

c_d is the concentration of the component measured in the dilution air, ppm

$m_{\text{ed},i}$ is the instantaneous mass of the diluted exhaust gas, kg

m_{ed} is the total mass of diluted exhaust gas over the cycle, kg

u_{gas} is the tabulated value from table 5

D is the dilution factor

8.4.3. Particulate determination

8.4.3.1. Introduction

The determination of the particulates requires double dilution of the sample with filtered ambient air, synthetic air or nitrogen. The flow capacity of the full flow double dilution system shall be large enough to completely eliminate water condensation in the dilution and sampling systems, and maintain the temperature of the diluted exhaust gas between 315 K (42 °C) and 325 K (52 °C) immediately upstream of the filter holders. Dehumidifying the dilution air before entering the dilution system is permitted, and especially useful if dilution air humidity is high. The temperature of the dilution air shall be ≥ 288 K (15 °C) in close proximity to the entrance into the dilution tunnel.

To determine the mass of the particulates, a particulate sampling system, a particulate sampling filter, a microgram balance, and a temperature and humidity controlled weighing chamber, are required. The details of the system are described in paragraph 9.4.

8.4.3.2. Particulate sampling

The particulate sampling probe shall be installed in close proximity to the gaseous emissions sampling probe, but sufficiently distant as to not cause interference, in the dilution tunnel. Therefore, the installation provisions of paragraph 8.3.2.2. also apply to particulate sampling. The sampling line shall conform to the requirements laid down in Annex 3.

8.4.3.3. Calculation of mass emission

The particulate mass (g/test) shall be calculated after buoyancy correction of the particulate sample mass according to paragraph 9.4.3.5. as follows:

$$m_{PM} = \frac{m_f}{m_{sep}} \times \frac{m_{ed}}{1,000} \quad (51)$$

where:

m_f is the particulate mass sampled over the cycle, mg

m_{sep} is the mass of diluted exhaust gas passing the particulate collection filters, kg

m_{ed} is the mass of diluted exhaust gas over the cycle, kg

with

$$m_{sep} = m_{set} - m_{ssd} \quad (52)$$

where:

m_{set} is the mass of double diluted exhaust gas through particulate filter, kg

m_{ssd} is the mass of secondary dilution air, kg

If the particulate background level of the dilution air is determined in accordance with paragraph 7.8.2.5, the particulate mass may be background corrected. In this case, the particulate mass (g/test) shall be calculated as follows:

$$m_{PM} = \left[\frac{m_l}{m_{sep}} - \left(\frac{m_b}{m_{sd}} \times \left(1 - \frac{1}{D} \right) \right) \right] \times \frac{m_{ed}}{1,000} \quad (53)$$

where:

m_{sep} is the mass of diluted exhaust gas passing the particulate collection filters, kg

m_{ed} is the mass of diluted exhaust gas over the cycle, kg

m_{sd} is the mass of dilution air sampled by background particulate sampler, kg

m_b is the mass of the collected background particulates of the dilution air, mg

D is the dilution factor as determined in paragraph 8.4.2.4.2.

8.5. General calculations

8.5.1. Calculation of NMHC and CH₄ with the non-methane cutter

The concentration of NMHC and CH₄ shall be calculated as follows:

$$c_{NMHC} = \frac{c_{HC(w/oCutter)} \times (1 - E_M) - c_{HC(w/Cutter)}}{E_E - E_M} \quad (54)$$

$$c_{CH4} = \frac{c_{HC(w/Cutter)} - c_{HC(w/oCutter)} \times (1 - E_E)}{E_E - E_M} \quad (55)$$

where:

$c_{HC(w/Cutter)}$ is the HC concentration with sample gas flowing through the NMC, ppm

$c_{HC(w/oCutter)}$ is the HC concentration with sample gas bypassing the NMC, ppm

E_M is the methane efficiency as determined per paragraph 9.3.8.1.

E_E is the ethane efficiency as determined per paragraph 9.3.8.2.

8.5.2. Calculation of the specific emissions

The specific emissions e_{gas} or e_{PM} (g/kWh) shall be calculated for each individual component in the following ways depending on the type of test cycle.

8.5.2.1. Test result

For the WHSC, hot WHTC, or cold WHTC, the following formula shall be applied:

$$e = \frac{m}{W_{act}} \quad (56)$$

where:

m is the mass emission of the component, g/test

W_{act} is the actual cycle work as determined according to paragraph 7.7.1., kWh

~~For the WHTC, the final test result shall be a weighted average from cold start test and hot start test by using either of the following options:~~

$$e = \frac{(0.14 \times m_{\text{cold}}) + (0.86 \times m_{\text{hot}})}{(0.14 \times W_{\text{act,cold}}) + (0.86 \times W_{\text{act,hot}})} \quad (57a)$$

$$e = \frac{(0.1 \times m_{\text{cold}}) + (0.9 \times m_{\text{hot}})}{(0.1 \times W_{\text{act,cold}}) + (0.9 \times W_{\text{act,hot}})} \quad (57b)$$

~~The option shall be selected by the Contracting Parties.~~

8.5.2.2. **Exhaust after-treatment systems with periodic regeneration (to be reviewed, put OICA proposal here)**

The hot start emissions shall be weighted as follows:

$$e_w = \frac{n \times \bar{e} + n_r \times \bar{e}_r}{n + n_r} \quad (58)$$

where:

- n is the number of WHTC hot start tests outside regenerations
- n_r is the number of WHTC hot start tests during regeneration (minimum one test)
- \bar{e} is the average specific emission outside regeneration, g/kWh
- \bar{e}_r is the average specific emission during regeneration, g/kWh

The regeneration factor k_r shall be determined as follows:

$$k_r = \frac{e_w}{\bar{e}} \quad (59)$$

The regeneration factor k_r :

- (a) shall be applied to the weighted WHTC test result of paragraph 8.5.2.2.,
- (b) may be applied to the WHSC and cold WHTC, if a regeneration occurs during the cycle,
- (c) may be extended to other members of the same engine family,
- (d) may be extended to other engine families using the same aftertreatment system with the prior approval of the type approval or certification authority based on technical evidence to be supplied by the manufacturer that the emissions are similar.

9. MEASUREMENT EQUIPMENT

*** The subgroups shall reference the following text, which is extracted from GTR 4, as well as GTR 2, and the EPA Draft Test Procedure. Final Measurement Equipment determination should be appropriate for light-duty vehicles and in following with the established measurement procedures. Where appropriate, and possible, alternatives for measurement equipment shall be provided. ***

This gtr does not contain details of flow, pressure, and temperature measuring equipment or systems. Instead, only the linearity requirements of such equipment or systems necessary for conducting an emissions test are given in paragraph 9.2.

9.1. Dynamometer specification

~~An engine dynamometer with adequate characteristics to perform the appropriate test cycle described in paragraphs 7.2. and 7.3. shall be used.~~

~~The instrumentation for torque and speed measurement shall allow the measurement accuracy of the shaft power as needed to comply with the cycle validation criteria. Additional calculations may be necessary. The accuracy of the measuring equipment shall be such that the linearity requirements given in paragraph 9.2., table 6 are not exceeded.~~

9.2. Linearity requirements

~~The calibration of all measuring instruments and systems shall be traceable to national (international) standards. The measuring instruments and systems shall comply with the linearity requirements given in table 6. The linearity verification according to paragraph 9.2.1. shall be performed for the gas analyzers at least every 3 months or whenever a system repair or change is made that could influence calibration. For the other instruments and systems, the linearity verification shall be done as required by internal audit procedures, by the instrument manufacturer or in accordance with ISO 9000 requirements.~~

Measurement system	Intercept b	Slope m	Standard error SEE	Coefficient of determination r^2
Engine speed	$\leq 0.05 \% \text{ max}$	0.98 – 1.02	$\leq 2 \% \text{ max}$	≥ 0.990
Engine torque	$\leq 1 \% \text{ max}$	0.98 – 1.02	$\leq 2 \% \text{ max}$	≥ 0.990
Fuel flow	$\leq 1 \% \text{ max}$	0.98 – 1.02	$\leq 2 \% \text{ max}$	≥ 0.990
Airflow	$\leq 1 \% \text{ max}$	0.98 – 1.02	$\leq 2 \% \text{ max}$	≥ 0.990
Exhaust gas flow	$\leq 1 \% \text{ max}$	0.98 – 1.02	$\leq 2 \% \text{ max}$	≥ 0.990
Dilution airflow	$\leq 1 \% \text{ max}$	0.98 – 1.02	$\leq 2 \% \text{ max}$	≥ 0.990
Diluted exhaust gas flow	$\leq 1 \% \text{ max}$	0.98 – 1.02	$\leq 2 \% \text{ max}$	≥ 0.990
Sample flow	$\leq 1 \% \text{ max}$	0.98 – 1.02	$\leq 2 \% \text{ max}$	≥ 0.990
Gas analyzers	$\leq 0.5 \% \text{ max}$	0.99 – 1.01	$\leq 1 \% \text{ max}$	≥ 0.998
Gas dividers	$\leq 0.5 \% \text{ max}$	0.98 – 1.02	$\leq 2 \% \text{ max}$	≥ 0.990
Temperatures	$\leq 1 \% \text{ max}$	0.99 – 1.01	$\leq 1 \% \text{ max}$	≥ 0.998
Pressures	$\leq 1 \% \text{ max}$	0.99 – 1.01	$\leq 1 \% \text{ max}$	≥ 0.998
PM balance	$\leq 1 \% \text{ max}$	0.99 – 1.01	$\leq 1 \% \text{ max}$	≥ 0.998

Table 6:
Linearity requirements of instruments and measurement systems

9.2.1. Linearity verification

9.2.1.1. Introduction

A linearity verification shall be performed for each measurement system listed in table 6. At least 10 reference values shall be introduced to the measurement system, and the measured values shall be compared to the reference values by using a least squares linear regression. The maximum limits in table 6 refer to the maximum values expected during testing.

9.2.1.2. General requirements

The measurement systems shall be warmed up according to the recommendations of the instrument manufacturer. The measurement systems shall be operated at their specified temperatures, pressures and flows.

9.2.1.3. Procedure

The linearity verification shall be run for each normally used operating range with the following steps.

- (a) The instrument shall be set at zero by introducing a zero signal. For gas analyzers, purified synthetic air (or nitrogen) shall be introduced directly to the analyzer port.

- ~~———— (b) The instrument shall be spanned by introducing a span signal. For gas analyzers, an appropriate span gas shall be introduced directly to the analyzer port.~~
- ~~———— (c) The zero procedure of (a) shall be repeated.~~
- ~~———— (d) The verification shall be established by introducing at least 10 reference values (including zero) that are within the range from zero to the highest values expected during emission testing. For gas analyzers, known gas concentrations shall be introduced directly to the analyzer port.~~
- ~~———— (e) At a recording frequency of at least 1 Hz, the reference values shall be measured and the measured values recorded for 30 s.~~
- ~~———— (f) The arithmetic mean values over the 30 s period shall be used to calculate the least squares linear regression parameters according to equation 6 in paragraph 7.7.2.~~
- ~~———— (g) The linear regression parameters shall meet the requirements of paragraph 9.2., table 6.~~
- ~~———— (h) The zero setting shall be rechecked and the verification procedure repeated, if necessary.~~

9.3. Gaseous emissions measurement and sampling system

9.3.1. Analyzer specifications

9.3.1.1. General

The analyzers shall have a measuring range and response time appropriate for the accuracy required to measure the concentrations of the exhaust gas components ~~under transient and steady state conditions.~~

- ~~———— The electromagnetic compatibility (EMC) of the equipment shall be on a level as to minimize additional errors.~~

9.3.1.2. Accuracy

- ~~———— Accuracy is defined as the deviation of the analyzer reading from the reference value. The accuracy shall not exceed ± 2 per cent of the reading or ± 0.3 per cent of full scale whichever is larger.~~

9.3.1.3. Precision

- ~~———— The precision, defined as 2.5 times the standard deviation of 10 repetitive responses to a given calibration or span gas, shall be no greater than 1 per cent of full scale concentration for each range used above 155 ppm (or ppm C) or 2 per cent of each range used below 155 ppm (or ppm C).~~

~~9.3.1.4. Noise~~

~~———— The analyzer peak to peak response to zero and calibration or span gases over any 10 seconds period shall not exceed 2 per cent of full scale on all ranges used.~~

~~9.3.1.5. Zero drift~~

~~———— Zero response is defined as the mean response, including noise, to a zero gas during a 30 s time interval. The drift of the zero response during a one hour period shall be less than 2 per cent of full scale on the lowest range used.~~

~~9.3.1.6. Span drift~~

~~———— Span response is defined as the mean response, including noise, to a span gas during a 30 s time interval. The drift of the span response during a one hour period shall be less than 2 per cent of full scale on the lowest range used.~~

~~9.3.1.7. Rise time~~

~~———— The rise time of the analyzer installed in the measurement system shall not exceed 2.5 s.~~

~~9.3.1.8. Gas drying~~

~~———— Exhaust gases may be measured wet or dry. A gas drying device, if used, shall have a minimal effect on the composition of the measured gases. Chemical dryers are not an acceptable method of removing water from the sample.~~

~~9.3.2. Gas analyzers~~

~~9.3.2.1. Introduction~~

~~———— Paragraphs 9.3.2.2 to 9.2.3.7 describe the measurement principles to be used. A detailed description of the measurement systems is given in Annex 3. The gases to be measured shall be analyzed with the following instruments. For non linear analyzers, the use of linearizing circuits is permitted.~~

~~9.3.2.2. Carbon monoxide (CO) analysis~~

~~———— The carbon monoxide analyzer shall be of the non dispersive infrared (NDIR) absorption type.~~

~~9.3.2.3. Carbon dioxide (CO₂) analysis~~

~~———— The carbon dioxide analyzer shall be of the non dispersive infrared (NDIR) absorption type.~~

~~9.3.2.4. Hydrocarbon (HC) analysis~~

~~———— The hydrocarbon analyzer shall be of the heated flame ionization detector (HFID) type with detector, valves, pipework, etc. heated so as to maintain a gas temperature of $463\text{ K} \pm 10\text{ K}$ ($190 \pm 10\text{ }^{\circ}\text{C}$). Optionally, for NG-fueled and PI engines, the hydrocarbon analyzer may be of the non-heated flame ionization detector (FID) type depending upon the method used (see Annex 3, paragraph A.3.1.3.).~~

~~9.3.2.5. Non-methane hydrocarbon (NMHC) analysis~~

~~———— The determination of the non-methane hydrocarbon fraction shall be performed with a heated non-methane cutter (NMC) operated in-line with an FID as per Annex 3, paragraph A.3.1.4. by subtraction of the methane from the hydrocarbons.~~

~~9.3.2.6. Oxides of nitrogen (NO_x) analysis~~

~~———— If measured on a dry basis, the oxides of nitrogen analyzer shall be of the chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD) type with a NO_2/NO converter. If measured on a wet basis, a HCLD with converter maintained above 328 K ($55\text{ }^{\circ}\text{C}$) shall be used, provided the water-quench check (see paragraph 9.3.9.2.2.) is satisfied. For both CLD and HCLD, the sampling path shall be maintained at a wall temperature of 328 K to 473 K ($55\text{ }^{\circ}\text{C}$ to $200\text{ }^{\circ}\text{C}$) up to the converter for dry measurement, and up to the analyzer for wet measurement.~~

~~9.3.2.7. Air-to-fuel measurement~~

~~———— The air-to-fuel measurement equipment used to determine the exhaust gas flow as specified in paragraph 8.3.1.6. shall be a wide-range air-to-fuel ratio sensor or lambda sensor of Zirconia type. The sensor shall be mounted directly on the exhaust pipe where the exhaust gas temperature is high enough to eliminate water condensation.~~

~~———— The accuracy of the sensor with incorporated electronics shall be within:~~

~~———— ± 3 per cent of reading for $\lambda < 2$~~

~~———— ± 5 per cent of reading for $2 \leq \lambda < 5$~~

~~———— ± 10 per cent of reading for $5 \leq \lambda$~~

~~———— To fulfill the accuracy specified above, the sensor shall be calibrated as specified by the instrument manufacturer.~~

~~9.3.3. Calibration gases~~

~~———— The shelf life of all calibration gases shall be respected. The expiration date of the calibration gases stated by the manufacturer shall be recorded.~~

~~9.3.3.1. Pure gases~~

~~The required purity of the gases is defined by the contamination limits given below.
The following gases shall be available for operation:~~

~~Purified nitrogen~~

~~(Contamination ≤ 1 ppm C1, ≤ 1 ppm CO, ≤ 400 ppm CO₂, ≤ 0.1 ppm NO)~~

~~Purified oxygen~~

~~(Purity > 99.5 per cent vol O₂)~~

~~Hydrogen helium mixture~~

~~(40 \pm 2 per cent hydrogen, balance helium)~~

~~(Contamination ≤ 1 ppm C1, ≤ 400 ppm CO₂)~~

~~Purified synthetic air~~

~~(Contamination ≤ 1 ppm C1, ≤ 1 ppm CO, ≤ 400 ppm CO₂, ≤ 0.1 ppm NO)~~

~~(Oxygen content between 18.21 per cent vol.)~~

~~9.3.3.2. Calibration and span gases~~

~~Mixtures of gases having the following chemical compositions shall be available.
Other gas combinations are allowed provided the gases do not react with one another:~~

~~C₃H₈ and purified synthetic air (see paragraph 9.3.3.1.);~~

~~CO and purified nitrogen;~~

~~NO_x and purified nitrogen (the amount of NO₂ contained in this calibration gas shall not exceed 5 per cent of the NO content);~~

~~CO₂ and purified nitrogen~~

~~CH₄ and purified synthetic air~~

~~C₂H₆ and purified synthetic air~~

~~The true concentration of a calibration and span gas shall be within ± 1 per cent of the nominal value, and shall be traceable to national or international standards. All concentrations of calibration gas shall be given on a volume basis (volume percent or volume ppm).~~

9.3.3.3. Gas dividers

- ~~The gases used for calibration and span may also be obtained by means of gas dividers (precision blending devices), diluting with purified N₂ or with purified synthetic air. The accuracy of the gas divider shall be such that the concentration of the blended calibration gases is accurate to within ± 2 per cent. This accuracy implies that primary gases used for blending shall be known to an accuracy of at least ± 1 per cent, traceable to national or international gas standards. The verification shall be performed at between 15 and 50 per cent of full scale for each calibration incorporating a gas divider. An additional verification may be performed using another calibration gas, if the first verification has failed.~~
- ~~Optionally, the blending device may be checked with an instrument which by nature is linear, e.g. using NO gas with a CLD. The span value of the instrument shall be adjusted with the span gas directly connected to the instrument. The gas divider shall be checked at the settings used and the nominal value shall be compared to the measured concentration of the instrument. This difference shall in each point be within ± 1 per cent of the nominal value.~~
- ~~For conducting the linearity verification according to paragraph 9.2.1., the gas divider shall be accurate to within ± 1 per cent.~~

9.3.3.4. Oxygen interference check gases

- ~~Oxygen interference check gases are a blend of propane, oxygen and nitrogen. They shall contain propane with 350 ppm C \pm 75 ppm C hydrocarbon. The concentration value shall be determined to calibration gas tolerances by chromatographic analysis of total hydrocarbons plus impurities or by dynamic blending. The oxygen concentrations required for positive ignition and compression ignition engine testing are listed in table 7 with the remainder being purified nitrogen.~~

Type of engine	O ₂ concentration (per cent)
Compression ignition	21 (20 to 22)
Compression and positive ignition	10 (9 to 11)
Compression and positive ignition	5 (4 to 6)
Positive ignition	0 (0 to 1)

~~Table 7:~~
Oxygen interference check gases

9.3.4. Leakage test

- ~~A system leakage test shall be performed. The probe shall be disconnected from the exhaust system and the end plugged. The analyzer pump shall be switched on. After an initial stabilization period all flowmeters will read approximately zero in the absence of a leak. If not, the sampling lines shall be checked and the fault corrected.~~

~~The maximum allowable leakage rate on the vacuum side shall be 0.5 per cent of the in-use flow rate for the portion of the system being checked. The analyzer flows and bypass flows may be used to estimate the in-use flow rates.~~

~~Alternatively, the system may be evacuated to a pressure of at least 20 kPa vacuum (80 kPa absolute). After an initial stabilization period the pressure increase Δp (kPa/min) in the system shall not exceed:~~

$$\Delta p = p / V_s \times 0.005 \times q_{vs} \quad (60)$$

~~where:~~

~~V_s is the system volume, l~~

~~q_{vs} is the system flow rate, l/min~~

~~Another method is the introduction of a concentration step change at the beginning of the sampling line by switching from zero to span gas. If for a correctly calibrated analyzer after an adequate period of time the reading is ≤ 99 per cent compared to the introduced concentration, this points to a leakage problem that shall be corrected.~~

9.3.5. Response time check of the analytical system

~~The system settings for the response time evaluation shall be exactly the same as during measurement of the test run (i.e. pressure, flow rates, filter settings on the analyzers and all other response time influences). The response time determination shall be done with gas switching directly at the inlet of the sample probe. The gas switching shall be done in less than 0.1 s. The gases used for the test shall cause a concentration change of at least 60 per cent full scale (FS).~~

~~The concentration trace of each single gas component shall be recorded. The response time is defined to be the difference in time between the gas switching and the appropriate change of the recorded concentration. The system response time (t_{90}) consists of the delay time to the measuring detector and the rise time of the detector. The delay time is defined as the time from the change (t_0) until the response is 10 per cent of the final reading (t_{10}). The rise time is defined as the time between 10 per cent and 90 per cent response of the final reading ($t_{90} - t_{10}$).~~

~~For time alignment of the analyzer and exhaust flow signals, the transformation time is defined as the time from the change (t_0) until the response is 50 per cent of the final reading (t_{50}).~~

~~The system response time shall be ≤ 10 s with a rise time of ≤ 2.5 s in accordance with paragraph 9.3.1.7. for all limited components (CO, NO_x, HC or NMHC) and all ranges used. When using a NMC for the measurement of NMHC, the system response time may exceed 10 s.~~

9.3.6. Efficiency test of NO_x-converter

The efficiency of the converter used for the conversion of NO₂ into NO is tested as given in paragraphs 9.3.6.1 to 9.3.6.8 (see figure 8).

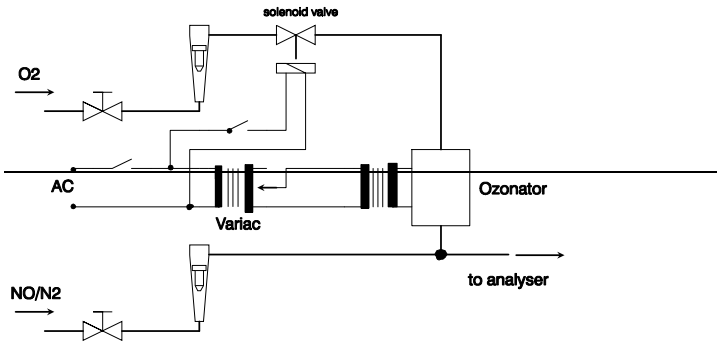


Figure 8:
Scheme of NO₂-converter efficiency device

9.3.6.1. Test setup

Using the test setup as schematically shown in figure 8 and the procedure below, the efficiency of the converter shall be tested by means of an ozonator.

9.3.6.2. Calibration

The CLD and the HCLD shall be calibrated in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which shall amount to about 80 per cent of the operating range and the NO₂ concentration of the gas mixture to less than 5 per cent of the NO concentration). The NO_x-analyzer shall be in the NO mode so that the span gas does not pass through the converter. The indicated concentration has to be recorded.

9.3.6.3. Calculation

The per cent efficiency of the converter shall be calculated as follows:

$$E_{NO_x} = \left(1 + \frac{a - b}{c - d} \right) \times 100 \tag{61}$$

- where:
- a is the NO_x-concentration according to paragraph 9.3.6.6.
 - b is the NO_x-concentration according to paragraph 9.3.6.7.
 - c is the NO concentration according to paragraph 9.3.6.4.
 - d is the NO concentration according to paragraph 9.3.6.5.

~~9.3.6.4. Adding of oxygen~~

~~———— Via a T fitting, oxygen or zero air shall be added continuously to the gas flow until the concentration indicated is about 20 per cent less than the indicated calibration concentration given in paragraph 9.3.6.2. (the analyzer is in the NO mode).~~

~~———— The indicated concentration (c) shall be recorded. The ozonator is kept deactivated throughout the process.~~

~~9.3.6.5. Activation of the ozonator~~

~~———— The ozonator shall be activated to generate enough ozone to bring the NO concentration down to about 20 per cent (minimum 10 per cent) of the calibration concentration given in paragraph 9.3.6.2. The indicated concentration (d) shall be recorded (the analyzer is in the NO mode).~~

~~9.3.6.6. NO_x mode~~

~~———— The NO analyzer shall be switched to the NO_x mode so that the gas mixture (consisting of NO, NO₂, O₂ and N₂) now passes through the converter. The indicated concentration (a) shall be recorded (the analyzer is in the NO_x mode).~~

~~9.3.6.7. Deactivation of the ozonator~~

~~———— The ozonator is now deactivated. The mixture of gases described in paragraph 9.3.6.6. passes through the converter into the detector. The indicated concentration (b) shall be recorded (the analyzer is in the NO_x mode).~~

~~9.3.6.8. NO mode~~

~~———— Switched to NO mode with the ozonator deactivated, the flow of oxygen or synthetic air shall be shut off. The NO_x reading of the analyzer shall not deviate by more than ± 5 per cent from the value measured according to paragraph 9.3.6.2. (the analyzer is in the NO mode).~~

~~9.3.6.9. Test interval~~

~~———— The efficiency of the converter shall be tested at least once per month.~~

~~9.3.6.10. Efficiency requirement~~

~~———— The efficiency of the converter E_{NO_x} shall not be less than 95 per cent.~~

~~———— If, with the analyzer in the most common range, the ozonator cannot give a reduction from 80 per cent to 20 per cent according to paragraph 9.3.6.5., the highest range which will give the reduction shall be used.~~

~~9.3.7. Adjustment of the FID~~

~~9.3.7.1. Optimization of the detector response~~

~~————— The FID shall be adjusted as specified by the instrument manufacturer. A propane in air span gas shall be used to optimize the response on the most common operating range.~~

~~————— With the fuel and airflow rates set at the manufacturer's recommendations, a 350 ± 75 ppm C span gas shall be introduced to the analyzer. The response at a given fuel flow shall be determined from the difference between the span gas response and the zero gas response. The fuel flow shall be incrementally adjusted above and below the manufacturer's specification. The span and zero response at these fuel flows shall be recorded. The difference between the span and zero response shall be plotted and the fuel flow adjusted to the rich side of the curve. This is the initial flow rate setting which may need further optimization depending on the results of the hydrocarbon response factors and the oxygen interference check according to paragraphs 9.3.7.2. and 9.3.7.3. If the oxygen interference or the hydrocarbon response factors do not meet the following specifications, the airflow shall be incrementally adjusted above and below the manufacturer's specifications, repeating paragraphs 9.3.7.2. and 9.3.7.3. for each flow.~~

~~————— The optimization may optionally be conducted using the procedures outlined in SAE paper No. 770141.~~

~~9.3.7.2. Hydrocarbon response factors~~

~~————— A linearity verification of the analyzer shall be performed using propane in air and purified synthetic air according to paragraph 9.2.1.3.~~

~~————— Response factors shall be determined when introducing an analyzer into service and after major service intervals. The response factor (r_h) for a particular hydrocarbon species is the ratio of the FID C1 reading to the gas concentration in the cylinder expressed by ppm C1.~~

~~————— The concentration of the test gas shall be at a level to give a response of approximately 80 per cent of full scale. The concentration shall be known to an accuracy of ± 2 per cent in reference to a gravimetric standard expressed in volume. In addition, the gas cylinder shall be preconditioned for 24 hours at a temperature of $298 \text{ K} \pm 5 \text{ K}$ ($25^\circ\text{C} \pm 5^\circ\text{C}$).~~

~~————— The test gases to be used and the relative response factor ranges are as follows:~~

- ~~————— (a) Methane and purified synthetic air $1.00 \leq r_h \leq 1.15$~~
- ~~————— (b) Propylene and purified synthetic air $0.90 \leq r_h \leq 1.1$~~
- ~~————— (c) Toluene and purified synthetic air $0.90 \leq r_h \leq 1.1$~~

~~————— These values are relative to a r_h of 1 for propane and purified synthetic air.~~

9.3.7.3. ~~Oxygen interference check~~

~~For raw exhaust gas analyzers only, the oxygen interference check shall be performed when introducing an analyzer into service and after major service intervals.~~

~~A measuring range shall be chosen where the oxygen interference check gases will fall in the upper 50 per cent. The test shall be conducted with the oven temperature set as required. Oxygen interference check gas specifications are found in paragraph 9.3.3.4.~~

- ~~(a) The analyzer shall be set at zero.~~
- ~~(b) The analyzer shall be spanned with the 0 per cent oxygen blend for positive ignition engines. Compression ignition engine instruments shall be spanned with the 21 per cent oxygen blend.~~
- ~~(c) The zero response shall be rechecked. If it has changed by more than 0.5 per cent of full scale, steps (a) and (b) of this paragraph shall be repeated.~~
- ~~(d) The 5 per cent and 10 per cent oxygen interference check gases shall be introduced.~~
- ~~(e) The zero response shall be rechecked. If it has changed by more than ± 1 per cent of full scale, the test shall be repeated.~~
- ~~(f) The oxygen interference E_{O_2} shall be calculated for each mixture in step (d) as follows:~~

$$E_{O_2} = (e_{ref,d} - e) \times 100 / e_{ref,d} \quad (62)$$

~~with the analyzer response being~~

$$e = \frac{C_{ref,b} \times C_{FS,b}}{C_{m,b}} \times \frac{C_{m,d}}{C_{FS,d}} \quad (63)$$

~~where:~~

- ~~$e_{ref,b}$ is the reference HC concentration in step (b), ppm C~~
- ~~$e_{ref,d}$ is the reference HC concentration in step (d), ppm C~~
- ~~$e_{FS,b}$ is the full scale HC concentration in step (b), ppm C~~
- ~~$e_{FS,d}$ is the full scale HC concentration in step (d), ppm C~~
- ~~$e_{m,b}$ is the measured HC concentration in step (b), ppm C~~
- ~~$e_{m,d}$ is the measured HC concentration in step (d), ppm C~~

- ~~(g) The oxygen interference E_{O_2} shall be less than ± 1.5 per cent for all required oxygen interference check gases prior to testing.~~
- ~~(h) If the oxygen interference E_{O_2} is greater than ± 1.5 per cent, corrective action may be taken by incrementally adjusting the airflow above and below the manufacturer's specifications, the fuel flow and the sample flow.~~
- ~~(i) The oxygen interference shall be repeated for each new setting.~~

9.3.8. ~~Efficiency of the non-methane cutter (NMC)~~

The NMC is used for the removal of the non-methane hydrocarbons from the sample gas by oxidizing all hydrocarbons except methane. Ideally, the conversion for methane is 0 per cent, and for the other hydrocarbons represented by ethane is 100 per cent. For the accurate measurement of NMHC, the two efficiencies shall be determined and used for the calculation of the NMHC emission mass flow rate (see paragraph 8.5.1.).

9.3.8.1. Methane Efficiency

Methane calibration gas shall be flown through the FID with and without bypassing the NMC and the two concentrations recorded. The efficiency shall be determined as follows:

$$E_M = 1 - \frac{c_{HC(w/cutter)}}{c_{HC(w/o\ cutter)}} \quad (64)$$

where:

$c_{HC(w/cutter)}$ is the HC concentration with CH_4 flowing through the NMC, ppm C

$c_{HC(w/o\ cutter)}$ is the HC concentration with CH_4 bypassing the NMC, ppm C

9.3.8.2. Ethane Efficiency

Ethane calibration gas shall be flown through the FID with and without bypassing the NMC and the two concentrations recorded. The efficiency shall be determined as follows:

$$E_E = 1 - \frac{c_{HC(w/cutter)}}{c_{HC(w/o\ cutter)}} \quad (65)$$

where:

$c_{HC(w/cutter)}$ is the HC concentration with C_2H_6 flowing through the NMC, ppm C

$c_{HC(w/o\ cutter)}$ is the HC concentration with C_2H_6 bypassing the NMC, ppm C

9.3.9. Interference effects

Other gases than the one being analyzed can interfere with the reading in several ways. Positive interference occurs in NDIR instruments where the interfering gas gives the same effect as the gas being measured, but to a lesser degree. Negative interference occurs in NDIR instruments by the interfering gas broadening the absorption band of the measured gas, and in CLD instruments by the interfering gas quenching the reaction. The interference checks in paragraphs 9.3.9.1. and 9.3.9.2. shall be performed prior to an analyzer's initial use and after major service intervals.

9.3.9.1. CO analyzer interference check

Water and CO_2 can interfere with the CO analyzer performance. Therefore, a CO_2 span gas having a concentration of 80 to 100 per cent of full scale of the maximum operating range used during testing shall be bubbled through water at room temperature and the analyzer response recorded. The analyzer response shall not be

~~more than 1 per cent of full scale for ranges equal to or above 300 ppm or more than 3 ppm for ranges below 300 ppm.~~

~~9.3.9.2. NO_x analyzer quench checks~~

~~The two gases of concern for CLD (and HCLD) analyzers are CO₂ and water vapour. Quench responses to these gases are proportional to their concentrations, and therefore require test techniques to determine the quench at the highest expected concentrations experienced during testing.~~

~~9.3.9.2.1. CO₂ quench check~~

~~A CO₂ span gas having a concentration of 80 to 100 per cent of full scale of the maximum operating range shall be passed through the NDIR analyzer and the CO₂ value recorded as *A*. It shall then be diluted approximately 50 per cent with NO span gas and passed through the NDIR and CLD, with the CO₂ and NO values recorded as *B* and *C*, respectively. The CO₂ shall then be shut off and only the NO span gas be passed through the (H)CLD and the NO value recorded as *D*.~~

~~The per cent quench shall be calculated as follows:~~

$$E_{\text{CO}_2} = \left[1 - \frac{(C \times A)}{(D \times A) - (D \times B)} \right] \times 100 \quad (66)$$

~~where:~~

~~*A* is the undiluted CO₂ concentration measured with NDIR, per cent~~

~~*B* is the diluted CO₂ concentration measured with NDIR, per cent~~

~~*C* is the diluted NO concentration measured with (H)CLD, ppm~~

~~*D* is the undiluted NO concentration measured with (H)CLD, ppm~~

~~Alternative methods of diluting and quantifying of CO₂ and NO span gas values such as dynamic mixing/blending are permitted with the approval of the type approval or certification authority.~~

~~9.3.9.2.2. Water quench check~~

~~This check applies to wet gas concentration measurements only. Calculation of water quench shall consider dilution of the NO span gas with water vapour and sealing of water vapour concentration of the mixture to that expected during testing.~~

~~A NO span gas having a concentration of 80 per cent to 100 per cent of full scale of the normal operating range shall be passed through the (H) CLD and the NO value recorded as *D*. The NO span gas shall then be bubbled through water at room temperature and passed through the (H) CLD and the NO value recorded as *C*. The water temperature shall be determined and recorded as *F*. The mixture's saturation vapour pressure that corresponds to the bubbler water temperature (*F*) shall be determined and recorded as *G*.~~

~~The water vapour concentration (in per cent) of the mixture shall be calculated as follows:~~

$$H = 100 \times (G / p_b) \quad (67)$$

~~and recorded as H . The expected diluted NO span gas (in water vapour) concentration shall be calculated as follows:~~

$$D_e = D \times (1 - H / 100) \quad (68)$$

~~and recorded as D_e . For diesel exhaust, the maximum exhaust water vapour concentration (in per cent) expected during testing shall be estimated, under the assumption of a fuel H/C ratio of 1.8/1, from the maximum CO_2 concentration in the exhaust gas A as follows:~~

$$H_m = 0.9 \times A \quad (69)$$

~~and recorded as H_m~~

~~The per cent water quench shall be calculated as follows:~~

$$E_{\text{H}_2\text{O}} = 100 \times ((D_e - C) / D_e) \times (H_m / H) \quad (70)$$

~~where:~~

~~D_e is the expected diluted NO concentration, ppm~~

~~C is the measured diluted NO concentration, ppm~~

~~H_m is the maximum water vapour concentration, per cent~~

~~H is the actual water vapour concentration, per cent~~

~~9.3.9.2.3. Maximum allowable quench~~

- ~~(a) For raw measurement:~~
 - ~~(i) CO₂ quench according to paragraph 9.3.9.2.1.: 2 per cent of full scale~~
 - ~~(ii) water quench according to paragraph 9.3.9.2.2.: 3 per cent of full scale~~
- ~~(b) For dilute measurement:~~
 - ~~(i) 2 per cent combined CO₂ and water quench.~~

~~9.3.9.2.4. Efficiency of the cooling bath~~

~~For dry CLD analyzers, it shall be demonstrated that for the highest expected water vapour concentration H_{m} (see paragraph 9.3.9.2.2.), the water removal technique maintains CLD humidity at ≤ 5 g water/kg dry air (or about 0.008 per cent H₂O), which is 100 per cent relative humidity at 3.9 °C and 101.3 kPa. This humidity specification is also equivalent to about 25 per cent relative humidity at 25 °C and 101.3 kPa. This may be demonstrated by measuring the temperature at the outlet of a thermal dehumidifier, or by measuring humidity at a point just upstream of the CLD. Humidity of the CLD exhaust might also be measured as long as the only flow into the CLD is the flow from the dehumidifier.~~

9.4. Particulate measurement and sampling system

9.4.1. General specifications

To determine the mass of the particulates, a particulate sampling system, a particulate sampling filter, a microgram balance, and a temperature and humidity controlled weighing chamber, are required. The particulate sampling system shall be designed to ensure a representative sample of the particulates proportional to the exhaust flow.

9.4.2. Particulate sampling filters

The diluted exhaust shall be sampled by a filter that meets the requirements of paragraphs 9.4.2.1. to 9.4.2.3. during the test sequence. Selection of the options in paragraphs 9.4.2.1. and 9.4.2.2. shall be decided by the Contracting Parties.

9.4.2.1. Filter specification

All filter types shall have a 0.3 µm DOP (di-octylphthalate) collection efficiency of at least 99 per cent. The filter material shall be either:

- (a) fluorocarbon (PTFE) coated glass fiber, or
- (b) fluorocarbon (PTFE) membrane.

9.4.2.2. Filter size

The filter size shall be either:

- (a) 47 mm diameter or
- (b) 70 mm diameter.

9.4.2.3. Filter face velocity

The face velocity through the filter shall not exceed 1 m/s. The pressure drop increase between the beginning and the end of the test shall not exceed 25 kPa.

9.4.3. Weighing chamber and analytical balance specifications

9.4.3.1. Weighing chamber conditions

The temperature of the chamber (or room) in which the particulate filters are conditioned and weighed shall be maintained to within $295 \text{ K} \pm 3 \text{ K}$ ($22^\circ\text{C} \pm 3^\circ\text{C}$) during all filter conditioning and weighing. The humidity shall be maintained to a dew point of $282.5 \text{ K} \pm 3 \text{ K}$ ($9.5^\circ\text{C} \pm 3^\circ\text{C}$) and a relative humidity of 45 per cent ± 8 per cent. For sensitive balances, it is recommended that the tolerance for the weighing chamber room air temperature and the dew point be $\pm 1 \text{ K}$.

9.4.3.2. Reference filter weighing

The chamber (or room) environment shall be free of any ambient contaminants (such as dust) that would settle on the particulate filters during their stabilization. Disturbances to weighing room specifications as outlined in paragraph 9.4.3.1. will be allowed if the duration of the disturbances does not exceed 30 minutes. The weighing room shall meet the required specifications prior to personal entrance into the weighing room. At least two unused reference filters shall be weighed within 12 hours of, but preferably at the same time as the sample filter weighing. They shall be the same size and material as the sample filters.

If the average weight of the reference filters changes between sample filter weighings by more than $10 \mu\text{g}$, all sample filters shall be discarded and the emissions test repeated.

9.4.3.3. Analytical balance

The analytical balance used to determine the filter weight shall meet the linearity verification criterion of paragraph 9.2., table 6. This implies a precision (standard deviation) of at least $2 \mu\text{g}$ and a resolution of at least $1 \mu\text{g}$ (1 digit = $1 \mu\text{g}$).

9.4.3.4. Elimination of static electricity effects

The filter shall be neutralized prior to weighing, e.g. by a Polonium neutralizer or a device of similar effect.

9.4.3.5. Buoyancy correction

The sampling filter shall be corrected for its buoyancy in air. The buoyancy correction depends on sampling filter density, air density and the density of the balance calibration weight, and does not account for the buoyancy of the PM itself.

If the density of the filter material is not known, the following densities shall be used:

- (a) teflon coated glass fiber filter: 2,300 kg/m³
- (b) teflon membrane filter: 2,144 kg/m³
- (c) teflon membrane filter with polymethylpentene support ring: 920 kg/m³

For stainless steel calibration weights, a density of 8,000 kg/m³ shall be used. If the material of the calibration weight is different, its density must be known.

The following equation shall be used:

$$m_f = m_{\text{uncor}} \times \left(\frac{1 - \frac{\rho_a}{\rho_w}}{1 - \frac{\rho_a}{\rho_f}} \right) \quad (71)$$

with

$$\rho_a = \frac{p_b \times 28.836}{8.3144 \times T_a} \quad (72)$$

where:

m_{uncor}	is the uncorrected particulate sample mass, mg
ρ_a	is the density of the air, kg/m ³
ρ_w	is the density of balance calibration weight, kg/m ³
ρ_f	is the density of the particulate sampling filter, kg/m ³
p_b	is the total atmospheric pressure, kPa
T_a	is the air temperature in the balance environment, K
28.836	is the molar mass of the air at reference humidity (9.5 K), g/mol
8.3144	is the molar gas constant

9.4.4. Specifications for differential flow measurement (partial flow dilution only)

For partial flow dilution systems, the accuracy of the sample flow q_{mp} is of special concern, if not measured directly, but determined by differential flow measurement:

$$q_{mp} = q_{mdew} - q_{mdw} \quad (73)$$

In this case, the maximum error of the difference shall be such that the accuracy of q_{mp} is within ± 5 per cent when the dilution ratio is less than 15. It can be calculated by taking root-mean-square of the errors of each instrument.

Acceptable accuracies of q_{mp} can be obtained by either of the following methods:

- (a) The absolute accuracies of q_{mdew} and q_{mdw} are ± 0.2 per cent which guarantees an accuracy of q_{mp} of ≤ 5 per cent at a dilution ratio of 15. However, greater errors will occur at higher dilution ratios.
- (b) Calibration of q_{mdw} relative to q_{mdew} is carried out such that the same accuracies for q_{mp} as in (a) are obtained. For details see paragraph 9.4.6.2.
- (c) The accuracy of q_{mp} is determined indirectly from the accuracy of the dilution ratio as determined by a tracer gas, e.g. CO₂. Accuracies equivalent to method (a) for q_{mp} are required.
- (d) The absolute accuracy of q_{mdew} and q_{mdw} is within ± 2 per cent of full scale, the maximum error of the difference between q_{mdew} and q_{mdw} is within 0.2 per cent, and the linearity error is within ± 0.2 per cent of the highest q_{mdew} observed during the test.

9.4.5. Additional specifications

All parts of the dilution system and the sampling system from the exhaust pipe up to the filter holder, which are in contact with raw and diluted exhaust gas, shall be designed to minimize deposition or alteration of the particulates. All parts shall be made of electrically conductive materials that do not react with exhaust gas components, and shall be electrically grounded to prevent electrostatic effects.

9.4.6. Calibration of the flow measurement instrumentation

9.4.6.1. General specifications

Each flowmeter used in a particulate sampling and partial flow dilution system shall be subjected to the linearity verification, as described in paragraph 9.2.1., as often as necessary to fulfil the accuracy requirements of this gr. For the flow reference values, an accurate flowmeter traceable to international and/or national standards shall be used.

9.4.6.2. Calibration of differential flow measurement (partial flow dilution only)

The flowmeter or the flow measurement instrumentation shall be calibrated in one of the following procedures, such that the probe flow q_{mp} into the tunnel shall fulfil the accuracy requirements of paragraph 9.4.4.:

- (a) The flowmeter for q_{mdw} shall be connected in series to the flowmeter for q_{mdew} , the difference between the two flowmeters shall be calibrated for at least 5 set points with flow values equally spaced between the lowest q_{mdw} value used during the test and the value of q_{mdew} used during the test. The dilution tunnel may be bypassed.
- (b) A calibrated flow device shall be connected in series to the flowmeter for q_{mdew} and the accuracy shall be checked for the value used for the test. The calibrated flow device shall be connected in series to the flowmeter for q_{mdw} ,

and the accuracy shall be checked for at least 5 settings corresponding to dilution ratio between 3 and 50, relative to q_{mdew} used during the test.

- (c) The transfer tube (TT) shall be disconnected from the exhaust, and a calibrated flow-measuring device with a suitable range to measure q_{mp} shall be connected to the transfer tube. q_{mdew} shall be set to the value used during the test, and q_{mdw} shall be sequentially set to at least 5 values corresponding to dilution ratios between 3 and 50. Alternatively, a special calibration flow path may be provided, in which the tunnel is bypassed, but the total and dilution airflow through the corresponding meters as in the actual test.
- (d) A tracer gas shall be fed into the exhaust transfer tube TT. This tracer gas may be a component of the exhaust gas, like CO₂ or NO_x. After dilution in the tunnel the tracer gas component shall be measured. This shall be carried out for 5 dilution ratios between 3 and 50. The accuracy of the sample flow shall be determined from the dilution ratio r_d :

$$q_{mp} = q_{mdew} / r_d \quad (74)$$

The accuracies of the gas analyzers shall be taken into account to guarantee the accuracy of q_{mp} .

9.4.7. Special requirements for the partial flow dilution system

9.4.7.1. Carbon flow check

A carbon flow check using actual exhaust is strongly recommended for detecting measurement and control problems and verifying the proper operation of the partial flow system. The carbon flow check should be run at least each time a new engine is installed, or something significant is changed in the test cell configuration.

The engine shall be operated at peak torque load and speed or any other steady state mode that produces 5 per cent or more of CO₂. The partial flow sampling system shall be operated with a dilution factor of about 15 to 1.

If a carbon flow check is conducted, the procedure given in Annex 5 shall be applied. The carbon flow rates shall be calculated according to equations 80 to 82 in Annex 5. All carbon flow rates should agree to within 3 per cent.

9.4.7.2. Pre-test check

A pre-test check shall be performed within 2 hours before the test run in the following way.

The accuracy of the flowmeters shall be checked by the same method as used for calibration (see paragraph 9.4.6.2.) for at least two points, including flow values of q_{mdw} that correspond to dilution ratios between 5 and 15 for the q_{mdew} value used during the test.

If it can be demonstrated by records of the calibration procedure under paragraph 9.4.6.2. that the flowmeter calibration is stable over a longer period of time, the pre-test check may be omitted.

9.4.7.3. Determination of the transformation time

The system settings for the transformation time evaluation shall be exactly the same as during measurement of the test run. The transformation time shall be determined by the following method.

An independent reference flowmeter with a measurement range appropriate for the probe flow shall be put in series with and closely coupled to the probe. This flowmeter shall have a transformation time of less than 100 ms for the flow step size used in the response time measurement, with flow restriction sufficiently low as to not affect the dynamic performance of the partial flow dilution system, and consistent with good engineering practice.

A step change shall be introduced to the exhaust flow (or airflow if exhaust flow is calculated) input of the partial flow dilution system, from a low flow to at least 90 per cent of full scale. The trigger for the step change shall be the same one used to start the look-ahead control in actual testing. The exhaust flow step stimulus and the flowmeter response shall be recorded at a sample rate of at least 10 Hz.

From this data, the transformation time shall be determined for the partial flow dilution system, which is the time from the initiation of the step stimulus to the 50 per cent point of the flowmeter response. In a similar manner, the transformation times of the q_{np} signal of the partial flow dilution system and of the $q_{mew,i}$ signal of the exhaust flowmeter shall be determined. These signals are used in the regression checks performed after each test (see paragraph 8.3.3.3.)

The calculation shall be repeated for at least 5 rise and fall stimuli, and the results shall be averaged. The internal transformation time (< 100 ms) of the reference flowmeter shall be subtracted from this value. This is the "look-ahead" value of the partial flow dilution system, which shall be applied in accordance with paragraph 8.3.3.3.

9.5. ~~Calibration of the CVS system~~

9.5.1. ~~General~~

~~The CVS system shall be calibrated by using an accurate flowmeter and a restricting device. The flow through the system shall be measured at different restriction settings, and the control parameters of the system shall be measured and related to the flow.~~

~~Various types of flowmeters may be used, e.g. calibrated venturi, calibrated laminar flowmeter, calibrated turbine meter.~~

9.5.2. ~~Calibration of the positive displacement pump (PDP)~~

~~All the parameters related to the pump shall be simultaneously measured along with the parameters related to a calibration venturi which is connected in series with the pump. The calculated flow rate (in m³/s at pump inlet, absolute pressure and temperature) shall be plotted versus a correlation function which is the value of a specific combination of pump parameters. The linear equation which relates the pump flow and the correlation function shall be determined. If a CVS has a multiple speed drive, the calibration shall be performed for each range used.~~

~~Temperature stability shall be maintained during calibration.~~

~~Leaks in all the connections and ducting between the calibration venturi and the CVS pump shall be maintained lower than 0.3 per cent of the lowest flow point (highest restriction and lowest PDP speed point).~~

9.5.2.1. ~~Data analysis~~

~~The airflow rate ($q_{v, CVS}$) at each restriction setting (minimum 6 settings) shall be calculated in standard m³/s from the flowmeter data using the manufacturer's prescribed method. The airflow rate shall then be converted to pump flow (V_0) in m³/rev at absolute pump inlet temperature and pressure as follows:~~

$$V_0 = \frac{q_{v, CVS}}{n} \times \frac{T}{273} \times \frac{101.3}{p_p} \quad (75)$$

~~where:~~

~~$q_{v, CVS}$ is the airflow rate at standard conditions (101.3 kPa, 273 K), m³/s~~

~~T is the temperature at pump inlet, K~~

p_p is the absolute pressure at pump inlet, kPa

n is the pump speed, rev/s

To account for the interaction of pressure variations at the pump and the pump slip rate, the correlation function (X_0) between pump speed, pressure differential from pump inlet to pump outlet and absolute pump outlet pressure shall be calculated as follows:

$$X_0 = \frac{1}{n} \times \sqrt{\frac{\Delta p_p}{p_p}} \quad (76)$$

where:

Δp_p is the pressure differential from pump inlet to pump outlet, kPa

p_p is the absolute outlet pressure at pump outlet, kPa

A linear least square fit shall be performed to generate the calibration equation as follows:

$$V_0 = D_0 + m \times X_0 \quad (77)$$

D_0 and m are the intercept and slope, respectively, describing the regression lines.

For a CVS system with multiple speeds, the calibration curves generated for the different pump flow ranges shall be approximately parallel, and the intercept values (D_0) shall increase as the pump flow range decreases.

The calculated values from the equation shall be within ± 0.5 per cent of the measured value of V_0 . Values of m will vary from one pump to another. Particulate influx over time will cause the pump slip to decrease, as reflected by lower values for m . Therefore, calibration shall be performed at pump start up, after major maintenance, and if the total system verification indicates a change of the slip rate.

9.5.3. Calibration of the critical flow venturi (CFV)

Calibration of the CFV is based upon the flow equation for a critical venturi. Gas flow is a function of venturi inlet pressure and temperature.

To determine the range of critical flow, K_v shall be plotted as a function of venturi inlet pressure. For critical (choked) flow, K_v will have a relatively constant value. As pressure decreases (vacuum increases), the venturi becomes unchoked and K_v decreases, which indicates that the CFV is operated outside the permissible range.

9.5.3.1. Data analysis

The airflow rate ($q_{v, CVS}$) at each restriction setting (minimum 8 settings) shall be calculated in standard m^3/s from the flowmeter data using the manufacturer's prescribed method. The calibration coefficient shall be calculated from the calibration data for each setting as follows:

$$K_v = \frac{q_{v, CVS} \times \sqrt{T}}{p_p} \quad (78)$$

where:

$q_{v, CVS}$ is the airflow rate at standard conditions (101.3 kPa, 273 K), m^3/s

T is the temperature at the venturi inlet, K

p_p is the absolute pressure at venturi inlet, kPa

The average K_v and the standard deviation shall be calculated. The standard deviation shall not exceed ± 0.3 per cent of the average K_v .

9.5.4. Calibration of the subsonic venturi (SSV)

Calibration of the SSV is based upon the flow equation for a subsonic venturi. Gas flow is a function of inlet pressure and temperature, pressure drop between the SSV inlet and throat, as shown in equation 43 (see paragraph 8.4.1.4.).

9.5.4.1. Data analysis

The airflow rate (Q_{SSV}) at each restriction setting (minimum 16 settings) shall be calculated in standard m^3/s from the flowmeter data using the manufacturer's prescribed method. The discharge coefficient shall be calculated from the calibration data for each setting as follows:

$$C_d = \frac{Q_{SSV}}{d_v^2 \times p_p \times \sqrt{\left[\frac{I}{T} \times (r_p^{1.4286} - r_p^{1.7143}) \times \left(\frac{I}{I - r_D^4 \times r_p^{1.4286}} \right) \right]}} \quad (79)$$

where:

Q_{SSV} is the airflow rate at standard conditions (101.3 kPa, 273 K), m^3/s

T is the temperature at the venturi inlet, K

d_v is the diameter of the SSV throat, m

r_p is the ratio of the SSV throat to inlet absolute static pressure = $1 - \frac{\Delta p}{p_p}$

r_D is the ratio of the SSV throat diameter, d_v , to the inlet pipe inner diameter D

To determine the range of subsonic flow, C_d shall be plotted as a function of Reynolds number Re , at the SSV throat. The Re at the SSV throat shall be calculated with the following equation:

$$Re = A_1 \times \frac{Q_{SSV}}{d_v \times \mu} \quad (80)$$

with

$$\mu = \frac{b \times T^{1.5}}{S + T} \quad (81)$$

where:

A_1 is 25.55152 in SI units of $\left(\frac{1}{m^3}\right)\left(\frac{min}{s}\right)\left(\frac{mm}{m}\right)$

Q_{SSV} is the airflow rate at standard conditions (101.3 kPa, 273 K), m^3/s

d_v is the diameter of the SSV throat, m

μ is the absolute or dynamic viscosity of the gas, kg/ms

b is 1.458×10^6 (empirical constant), kg/ms $K^{0.5}$

S is 110.4 (empirical constant), K

Because Q_{SSV} is an input to the Re equation, the calculations must be started with an initial guess for Q_{SSV} or C_d of the calibration venturi, and repeated until Q_{SSV} converges. The convergence method shall be accurate to 0.1 per cent of point or better.

For a minimum of sixteen points in the region of subsonic flow, the calculated values of C_d from the resulting calibration curve fit equation must be within ± 0.5 per cent of the measured C_d for each calibration point.

9.5.5. Total system verification

~~The total accuracy of the CVS sampling system and analytical system shall be determined by introducing a known mass of a pollutant gas into the system while it is being operated in the normal manner. The pollutant is analyzed, and the mass calculated according to paragraph 8.4.2.4, except in the case of propane where a u factor of 0.000472 is used in place of 0.000480 for HC. Either of the following two techniques shall be used:~~

9.5.5.1. Metering with a critical flow orifice

~~A known quantity of pure gas (carbon monoxide or propane) shall be fed into the CVS system through a calibrated critical orifice. If the inlet pressure is high enough, the flow rate, which is adjusted by means of the critical flow orifice, is independent of the orifice outlet pressure (critical flow). The CVS system shall be operated as in a normal exhaust emission test for about 5 to 10 minutes. A gas sample shall be analyzed with the usual equipment (sampling bag or integrating method), and the~~

~~mass of the gas calculated. The mass so determined shall be within ± 3 per cent of the known mass of the gas injected.~~

~~9.5.5.2. Metering by means of a gravimetric technique~~

~~The mass of a small cylinder filled with carbon monoxide or propane shall be determined with a precision of ± 0.01 g. For about 5 to 10 minutes, the CVS system shall be operated as in a normal exhaust emission test, while carbon monoxide or propane is injected into the system. The quantity of pure gas discharged shall be determined by means of differential weighing. A gas sample shall be analyzed with the usual equipment (sampling bag or integrating method), and the mass of the gas calculated. The mass so determined shall be within ± 3 per cent of the known mass of the gas injected.~~

Annex 1

Insert new WLTP DHC drive cycle results here.

Annex 2

Insert results from WLTP DTP Reference Fuel Subgroup here.

A.2.1. EUROPEAN DIESEL REFERENCE FUEL

Parameter	Unit	Limits 1/		Test method	
		Minimum	Maximum		
Cetene number		52	54	ISO 5165	
Density at 15 °C	kg/m ³	833	837	ISO 3675	
Distillation:					
- 50 per cent vol.	°C	245		ISO 3405	
- 95 per cent vol	°C	345	350		
- final boiling point	°C		370		
Flash point	°C	55		ISO 2719	
Cold filter plugging point	°C		-5	EN 116	
Kinematic viscosity at 40 °C	mm ² /s	2.3	3.3	ISO 3104	
Polycyclic aromatic hydrocarbons	per cent m/m	2.0	6.0	EN 12916	
Conradson carbon residue (10 per cent DR)	per cent m/m		0.2	ISO 10370	
Ash content	per cent m/m		0.01	EN-ISO 6245	
Water content	per cent m/m		0.02	EN-ISO 12937	
Sulphur content	mg/kg		10	EN-ISO 14596	
Copper corrosion at 50 °C			1	EN-ISO 2160	
Lubricity (HFRR at 60 °C)	µm		400	CEC F-06-A-96	
Neutralisation number	mg KOH/g		0.02		
Oxidation stability	mg/ml		0.025	EN-ISO 12205	

1/ The values quoted in the specification are "true values". In establishment of their limit values the terms of ISO 4259 "Petroleum products - Determination and application of precision data in relation to methods of test." have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility).

Notwithstanding this measure, which is necessary for statistical reasons, the manufacturer of fuels should nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify the question as to whether a fuel meets the requirements of the specifications, the terms of ISO 4259 should be applied.

A.2.2. UNITED STATES OF AMERICA DIESEL REFERENCE FUEL 2-D

Parameter	Unit	Test method	Limits	
			min.	max.
Cetane number	1	ASTM D 613	40	50
Cetane index	1	ASTM D 976	40	50
Density at 15 °C	kg/m ³	ASTM D 1298	840	865
Distillation		ASTM D 86		
Initial boiling point	°C		171	204
10 per cent Vol.	°C		204	238
50 per cent Vol.	°C		243	282
90 per cent Vol.	°C		293	332
Final boiling point	°C		321	366
Flash point	°C	ASTM D 93	54	-
Kinematic viscosity at 37.9 °C	mm ² /s	ASTM D 445	2	3.2
Mass fraction of sulphur	ppm	ASTM D 2785	7	15
Volume fraction of aromatics	per cent v/v	ASTM D 1319	27	-

A.2.3. JAPAN DIESEL REFERENCE FUEL

Property	Unit	Test method	Grade 1		Grade 2		Cert. Diesel	
			min.	max.	min.	max.	min.	max.
Cetane index		ISO 4264	50	-	45	-	45	-
Distillation		ISO 3405						
90 per cent Vol.	°C		-	360	-	350	-	350
Flash point	°C	ISO 3405	50	-	50	-	50	-
Cold filter plugging point	°C	ICS 75.160.20	-	-1	-	-5	-	-
Pour point	°C	ISO 3015	-	-2.5	-	-7.5	-	-
Kinematic viscosity at 30 °C	mm ² /s	ISO 2909	2.7	-	2.5	-	2.5	-
Mass fraction of sulphur	per cent	ISO 4260	-	0.005	-	0.005	-	0.005
Mass fraction of carbon residue (10 per cent bottom)	mg	ISO 4260	-	0.1	-	0.1	-	-

Annex 3

MEASUREMENT EQUIPMENT

*** The subgroups shall reference the following text, which is extracted from GTR 4, as well as GTR 2, and the EPA Draft Test Procedure. Final Measurement Equipment determination should be appropriate for light-duty vehicles and in following with the established measurement procedures. Where appropriate, and possible, alternatives for measurement equipment shall be provided. ***

A.3.1. ~~Analytical system~~

A.3.1.1. ~~Introduction~~

~~———— This annex contains the basic requirements and the general descriptions of the sampling and analyzing systems. Since various configurations can produce equivalent results, exact conformance with figures 9 and 10 is not required. However, conformance with the basic requirements such as sampling line dimensions, heating and design is mandatory. Components such as instruments, valves, solenoids, pumps, flow devices and switches may be used to provide additional information and coordinate the functions of the component systems. Other components which are not needed to maintain the accuracy on some systems, may be excluded if their exclusion is based upon good engineering judgement.~~

A.3.1.2. ~~Description of the analytical system~~

~~———— Analytical system for the determination of the gaseous emissions in the raw exhaust gas (figure 9) or in the diluted exhaust gas (figure 10) are described based on the use of:~~

- ~~———— (a) HFID or FID analyzer for the measurement of hydrocarbons;~~
- ~~———— (b) NDIR analyzers for the measurement of carbon monoxide and carbon dioxide;~~
- ~~———— (c) HCLD or CLD analyzer for the measurement of the oxides of nitrogen.~~

~~———— The sample for all components should be taken with one sampling probe and internally split to the different analyzers. Optionally, two sampling probes located in close proximity may be used. Care must be taken that no unintended condensation of exhaust components (including water and sulphuric acid) occurs at any point of the analytical system.~~

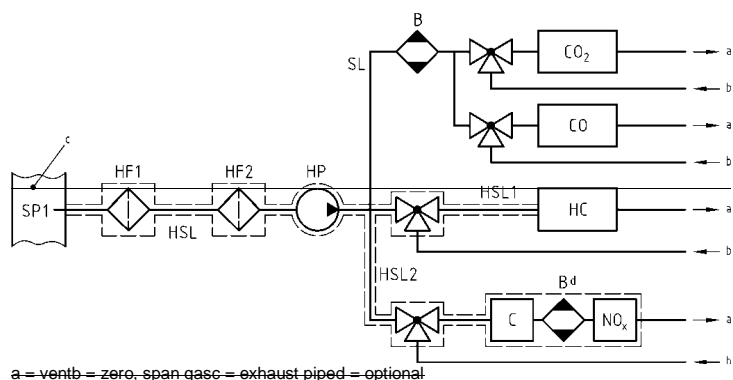


Figure 9

Schematic flow diagram of raw exhaust gas analysis system for CO, CO₂, NO_x, HC

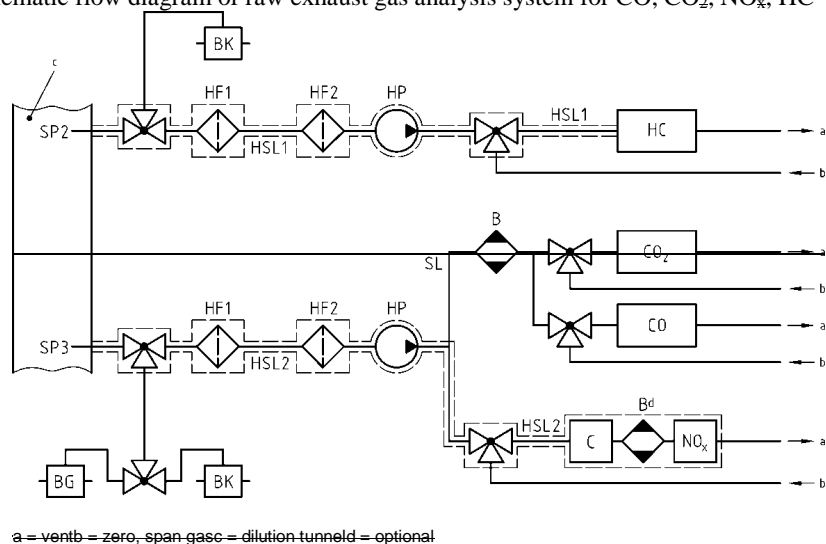


Figure 10

Schematic flow diagram of diluted exhaust gas analysis system for CO, CO₂, NO_x, HC

A.3.1.3. Components of figures 9 and 10

— EP — Exhaust pipe

— SP — Raw exhaust gas sampling probe (figure 9 only)

— A stainless steel straight closed end multi hole probe is recommended. The inside diameter shall not be greater than the inside diameter of the sampling line. The wall

~~thickness of the probe shall not be greater than 1 mm. There shall be a minimum of 3 holes in 3 different radial planes sized to sample approximately the same flow. The probe shall extend across at least 80 per cent of the diameter of the exhaust pipe. One or two sampling probes may be used.~~

~~SP2 Dilute exhaust gas HC sampling probe (figure 10 only)~~

~~The probe shall:~~

- ~~(a) be defined as the first 254 mm to 762 mm of the heated sampling line HSL1~~
- ~~(b) have a 5 mm minimum inside diameter~~
- ~~(c) be installed in the dilution tunnel DT (figure 15) at a point where the dilution air and exhaust gas are well mixed (i.e. approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel)~~
- ~~(d) be sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influence of any wakes or eddies~~
- ~~(e) be heated so as to increase the gas stream temperature to 463 K \pm 10 K (190 °C \pm 10 °C) at the exit of the probe, or to 385 K \pm 10 K (112 °C \pm 10 °C) for positive ignition engines~~
- ~~(f) non heated in case of FID measurement (cold)~~

~~SP3 Dilute exhaust gas CO, CO₂, NO_x-sampling probe (figure 10 only)~~

~~The probe shall:~~

- ~~(a) be in the same plane as SP2~~
- ~~(b) be sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influence of any wakes or eddies~~
- ~~(c) be heated and insulated over its entire length to a minimum temperature of 328 K (55 °C) to prevent water condensation~~

~~HF1 Heated pre filter (optional)~~

~~The temperature shall be the same as HSL1.~~

~~HF2 Heated filter~~

~~The filter shall extract any solid particles from the gas sample prior to the analyzer. The temperature shall be the same as HSL1. The filter shall be changed as needed.~~

~~HSL1 Heated sampling line~~

~~The sampling line provides a gas sample from a single probe to the split point(s) and the HC analyzer.~~

~~The sampling line shall:~~

- ~~(a) have a 4 mm minimum and a 13.5 mm maximum inside diameter~~

- ~~_____ (b) be made of stainless steel or PTFE~~
- ~~_____ (c) maintain a wall temperature of $463\text{ K} \pm 10\text{ K}$ ($190\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$) as measured at every separately controlled heated section, if the temperature of the exhaust gas at the sampling probe is equal to or below 463 K ($190\text{ }^{\circ}\text{C}$)~~
- ~~_____ (d) maintain a wall temperature greater than 453 K ($180\text{ }^{\circ}\text{C}$), if the temperature of the exhaust gas at the sampling probe is above 463 K ($190\text{ }^{\circ}\text{C}$)~~
- ~~_____ (e) maintain a gas temperature of $463\text{ K} \pm 10\text{ K}$ ($190\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$) immediately before the heated filter HF2 and the HFID~~

~~_____ HSL2 Heated NO_x sampling line~~

~~_____ The sampling line shall:~~

- ~~_____ (a) maintain a wall temperature of 328 K to 473 K ($55\text{ }^{\circ}\text{C}$ to $200\text{ }^{\circ}\text{C}$), up to the converter for dry measurement, and up to the analyzer for wet measurement~~
- ~~_____ (b) be made of stainless steel or PTFE~~

~~_____ HP Heated sampling pump~~

~~_____ The pump shall be heated to the temperature of HSL.~~

~~_____ SL Sampling line for CO and CO_2~~

~~_____ The line shall be made of PTFE or stainless steel. It may be heated or unheated.~~

~~_____ HC HFID analyzer~~

~~_____ Heated flame ionization detector (HFID) or flame ionization detector (FID) for the determination of the hydrocarbons. The temperature of the HFID shall be kept at 453 K to 473 K ($180\text{ }^{\circ}\text{C}$ to $200\text{ }^{\circ}\text{C}$).~~

~~_____ CO , CO_2 NDIR analyzer~~

~~_____ NDIR analyzers for the determination of carbon monoxide and carbon dioxide (optional for the determination of the dilution ratio for PT measurement).~~

~~_____ NO_x CLD analyzer~~

~~_____ CLD or HCLD analyzer for the determination of the oxides of nitrogen. If a HCLD is used it shall be kept at a temperature of 328 K to 473 K ($55\text{ }^{\circ}\text{C}$ to $200\text{ }^{\circ}\text{C}$).~~

~~_____ B Cooling bath (optional for NO measurement)~~

~~_____ To cool and condense water from the exhaust sample. It is optional if the analyzer is free from water vapour interference as determined in paragraph 9.3.9.2.2. If water is removed by condensation, the sample gas temperature or dew point shall be monitored either within the water trap or downstream. The sample gas temperature~~

or dew point shall not exceed 280 K (7 °C). Chemical dryers are not allowed for removing water from the sample.

—— BK —— Background bag (optional; figure 10 only)

—— For the measurement of the background concentrations.

—— BG —— Sample bag (optional; figure 10 only)

—— For the measurement of the sample concentrations.

A.3.1.4. Non methane cutter method (NMC)

—— The cutter oxidizes all hydrocarbons except CH_4 to CO_2 and H_2O , so that by passing the sample through the NMC only CH_4 is detected by the HFID. In addition to the usual HC sampling train (see figures 9 and 10), a second HC sampling train shall be installed equipped with a cutter as laid out in figure 11. This allows simultaneous measurement of total HC and NMHC.

—— The cutter shall be characterized at or above 600 K (327°C) prior to test work with respect to its catalytic effect on CH_4 and C_2H_6 at H_2O values representative of exhaust stream conditions. The dew point and O_2 level of the sampled exhaust stream must be known. The relative response of the FID to CH_4 and C_2H_6 shall be determined in accordance with paragraph 9.3.8.

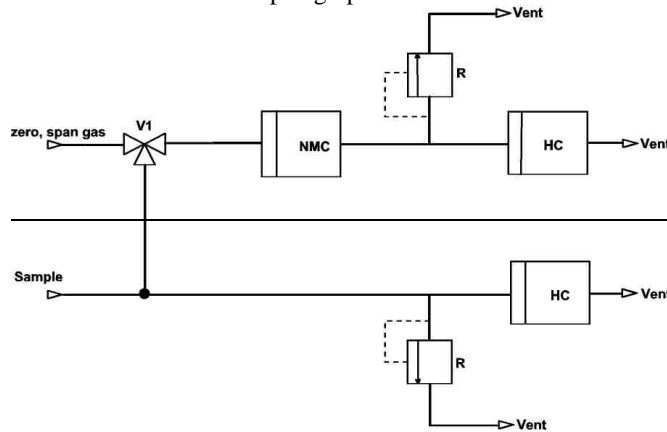


Figure 11
Schematic flow diagram of methane analysis with the NMC

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Annex 3

A.3.1.5. Components of figure 11

—— NMC —— Non-methane cutter

—— To oxidize all hydrocarbons except methane

—— HC

—— Heated flame ionization detector (HFID) or flame ionization detector (FID) to measure the HC and CH₄ concentrations. The temperature of the HFID shall be kept at 453 K to 473 K (180 °C to 200 °C).

—— V1 —— Selector valve

—— To select zero and span gas

—— R —— Pressure regulator

—— To control the pressure in the sampling line and the flow to the HFID

A.3.2. Dilution and particulate sampling system

A.3.2.1. Introduction

—— This annex contains the basic requirements and the general descriptions of the dilution and particulate sampling systems. Since various configurations can produce equivalent results, exact conformance with figures 12 to 17 is not required. However, conformance with the basic requirements such as sampling line dimensions, heating and design is mandatory. Additional components such as instruments, valves, solenoids, pumps, and switches may be used to provide additional information and coordinate the functions of the component systems. Other components which are not needed to maintain the accuracy on some systems, may be excluded if their exclusion is based upon good engineering judgment.

A.3.2.2. Description of partial flow system

—— A dilution system is described based upon the dilution of a part of the exhaust stream. Splitting of the exhaust stream and the following dilution process may be done by different dilution system types. For subsequent collection of the particulates, the entire dilute exhaust gas or only a portion of the dilute exhaust gas is passed to the particulate sampling system. The first method is referred to as total sampling type, the second method as fractional sampling type. The calculation of the dilution ratio depends upon the type of system used.

—— With the total sampling system as shown in figure 12, raw exhaust gas is transferred from the exhaust pipe (EP) to the dilution tunnel (DT) through the sampling probe

(SP) and the transfer tube (TT). The total flow through the tunnel is adjusted with the flow controller FC2 and the sampling pump (P) of the particulate sampling system (see figure 16). The dilution airflow is controlled by the flow controller FC1, which may use q_{mew} or q_{maw} and q_{mt} as command signals, for the desired exhaust split. The sample flow into DT is the difference of the total flow and the dilution airflow. The dilution airflow rate is measured with the flow measurement device FM1, the total flow rate with the flow measurement device FM3 of the particulate sampling system (see figure 16). The dilution ratio is calculated from these two flow rates.

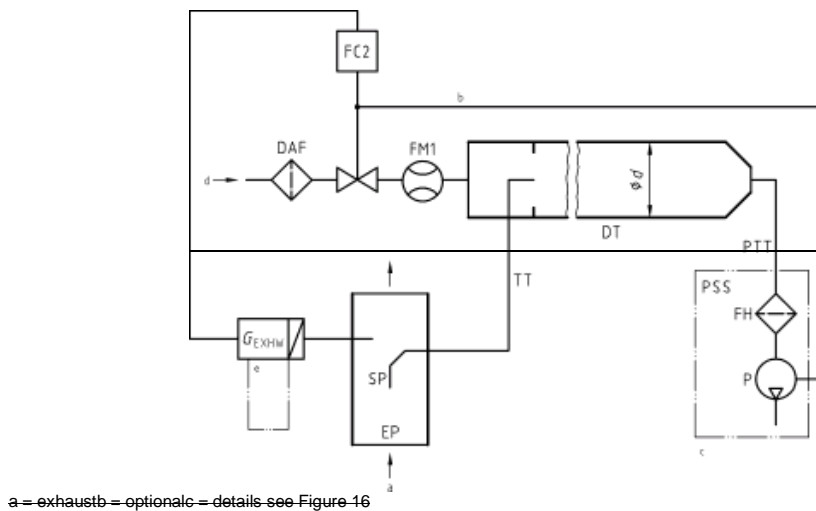


Figure 12
Scheme of partial flow dilution system (total sampling type)

With the fractional sampling system as shown in figure 13, raw exhaust gas is transferred from the exhaust pipe EP to the dilution tunnel DT through the sampling probe SP and the transfer tube TT. The total flow through the tunnel is adjusted with the flow controller FC1 connected either to the dilution airflow or to the suction blower for the total tunnel flow. The flow controller FC1 may use q_{mew} or q_{maw} and q_{mt} as command signals for the desired exhaust split. The sample flow into DT is the difference of the total flow and the dilution airflow. The dilution airflow rate is measured with the flow measurement device FM1, the total flow rate with the flow measurement device FM2. The dilution ratio is calculated from these two flow rates. From DT, a particulate sample is taken with the particulate sampling system (see figure 16).



~~A.3.2.3. Components of figures 12 and 13~~

The exhaust pipe may be insulated. To reduce the thermal inertia of the exhaust pipe a thickness to diameter ratio of 0.015 or less is recommended. The use of flexible sections shall be limited to a length to diameter ratio of 12 or less. Bends shall be minimized to reduce inertial deposition. If the system includes a test bed silencer the silencer may also be insulated. It is recommended to have a straight pipe of 6 pipe diameters upstream and 3 pipe diameters downstream of the tip of the probe.

(d) ~~hatted probe facing upstream on the exhaust pipe centreline as shown in figure 14~~

~~The minimum inside diameter of the probe tip shall be 4 mm. The minimum diameter ratio between exhaust pipe and probe shall be 4.~~

When using probe type (a), an inertial pre classifier (cyclone or impactor) with at 50 per cent cut point between 2.5 and 10 μm shall be installed immediately upstream of the filter holder.

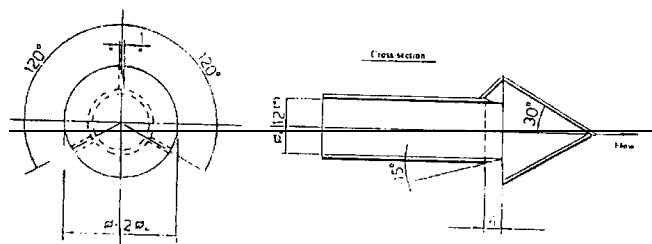


Figure 14
Scheme of hatted probe

TT Exhaust transfer tube

The transfer tube shall be:

- (a) as short as possible, but not more than 1 m in length;
- (b) equal to or greater than the probe diameter, but not more than 25 mm in diameter;
- (c) exiting on the centreline of the dilution tunnel and pointing downstream.

The tube shall be insulated with material with a maximum thermal conductivity of 0.05 W/mK with a radial insulation thickness corresponding to the diameter of the probe, or heated.

FC1 Flow controller

A flow controller shall be used to control the dilution airflow through the pressure blower PB and/or the suction blower SB. It may be connected to the exhaust flow sensor signals specified in paragraph 8.3.1. The flow controller may be installed upstream or downstream of the respective blower. When using a pressurized air supply, FC1 directly controls the airflow.

FM1 Flow measurement device

Gas meter or other flow instrumentation to measure the dilution airflow. FM1 is optional if the pressure blower PB is calibrated to measure the flow.

DAF Dilution air filter

The dilution air (ambient air, synthetic air, or nitrogen) shall be filtered with a high efficiency (HEPA) filter that has an initial minimum collection efficiency

~~of 99.97 per cent. The dilution air shall have a temperature of ≥ 288 K (15°C), and may be dehumidified.~~

~~FM2 Flow measurement device (fractional sampling type, figure 13 only)~~

~~Gas meter or other flow instrumentation to measure the diluted exhaust gas flow. FM2 is optional if the suction blower SB is calibrated to measure the flow.~~

~~PB Pressure blower (fractional sampling type, figure 13 only)~~

~~To control the dilution airflow rate, PB may be connected to the flow controllers FC1 or FC2. PB is not required when using a butterfly valve. PB may be used to measure the dilution airflow, if calibrated.~~

~~SB Suction blower (fractional sampling type, figure 13 only)~~

~~SB may be used to measure the diluted exhaust gas flow, if calibrated.~~

~~DT Dilution tunnel~~

~~The dilution tunnel:~~

- ~~(a) shall be of a sufficient length to cause complete mixing of the exhaust and dilution air under turbulent flow conditions for a fractional sampling system; i.e. complete mixing is not required for a total sampling system;~~
- ~~(b) shall be constructed of stainless steel;~~
- ~~(c) shall be at least 75 mm in diameter for the fractional sampling type;~~
- ~~(d) is recommended to be at least 25 mm in diameter for the total sampling type;~~
- ~~(e) may be heated to no greater than 325 K (52°C) wall temperature;~~
- ~~(f) may be insulated.~~

~~PSP Particulate sampling probe (fractional sampling type, figure 13 only)~~

~~The particulate sampling probe is the leading section of the particulate transfer tube PTT (see paragraph A.3.2.7.) and:~~

- ~~(a) shall be installed facing upstream at a point where the dilution air and exhaust gas are well mixed, i.e. on the dilution tunnel DT centreline approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel;~~
- ~~(b) shall be 12 mm in minimum inside diameter;~~
- ~~(c) may be heated to no greater than 325 K (52°C) wall temperature by direct heating or by dilution air pre heating, provided the dilution air temperature does not exceed 325 K (52°C) prior to the introduction of the exhaust into the dilution tunnel;~~
- ~~(d) may be insulated.~~

A.3.2.4. Description of full flow dilution system

- A dilution system is described based upon the dilution of the total amount of raw exhaust gas in the dilution tunnel DT using the CVS (constant volume sampling) concept, and is shown in figure 15.
- The diluted exhaust gas flow rate shall be measured either with a positive displacement pump (PDP), with a critical flow venturi (CFV) or with a subsonic venturi (SSV). A heat exchanger (HE) or electronic flow compensation (EFC) may be used for proportional particulate sampling and for flow determination. Since particulate mass determination is based on the total diluted exhaust gas flow, it is not necessary to calculate the dilution ratio.
- For subsequent collection of the particulates, a sample of the dilute exhaust gas shall be passed to the double dilution particulate sampling system (see figure 17). Although partly a dilution system, the double dilution system is described as a modification of a particulate sampling system, since it shares most of the parts with a typical particulate sampling system.

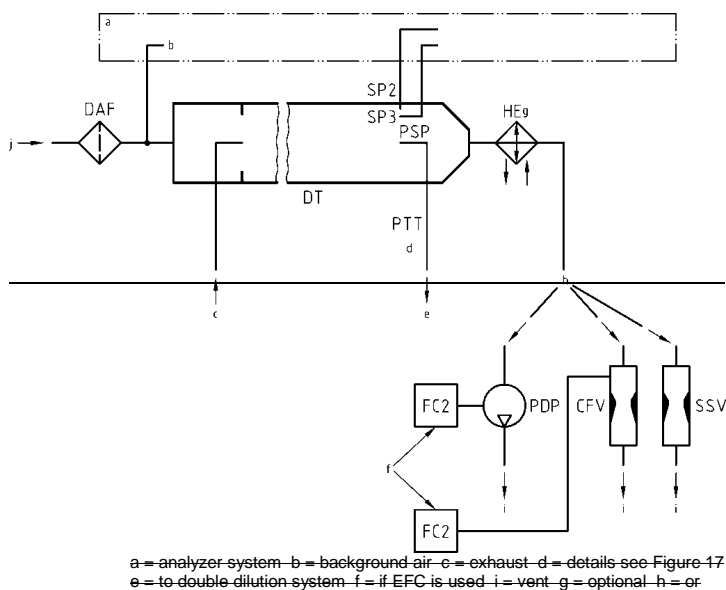


Figure 15
Scheme of full flow dilution system (CVS)

A.3.2.5. Components of figure 15

EP Exhaust pipe

The exhaust pipe length from the exit of the engine exhaust manifold, turbocharger outlet or after-treatment device to the dilution tunnel shall be not more than 10 m. If the system exceeds 4 m in length, then all tubing in excess of 4 m shall be insulated, except for an in-line smoke meter, if used. The radial thickness of the insulation shall be at least 25 mm. The thermal conductivity of the insulating material shall have a value no greater than 0.1 W/mK measured at 673 K. To reduce the thermal inertia of the exhaust pipe a thickness to diameter ratio of 0.015 or less is recommended. The use of flexible sections shall be limited to a length to diameter ratio of 12 or less.

PDP Positive displacement pump

The PDP meters total diluted exhaust flow from the number of the pump revolutions and the pump displacement. The exhaust system backpressure shall not be artificially lowered by the PDP or dilution air inlet system. Static exhaust backpressure measured with the PDP system operating shall remain within ± 1.5 kPa of the static pressure measured without connection to the PDP at identical engine speed and load. The gas mixture temperature immediately ahead of the PDP shall be within ± 6 K of the average operating temperature observed during the test, when no flow compensation (EFC) is used. Flow compensation is only permitted, if the temperature at the inlet to the PDP does not exceed 323 K (50 °C).

CFV Critical flow venturi

CFV measures total diluted exhaust flow by maintaining the flow at choked conditions (critical flow). Static exhaust backpressure measured with the CFV system operating shall remain within ± 1.5 kPa of the static pressure measured without connection to the CFV at identical engine speed and load. The gas mixture temperature immediately ahead of the CFV shall be within ± 11 K of the average operating temperature observed during the test, when no flow compensation (EFC) is used.

SSV Subsonic venturi

SSV measures total diluted exhaust flow by using the gas flow function of a subsonic venturi in dependence of inlet pressure and temperature and pressure drop between venturi inlet and throat. Static exhaust backpressure measured with the SSV system operating shall remain within ± 1.5 kPa of the static pressure measured without connection to the SSV at identical engine speed and load. The gas mixture temperature immediately ahead of the SSV shall be within ± 11 K of the average operating temperature observed during the test, when no flow compensation (EFC) is used.

~~HE Heat exchanger (optional)~~

~~The heat exchanger shall be of sufficient capacity to maintain the temperature within the limits required above. If EFC is used, the heat exchanger is not required.~~

~~EFC Electronic flow compensation (optional)~~

~~If the temperature at the inlet to the PDP, CFV or SSV is not kept within the limits stated above, a flow compensation system is required for continuous measurement of the flow rate and control of the proportional sampling into the double dilution system. For that purpose, the continuously measured flow rate signals are used to maintain the proportionality of the sample flow rate through the particulate filters of the double dilution system (see figure 17) within ± 2.5 per cent.~~

~~DT Dilution tunnel~~

~~The dilution tunnel~~

- ~~(a) shall be small enough in diameter to cause turbulent flow (Reynolds Number greater than 4,000) and of sufficient length to cause complete mixing of the exhaust and dilution air;~~
- ~~(b) shall be at least 75 mm in diameter;~~
- ~~(c) may be insulated.~~

~~The engine exhaust shall be directed downstream at the point where it is introduced into the dilution tunnel, and thoroughly mixed. A mixing orifice may be used.~~

~~For the double dilution system, a sample from the dilution tunnel is transferred to the secondary dilution tunnel where it is further diluted, and then passed through the sampling filters (figure 17). The flow capacity of the PDP or CFV must be sufficient to maintain the diluted exhaust stream in the DT at a temperature of less than or equal to 464 K (191 °C) at the sampling zone. The secondary dilution system shall provide sufficient secondary dilution air to maintain the doubly diluted exhaust stream at a temperature between 315 K (42 °C) and 325 K (52 °C) immediately before the particulate filter.~~

~~DAF Dilution air filter~~

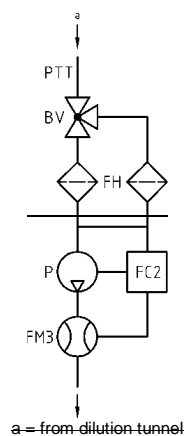
~~The dilution air (ambient air, synthetic air, or nitrogen) shall be filtered with a high-efficiency (HEPA) filter that has an initial minimum collection efficiency of 99.97 per cent. The dilution air shall have a temperature of ≥ 288 K (15 °C), and may be dehumidified.~~

~~PSP Particulate sampling probe~~

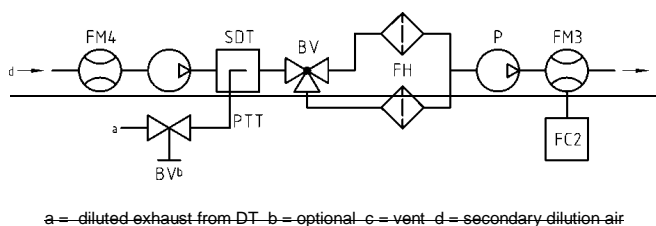
- ~~———— The probe is the leading section of PTT and~~
- ~~———— (a) shall be installed facing upstream at a point where the dilution air and exhaust gases are well mixed, i.e. on the dilution tunnel DT centreline of the dilution systems, approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel;~~
- ~~———— (b) shall be of 12 mm minimum inside diameter;~~
- ~~———— (c) may be heated to no greater than 325 K (52 °C) wall temperature by direct heating or by dilution air pre heating, provided the air temperature does not exceed 325 K (52 °C) prior to the introduction of the exhaust in the dilution tunnel;~~
- ~~———— (d) may be insulated.~~

~~A.3.2.6. Description of particulate sampling system~~

- ~~———— The particulate sampling system is required for collecting the particulates on the particulate filter and is shown in figures 16 and 17. In the case of total sampling partial flow dilution, which consists of passing the entire diluted exhaust sample through the filters, the dilution and sampling systems usually form an integral unit (see figure 12). In the case of fractional sampling partial flow dilution or full flow dilution, which consists of passing through the filters only a portion of the diluted exhaust, the dilution and sampling systems usually form different units.~~
- ~~———— For a partial flow dilution system, a sample of the diluted exhaust gas is taken from the dilution tunnel DT through the particulate sampling probe PSP and the particulate transfer tube PTT by means of the sampling pump P, as shown in figure 16. The sample is passed through the filter holder(s) FH that contain the particulate sampling filters. The sample flow rate is controlled by the flow controller FC3.~~
- ~~———— For of full flow dilution system, a double dilution particulate sampling system shall be used, as shown in figure 17. A sample of the diluted exhaust gas is transferred from the dilution tunnel DT through the particulate sampling probe PSP and the particulate transfer tube PTT to the secondary dilution tunnel SDT, where it is diluted once more. The sample is then passed through the filter holder(s) FH that contain the particulate sampling filters. The dilution airflow rate is usually constant whereas the sample flow rate is controlled by the flow controller FC3. If electronic flow compensation EFC (see figure 15) is used, the total diluted exhaust gas flow is used as command signal for FC3.~~

**Figure 16**

Scheme of particulate sampling system

**Figure 17**

Scheme of double dilution particulate sampling system

A.3.2.7. Components of figures 16 (partial flow system only) and 17 (full flow system only)

—— PTT —— Particulate transfer tube

—— The particulate transfer tube shall not exceed 1,020 mm in length, and shall be minimized in length whenever possible.

—— The dimensions are valid for:

- (a) the partial flow dilution fractional sampling system from the probe tip to the filter holder;
- (b) the partial flow dilution total sampling system from the end of the dilution tunnel to the filter holder;
- (c) the full flow double dilution system from the probe tip to the entrance of the secondary dilution tunnel.

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~~_____ The transfer tube:~~

~~_____ (a) may be heated to no greater than 325 K (52 °C) wall temperature;~~

~~_____ (b) may be insulated.~~

~~_____ SDT _____ Secondary dilution tunnel (figure 17 only)~~

~~_____ The secondary dilution tunnel should have a minimum diameter of 75 mm, and should be of sufficient length so as to provide a residence time of at least 0.25 s for the doubly diluted sample. The filter holder FH shall be located within 300 mm of the exit of the SDT.~~

~~_____ The secondary dilution tunnel:~~

~~_____ (a) may be heated to no greater than 325 K (52 °C) wall temperature by direct heating or by dilution air pre heating, provided the air temperature does not exceed 325 K (52 °C) prior to the introduction of the exhaust into the dilution tunnel;~~

~~_____ (b) may be insulated.~~

~~_____ FH _____ Filter holder~~

~~_____ The filter holder:~~

~~_____ (a) may be heated to no greater than 325 K (52 °C) wall temperature;~~

~~_____ (b) may be insulated.~~

~~_____ An inertial pre-classifier with a 50 per cent cut point between 2.5 µm and 10 µm shall be installed immediately upstream of the filter holder, if an open tube sampling probe facing upstream is used.~~

~~_____ P _____ Sampling pump~~

~~_____ FC2 _____ Flow controller~~

~~_____ A flow controller shall be used for controlling the particulate sample flow rate.~~

~~_____ FM3 _____ Flow measurement device~~

~~_____ Gas meter or flow instrumentation to determine the particulate sample flow through the particulate filter. It may be installed upstream or downstream of the sampling pump P.~~

~~_____ FM4 _____ Flow measurement device~~

~~_____ Gas meter or flow instrumentation to determine the secondary dilution airflow through the particulate filter.~~

~~———— BV ——— Ball valve (optional)~~

~~———— The ball valve shall have an inside diameter not less than the inside diameter of the particulate transfer tube PTT, and a switching time of less than 0.5 s.~~

Annex 4

DETERMINATION OF SYSTEM EQUIVALENCE

The determination of system equivalency according to paragraph 5.1.1. shall be based on a 7 sample pair (or larger) correlation study between the candidate system and one of the accepted reference systems of this gtr using the appropriate test cycle(s). The equivalency criteria to be applied shall be the *F*-test and the two-sided Student *t*-test.

This statistical method examines the hypothesis that the sample standard deviation and sample mean value for an emission measured with the candidate system do not differ from the sample standard deviation and sample mean value for that emission measured with the reference system. The hypothesis shall be tested on the basis of a 10 per cent significance level of the *F* and *t* values. The critical *F* and *t* values for 7 to 10 sample pairs are given in table 8. If the *F* and *t* values calculated according to the equation below are greater than the critical *F* and *t* values, the candidate system is not equivalent.

The following procedure shall be followed. The subscripts R and C refer to the reference and candidate system, respectively:

- (a) Conduct at least 7 tests with the candidate and reference systems operated in parallel. The number of tests is referred to as n_R and n_C .
- (b) Calculate the mean values $\overline{x_R}$ and $\overline{x_C}$ and the standard deviations s_R and s_C .
- (c) Calculate the *F* value, as follows:

$$F = \frac{s_{\text{major}}^2}{s_{\text{minor}}^2} \quad (82)$$

(the greater of the two standard deviations s_R or s_C must be in the numerator)

- (d) Calculate the *t* value, as follows:

$$t = \frac{|\overline{x_C} - \overline{x_R}|}{\sqrt{(n_C - 1) \times s_C^2 + (n_R - 1) \times s_R^2}} \times \sqrt{\frac{n_C \times n_R \times (n_C + n_R - 2)}{n_C + n_R}} \quad (83)$$

- (e) Compare the calculated *F* and *t* values with the critical *F* and *t* values corresponding to the respective number of tests indicated in table 8. If larger sample sizes are selected, consult statistical tables for 10 per cent significance (90 per cent confidence) level.
- (f) Determine the degrees of freedom (*df*), as follows:

$$\text{for the } F\text{-test:} \quad df = n_R - 1 / n_C - 1 \quad (84)$$

$$\text{for the } t\text{-test:} \quad df = n_C + n_R - 2 \quad (85)$$

- (g) Determine the equivalency, as follows:
- (i) if $F < F_{\text{crit}}$ and $t < t_{\text{crit}}$, then the candidate system is equivalent to the reference system of this gtr
 - (ii) if $F \geq F_{\text{crit}}$ or $t \geq t_{\text{crit}}$, then the candidate system is different from the reference system of this gtr

Sample Size	<i>F</i> -test		<i>t</i> -test	
	<i>df</i>	F_{crit}	<i>df</i>	t_{crit}
7	6/6	3.055	12	1.782
8	7/7	2.785	14	1.761
9	8/8	2.589	16	1.746
10	9/9	2.440	18	1.734

Table 8
t and *F* values for selected sample sizes

Annex 5

EMISSIONS TEST PROCEDURE FOR A VEHICLE EQUIPPED WITH A PERIODICALLY REGENERATING SYSTEM

1. INTRODUCTION

This annex defines the specific provisions regarding type-approval of a vehicle equipped with a periodically regenerating system as defined in paragraph 2.20. of this Regulation.

2. SCOPE AND EXTENSION OF THE TYPE APPROVAL

2.1. Vehicle family groups equipped with periodically regenerating system

The procedure applies to vehicles equipped with a periodically regenerating system as defined in paragraph 2.20. of this Regulation. For the purpose of this annex vehicle family groups may be established. Accordingly, those vehicle types with regenerative systems, whose parameters described below are identical, or within the stated tolerances, shall be considered to belong to the same family with respect to measurements specific to the defined periodically regenerating systems.

2.1.1. Identical parameters are:

Engine:

- (a) Combustion process.

Periodically regenerating system (i.e. catalyst, particulate trap):

- (a) Construction (i.e. type of enclosure, type of precious metal, type of substrate, cell density),
- (b) Type and working principle,
- (c) Dosage and additive system,
- (d) Volume ± 10 per cent,
- (e) Location (temperature ± 50 °C at 120 km/h or 5 per cent difference of max. temperature / pressure).

2.2. Vehicle types of different reference masses

The K_i factors developed by the procedures in this annex for type approval of a vehicle type with a periodically regenerating system as defined in paragraph 2.20. of this Regulation, may be extended to other vehicles in the family group with a reference mass within the next two higher equivalent inertia classes or any lower equivalent inertia.

3. TEST PROCEDURE

The vehicle may be equipped with a switch capable of preventing or permitting the regeneration process provided that this operation has no effect on original engine calibration. This switch shall be permitted only for the purpose of preventing regeneration during loading of the regeneration system and during the pre-conditioning cycles. However, it shall not be used during the measurement of emissions during the regeneration phase; rather the emission test shall be carried out with the unchanged Original Equipment Manufacturer's (OEM) control unit.

3.1. Exhaust emission measurement between two cycles where regenerative phases occur

Average emissions between regeneration phases and during loading of the regenerative device shall be determined from the arithmetic mean of several approximately equidistant (if more than 2) Type I operating cycles or equivalent engine test bench cycles. As an alternative the manufacturer may provide data to show that the emissions remain constant ($\nabla 15$ per cent) between regeneration phases. In this case, the emissions measured during the regular Type I test may be used. In any other case emissions measurement for at least two Type I operating cycles or equivalent engine test bench cycles must be completed: one immediately after regeneration (before new loading) and one as close as possible prior to a regeneration phase. All emissions measurements and calculations shall be carried out according to Annex 4, paragraphs 5., 6., 7. and 8.

3.1.2. The loading process and K_i determination shall be made during the Type I operating cycle, on a chassis dynamometer or on an engine test bench using an equivalent test cycle. These cycles may be run continuously (i.e. without the need to switch the engine off between cycles). After any number of completed cycles, the vehicle may be removed from the chassis dynamometer, and the test continued at a later time.

3.1.3. The number of cycles (D) between two cycles where regeneration phases occur, the number of cycles over which emissions measurements are made (n), and each emissions measurement (M'_{sij}) shall be reported in Annex 1, items 4.2.11.2.1.10.1. to 4.2.11.2.1.10.4. or 4.2.11.2.5.4.1. to 4.2.11.2.5.4.4. as applicable.

3.2. Measurement of emissions during regeneration

3.2.1. Preparation of the vehicle, if required, for the emissions test during a regeneration phase, may be completed using the preparation cycles in paragraph 5.3. of Annex 4 or equivalent engine test bench cycles, depending on the loading procedure chosen in paragraph 3.1.2. above.

3.2.2. The test and vehicle conditions for the Type I test described in Annex 4 apply before the first valid emission test is carried out.

- 3.2.3. Regeneration must not occur during the preparation of the vehicle. This may be ensured by one of the following methods:
- 3.2.3.1. A "dummy" regenerating system or partial system may be fitted for the pre-conditioning cycles.
- 3.2.3.2. Any other method agreed between the manufacturer and the type approval authority.
- 3.2.4. A cold-start exhaust emission test including a regeneration process shall be performed according to the Type I operating cycle, or equivalent engine test bench cycle. If the emissions tests between two cycles where regeneration phases occur are carried out on an engine test bench, the emissions test including a regeneration phase shall also be carried out on an engine test bench.
- 3.2.5. If the regeneration process requires more than one operating cycle, subsequent test cycle(s) shall be driven immediately, without switching the engine off, until complete regeneration has been achieved (each cycle shall be completed). The time necessary to set up a new test should be as short as possible (e.g. particular matter filter change). The engine must be switched off during this period.
- 3.2.6. The emission values during regeneration (M_{ri}) shall be calculated according to Annex 4, paragraph 8. The number of operating cycles (d) measured for complete regeneration shall be recorded.

3.3. Calculation of the combined exhaust emissions

$$M_{si} = \frac{\sum_{j=1}^n M'_{sij}}{n} \quad n \geq 2; \quad M_{ri} = \frac{\sum_{j=1}^d M'_{rij}}{d}$$

$$M_{pi} = \left\{ \frac{M_{si} * D + M_{ri} * d}{D + d} \right\}$$

where for each pollutant (i) considered:

- M'_{sij} = mass emissions of pollutant (i) in g/km over one Type I operating cycle (or equivalent engine test bench cycle) without regeneration
- M'_{rij} = mass emissions of pollutant (i) in g/km over one Type I operating cycle (or equivalent engine test bench cycle) during regeneration. (when $n > 1$, the first Type I test is run cold, and subsequent cycles are hot)
- M_{si} = mean mass emission of pollutant (i) in g/km without regeneration
- M_{ri} = mean mass emission of pollutant (i) in g/km during regeneration
- M_{pi} = mean mass emission of pollutant (i) in g/km

- n = number of test points at which emissions measurements (Type I operating cycles or equivalent engine test bench cycles) are made between two cycles where regenerative phases occur, ≥ 2
d = number of operating cycles required for regeneration
D = number of operating cycles between two cycles where regenerative phases occur

For exemplary illustration of measurement parameters see Figure 8/1.

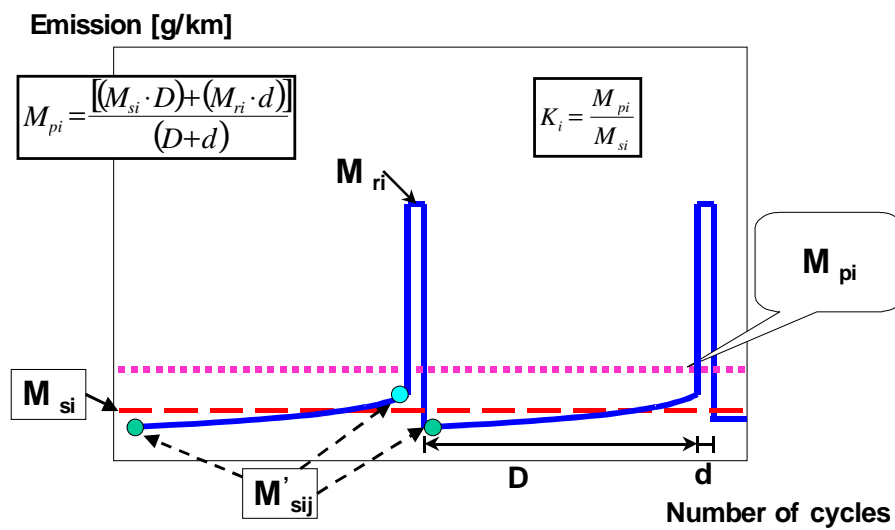


Figure 8/1: Parameters measured during emissions test during and between cycles where regeneration occurs (schematic example, the emissions during 'D' may increase or decrease)

3.4. Calculation of the regeneration factor K for each pollutant (i) considered

$$K_i = M_{pi} / M_{si}$$

M_{si} , M_{pi} and K_i results shall be recorded in the test report delivered by the technical service.

K_i may be determined following the completion of a single sequence.

Annex 6

EXAMPLE OF CALCULATION PROCEDURE

*** While an example should remain in this annex, there is still a question as to how the results should be presented: SI Units, multiple results for g/km, g/mile, etc ... ***

A.6.1. Basic data for stoichiometric calculations

Atomic mass of hydrogen	1.00794 g/atom
Atomic mass of carbon	12.011 g/atom
Atomic mass of sulphur	32.065 g/atom
Atomic mass of nitrogen	14.0067 g/atom
Atomic mass of oxygen	15.9994 g/atom
Atomic mass of argon	39.9 g/atom
Molar mass of water	18.01534 g/mol
Molar mass of carbon dioxide	44.01 g/mol
Molar mass of carbon monoxide	28.011 g/mol
Molar mass of oxygen	31.9988 g/mol
Molar mass of nitrogen	28.011 g/mol
Molar mass of nitric oxide	30.008 g/mol
Molar mass of nitrogen dioxide	46.01 g/mol
Molar mass of sulphur dioxide	64.066 g/mol
Molar mass of dry air	28.965 g/mol

Assuming no compressibility effects, all gases involved in the engine intake/combustion/exhaust process can be considered to be ideal and any volumetric calculations shall therefore be based on a molar volume of 22.414 l/mol according to Avogadro's hypothesis.

A.6.2. replace by example calculation based on R83 provisions
Gaseous emissions (diesel fuel)

~~The measurement data of an individual point of the test cycle (data sampling rate of 1 Hz) for the calculation of the instantaneous mass emission are shown below. In this example, CO and NO_x are measured on a dry basis, HC on a wet basis. The HC concentration is given in propane equivalent (C3) and has to be multiplied by 3 to result in the C1 equivalent. The calculation procedure is identical for the other points of the cycle.~~

~~The calculation example shows the rounded intermediate results of the different steps for better illustration. It should be noted that for actual calculation, rounding of intermediate results is not permitted (see paragraph 8.).~~

$T_{a,i}$ (K)	$H_{a,i}$ (g/kg)	W_{aet} kWh	$q_{mew,i}$ (kg/s)	$q_{maw,i}$ (kg/s)	$q_{mf,i}$ (kg/s)	$e_{HC,i}$ (ppm)	$e_{CO,i}$ (ppm)	$e_{NOx,i}$ (ppm)
295	8.0	40	0.155	0.150	0.005	10	40	500

The following fuel composition is considered:

Component	Molar ratio	per cent mass
H	$\alpha=1.8529$	$w_{ALF}=13.45$
C	$\beta=1.0000$	$w_{BET}=86.50$
S	$\gamma=0.0002$	$w_{GAM}=0.050$
N	$\delta=0.0000$	$w_{DEL}=0.000$
O	$\epsilon=0.0000$	$w_{EPS}=0.000$

Step 1: Dry/wet correction (paragraph 8.1.):

Equation (11): $k_i = 0.055584 \times 13.45 - 0.0001083 \times 86.5 - 0.0001562 \times 0.05 = 0.7382$

Equation (8): $k_{w,i} = \left(1 - \frac{1.2434 \times 8 + 111.12 \times 13.45 \times \frac{0.005}{0.148}}{773.4 + 1.2434 \times 8 + \frac{0.005}{0.148} \times 0.7382 \times 1,000} \right) \times 1.008 = 0.9331$

Equation (7): $e_{CO,i}(\text{wet}) = 40 \times 0.9331 = 37.3 \text{ ppm}$

$e_{NOx,i}(\text{wet}) = 500 \times 0.9331 = 466.6 \text{ ppm}$

Step 2: NO_x correction for temperature and humidity (paragraph 8.2.1.):

Equation (18): $k_{h,D} = \frac{15.698 \times 8.00}{1,000} + 0.832 = 0.9576$

Step 3: Calculation of the instantaneous emission of each individual point of the cycle (paragraph 8.3.2.4.):

Equation (25): $m_{HC,i} = 10 \times 3 \times 0.155 = 4.650$

$m_{CO,i} = 37.3 \times 0.155 = 5.782$

$m_{NOx,i} = 466.6 \times 0.9576 \times 0.155 = 69.26$

~~Step 4: Calculation of the mass emission over the cycle by integration of the instantaneous emission values and the u values from table 4 (paragraph 8.3.2.4.):~~

~~The following calculation is assumed for the WHTC cycle (1,800 s) and the same emission in each point of the cycle.~~

~~Equation (25): $m_{HC} = 0.000479 \times \sum_{i=1}^{1800} 4.650 = 4.01 \text{ g/test}$~~
 ~~$m_{CO} = 0.000966 \times \sum_{i=1}^{1800} 5.782 = 10.05 \text{ g/test}$~~
 ~~$m_{NOx} = 0.001586 \times \sum_{i=1}^{1800} 69.26 = 197.72 \text{ g/test}$~~

~~Step 5: Calculation of the specific emissions (paragraph 8.5.2.1.):~~

~~Equation (56): $e_{HC} = 4.01 / 40 = 0.10 \text{ g/kWh}$~~
 ~~$e_{CO} = 10.05 / 40 = 0.25 \text{ g/kWh}$~~
 ~~$e_{NOx} = 197.72 / 40 = 4.94 \text{ g/kWh}$~~

A.6.3. Particulate Emission (diesel fuel)

p_b (kPa)	W_{act} (kWh)	$q_{mew,i}$ (kg/s)	$q_{mf,i}$ (kg/s)	$q_{mdw,i}$ (kg/s)	$q_{mdew,i}$ (kg/s)	m_{uncor} (mg)	m_{sep} (kg)
99	40	0.155	0.005	0.0015	0.0020	1.7000	1.515

~~Step 1: Calculation of m_{edf} (paragraph 8.3.3.5.2.):~~

~~Equation (37): $r_{d,i} = \frac{0.002}{(0.002 - 0.0015)} = 4$~~
~~Equation (36): $q_{medf,i} = 0.155 \times 4 = 0.620 \text{ kg/s}$~~
~~Equation (35): $m_{edf} = \sum_{i=1}^{1800} 0.620 = 1,116 \text{ kg/test}$~~

~~Step 2: Buoyancy correction of the particulate mass (paragraph 9.4.3.5.)~~

~~Equation (72): $\rho_a = \frac{99 \times 28.836}{8.3144 \times 295} = 1.164 \text{ kg/m}^3$~~

~~Equation (71): $m_f = 1.7000 \times \frac{(1 - 1.164/8,000)}{(1 - 1.164/2,300)} = 1.7006 \text{ mg}$~~

~~Step 3: Calculation of the particulate mass emission (paragraph 8.3.3.5.2.):~~

~~Equation (34): $m_{PM} = \frac{1.7006}{1.515} \times \frac{1,116}{1,000} = 1.253 \text{ g/test}$~~

~~Step 4: Calculation of the specific emission (paragraph 8.5.2.1.):~~

~~Equation (56): $e_{PM} = 1.253 / 40 = 0.031 \text{ g/kWh}$~~

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Annex 14

Annex 7

FUEL FIRED HEATER EMISSIONS

Annex 8

EMISSIONS TEST PROCEDURE AND CALCULATION FOR ELECTRIFIED VEHICLES

1. INTRODUCTION

- 1.1. This annex defines the specific provisions regarding type-approval of a hybrid electric vehicle (HEV) as defined in paragraph 2.21.2. of this Regulation.
- 1.2. As a general principle, for the tests of Type I, II, III, IV, V, VI and OBD, hybrid electric vehicles shall be tested according to Annex 4, 5, 6, 7, 9, 8 and 11 respectively, unless modified by this annex.
- 1.3. For the Type I test only, OVC vehicles (as categorized in paragraph 2.) shall be tested according to condition A and to condition B. The test results under both conditions A and B and the weighted values shall be reported in the communication form.
- 1.4. The emissions test results shall comply with the limits under all specified test conditions of this Regulation.

2. CATEGORIES OF HYBRID ELECTRIC VEHICLES

Vehicle charging	Off-Vehicle Charging (1) (OVC)		Not Off-Vehicle Charging (2) (NOVC)	
Operating mode switch	Without	With	Without	With

(1) also known as "externally chargeable"

(2) also known as "not externally chargeable"

3. TYPE I TEST METHODS

3.1. EXTERNALLY CHARGEABLE (OVC HEV) WITHOUT AN OPERATING MODE SWITCH

- 3.1.1. Two tests shall be performed under the following conditions:

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Condition A: test shall be carried out with a fully charged electrical energy/power storage device.

Condition B: test shall be carried out with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity).

The profile of the state of charge (SOC) of the electrical energy/power storage device during different stages of the Type I test is given in Appendix 1.

3.1.2. Condition A

3.1.2.1. The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving (on the test track, on a chassis dynamometer, etc.):

- at a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up,
- or, if a vehicle cannot reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine does not start up for a defined time/distance (to be specified between technical service and manufacturer),
- or with manufacturer's recommendation.

The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

3.1.2.2. Conditioning of vehicle

3.1.2.2.1. For compression-ignition engined vehicles the Part Two cycle described in Appendix 1 of Annex 4 shall be used. Three consecutive cycles shall be driven according to paragraph 3.1.2.5.3. below.

3.1.2.2.2. Vehicles fitted with positive-ignition engines shall be preconditioned with one Part One and two Part Two driving cycles according to paragraph 3.1.2.5.3. below.

3.1.2.3. After this preconditioning, and before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20 °C and 30 °C). This conditioning shall be carried out for at least six hours and continue until the engine oil temperature and coolant, if any, are within ± 2 K of the

temperature of the room, and the electrical energy/power storage device is fully charged as a result of the charging prescribed in paragraph 3.1.2.4. below.

3.1.2.4. During soak, the electrical energy/power storage device shall be charged:

- (a) with the on board charger if fitted, or
- (b) with an external charger recommended by the manufacturer, using the normal overnight charging procedure.

This procedure excludes all types of special charges that could be automatically or manually initiated like, for instance, the equalization charges or the servicing charges.

The manufacturer shall declare that during the test, a special charge procedure has not occurred.

3.1.2.5. Test procedure

3.1.2.5.1. The vehicle shall be started up by the means provided for normal use to the driver. The first cycle starts on the initiation of the vehicle start-up procedure.

3.1.2.5.2. Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and end on conclusion of the final idling period in the extra-urban cycle (Part Two, end of sampling (ES)).

3.1.2.5.3. The vehicle shall be driven according to Annex 4, or in case of special gear shifting strategy according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles and indicated by a technical gear shift instrument (for drivers information). For these vehicles the gear shifting points prescribed in Annex 4, Appendix 1 are not applied. For the pattern of the operating curve the description according to paragraph 2.3.3. in Annex 4 shall apply.

3.1.2.5.4. The exhaust gases shall be analyzed according to Annex 4.

3.1.2.6. The test results shall be compared to the limits prescribed in paragraph 5.3.1.4. of this Regulation and the average emission of each pollutant for Condition A shall be calculated (M1_i).

3.1.3. Condition B

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3.1.3.1. Conditioning of vehicle

3.1.3.1.1. For compression-ignition engined vehicles the Part Two cycle described in Appendix 1 of Annex 4 shall be used. Three consecutive cycles shall be driven according to paragraph 3.1.3.4.3. below.

3.1.3.1.2. Vehicles fitted with positive-ignition engines shall be preconditioned with one Part One and two Part Two driving cycles according to paragraph 3.1.3.4.3. below.

3.1.3.2. The electrical energy/power storage device of the vehicle shall be discharged while driving (on the test track, on a chassis dynamometer, etc.):

- at a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up,
- or if a vehicle can not reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine just does not start up for a defined time/distance (to be specified between technical service and manufacturer),
- or with manufacturer's recommendation.

The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

3.1.3.3. After this preconditioning, and before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20 °C and 30 °C). This conditioning shall be carried out for at least six hours and continue until the engine oil temperature and coolant, if any, are within ± 2 K of the temperature of the room.

3.1.3.4. Test procedure

3.1.3.4.1. The vehicle shall be started up by the means provided for normal use to the driver. The first cycle starts on the initiation of the vehicle start-up procedure.

3.1.3.4.2. Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and end on conclusion of the final idling period in the extra-urban cycle (Part Two, end of sampling (ES)).

3.1.3.4.3. The vehicle shall be driven according to Annex 4, or in case of special gear shifting strategy according to the manufacturer's instructions, as incorporated in the drivers'

handbook of production vehicles and indicated by a technical gear shift instrument (for drivers information). For these vehicles the gear shifting points prescribed in Annex 4, Appendix 1 are not applied. For the pattern of the operating curve the description according to paragraph 2.3.3. in Annex 4 shall apply.

- 3.1.3.4.4. The exhaust gases shall be analyzed according to Annex 4.
- 3.1.3.5. The test results shall be compared to the limits prescribed in paragraph 5.3.1.4. of this Regulation and the average emission of each pollutant for Condition B shall be calculated (M_{2i}).
- 3.1.4. Test results
- 3.1.4.1. For communication, the weighted values shall be calculated as below:

$$M_i = (De \cdot A \cdot M_{1i} + Dav \cdot A \cdot M_{2i}) / (De + Dav)$$

Where:

- M_i = mass emission of the pollutant i in grams per kilometre.
- M_{1i} = average mass emission of the pollutant i in grams per kilometre with a fully charged electrical energy/power storage device calculated in paragraph 3.1.2.6.
- M_{2i} = average mass emission of the pollutant i in grams per kilometre with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity) calculated in paragraph 3.1.3.5.
- De = vehicle electric range, according to the procedure described in Regulation No. 101, Annex 7, where the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric mode.
- Dav = 25 km (average distance between two battery recharges)

- 3.2. EXTERNALLY CHARGEABLE (OVC HEV) WITH AN OPERATING MODE SWITCH
- 3.2.1. Two tests shall be performed under the following conditions:
 - 3.2.1.1. Condition A: test shall be carried out with a fully charged electrical energy/power storage device.

3.2.1.2. Condition B: test shall be carried out with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity)

3.2.1.3. The operating mode switch shall be positioned according the table below:

Battery state of charge	Hybrid-modes	-Pure electric	-Pure fuel consuming	-Pure electric	-Hybrid mode n (1)
		-Hybrid	-Hybrid	-Pure fuel consuming -Hybrid mode m (1)
		Switch in position	Switch in position	Switch in position	Switch in position
Condition A Fully charged	Hybrid	Hybrid	Hybrid	Hybrid	Most electric hybrid mode (2)
Condition B Min. state of charge	Hybrid	Fuel consuming	Fuel consuming	Fuel consuming	Most fuel consuming mode (3)

(1) For instance: sport, economic, urban, extra-urban position ...

(2) Most electric hybrid mode:

The hybrid mode which can be proven to have the highest electricity consumption of all selectable hybrid modes when tested in accordance with condition A of paragraph 4. of Annex 10 to Regulation No.101, to be established based on information provided by the manufacturer and in agreement with the technical service.

(3) Most fuel consuming mode:

The hybrid mode which can be proven to have the highest fuel consumption of all selectable hybrid modes when tested in accordance with condition B of paragraph 4. of Annex 10 to Regulation No.101, to be established based on information provided by the manufacturer and in agreement with the technical service.

3.2.2. Condition A

3.2.2.1. If the pure electric range of the vehicle is higher than one complete cycle, on the request of the manufacturer, the Type I test may be carried out in pure electric mode. In this case, engine preconditioning prescribed in paragraph 3.2.2.3.1. or 3.2.2.3.2. can be omitted.

3.2.2.2. The procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving with the switch in pure electric position (on the test track, on a chassis dynamometer, etc.) at a steady speed of 70 per

cent \pm 5 per cent of the maximum thirty minutes speed of the vehicle (determined according to Regulation No. 101).

Stopping the discharge occurs:

- when the vehicle is not able to run at 65 per cent of the maximum thirty minutes speed; or
- when an indication to stop the vehicle is given to the driver by the standard on-board instrumentation, or
- after covering the distance of 100 km.

If the vehicle is not equipped with a pure electric mode, the electrical energy/power storage device discharge shall be achieved by driving the vehicle (on the test track, on a chassis dynamometer, etc.):

- at a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up, or
- if a vehicle cannot reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine does not start up for a defined time/distance (to be specified between technical service and manufacturer), or
- with manufacturer's recommendation.

The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

3.2.2.3. Conditioning of vehicle

3.2.2.3.1. For compression-ignition engined vehicles the Part Two cycle described in Appendix 1 to the Annex 4 shall be used. Three consecutive cycles shall be driven according to paragraph 3.2.2.6.3. below.

3.2.2.3.2. Vehicles fitted with positive-ignition engines shall be preconditioned with one Part One and two Part Two driving cycles according to paragraph 3.2.2.6.3. below.

3.2.2.4. After this preconditioning, and before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20 °C and 30 °C). This conditioning shall be carried out for at least six hours and continue until the engine oil temperature and coolant, if any, are within ± 2 K of the temperature of the room, and the electrical energy/power storage device is fully charged as a result of the charging prescribed in paragraph 3.2.2.5.

3.2.2.5. During soak, the electrical energy/power storage device shall be charged:

- (a) with the on board charger if fitted, or
- (b) with an external charger recommended by the manufacturer, using the normal overnight charging procedure.

This procedure excludes all types of special charges that could be automatically or manually initiated like, for instance, the equalisation charges or the servicing charges.

The manufacturer shall declare that during the test, a special charge procedure has not occurred.

3.2.2.6. Test procedure

3.2.2.6.1. The vehicle shall be started up by the means provided for normal use to the driver. The first cycle starts on the initiation of the vehicle start-up procedure.

3.2.2.6.2. Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure and end on conclusion of the final idling period in the extra-urban cycle (Part Two, end of sampling (ES)).

3.2.2.6.3. The vehicle shall be driven according to Annex 4, or in case of special gear shifting strategy according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles and indicated by a technical gear shift instrument (for drivers information). For these vehicles the gear shifting points prescribed in Annex 4, Appendix 1 are not applied. For the pattern of the operating curve the description according to paragraph 2.3.3. in Annex 4 shall apply.

3.2.2.6.4. The exhaust gases shall be analysed according to Annex 4.

3.2.2.7. The test results shall be compared to the limits prescribed in paragraph 5.3.1.4. of this Regulation and the average emission of each pollutant for Condition A shall be calculated ($M1_i$).

- 3.2.3. Condition B
- 3.2.3.1. Conditioning of vehicle
- 3.2.3.1.1. For compression-ignition engined vehicles the Part Two cycle described in Appendix 1 to the Annex 4 shall be used. Three consecutive cycles shall be driven according to paragraph 3.2.3.4.3. below.
- 3.2.3.1.2. Vehicles fitted with positive-ignition engines shall be preconditioned with one Part One and two Part Two driving cycles according to paragraph 3.2.3.4.3. below.
- 3.2.3.2. The electrical energy/power storage device of the vehicle shall be discharged according to paragraph 3.2.2.2.
- 3.2.3.3. After this preconditioning, and before testing, the vehicle shall be kept in a room in which the temperature remains relatively constant between 293 and 303 K (20 °C and 30 °C). This conditioning shall be carried out for at least six hours and continue until the engine oil temperature and coolant, if any, are within ± 2 K of the temperature of the room.
- 3.2.3.4. Test procedure
- 3.2.3.4.1. The vehicle shall be started up by the means provided for normal use to the driver. The first cycle starts on the initiation of the vehicle start-up procedure.
- 3.2.3.4.2. Sampling shall begin (BS) before or at the initiation of the vehicle start up procedure
- and end on conclusion of the final idling period in the extra-urban cycle (Part Two, end of sampling (ES)).
- 3.2.3.4.3. The vehicle shall be driven according to Annex 4, or in case of special gear shifting strategy according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles and indicated by a technical gear shift instrument (for drivers information). For these vehicles the gear shifting points prescribed in Annex 4, Appendix 1 are not applied. For the pattern of the operating curve the description according to paragraph 2.3.3. in Annex 4 shall apply.
- 3.2.3.4.4. The exhaust gases shall be analysed according to Annex 4.

3.2.3.5. The test results shall be compared to the limits prescribed in paragraph 5.3.1.4. of this Regulation and the average emission of each pollutant for Condition B shall be calculated (M_{2i}).

3.2.4. Test results

3.2.4.1. For communication, the weighted values shall be calculated as below:

$$M_i = (De \cdot A \cdot M_{1i} + Dav \cdot A \cdot M_{2i}) / (De + Dav)$$

Where :

M_i = mass emission of the pollutant i in grams per kilometre

M_{1i} = average mass emission of the pollutant i in grams per kilometre with a fully charged electrical energy/power storage device calculated in paragraph 3.2.2.7.

M_{2i} = average mass emission of the pollutant i in grams per kilometre with an electrical energy/power storage device in minimum state of charge (maximum discharge of capacity) calculated in paragraph 3.2.3.5.

De = vehicle electric range with the switch in pure electric position, according to the procedure described in Regulation No. 101, Annex 7. If there is not a pure electric position, the manufacturer must provide the means for performing the measurement with the vehicle running in pure electric mode.

Dav = 25 km (average distance between two battery recharge).

3.3. NOT EXTERNALLY CHARGEABLE (NOTOVC HEV) WITHOUT AN OPERATING MODE SWITCH

3.3.1. These vehicles shall be tested according to Annex 4.

3.3.2. For preconditioning, at least two consecutive complete driving cycles (one Part One and one Part Two) are carried out without soak.

3.3.3. The vehicle shall be driven according to Annex 4, or in case of special gear shifting strategy according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles and indicated by a technical gear shift instrument (for drivers information). For these vehicles the gear shifting points prescribed in Annex 4, Appendix 1 are not applied. For the pattern of the operating curve the description according to paragraph 2.3.3. in Annex 4 shall apply.

3.4. NOT EXTERNALLY CHARGEABLE (NOTOVC HEV) WITH AN OPERATING MODE SWITCH

- 3.4.1. These vehicles are preconditioned and tested in hybrid mode according to Annex 4. If several hybrid modes are available, the test shall be carried out in the mode that is automatically set after turn on of the ignition key (normal mode). On the basis of information provided by the manufacturer, the Technical Service will make sure that the limit values are met in all hybrid modes.
- 3.4.2. For preconditioning, at least two consecutive complete driving cycles (one Part One and one Part Two) shall be carried out without soak.
- 3.4.3. The vehicle shall be driven according to Annex 4, or in case of special gear shifting strategy according to the manufacturer's instructions, as incorporated in the drivers' handbook of production vehicles and indicated by a technical gear shift instrument (for drivers information). For these vehicles the gear shifting points prescribed in Annex 4, Appendix 1 are not applied. For the pattern of the operating curve the description according to paragraph 2.3.3. in Annex 4 shall apply.
4. TYPE II TEST METHODS
- 4.1. The vehicles shall be tested according to Annex 5 with the fuel consuming engine running. The manufacturer shall provide a "service mode" that makes execution of this test possible.
- If necessary, the special procedure provided for in paragraph 5.1.6. to the Regulation shall be used.
5. TYPE III TEST METHODS
- 5.1. The vehicles shall be tested according to Annex 6 with the fuel consuming engine running. The manufacturer shall provide a "service mode" that makes execution of this test possible.
- 5.2. The tests shall be carried out only for conditions 1 and 2 of the paragraph 3.2. of Annex 6. If for any reasons it is not possible to test on condition 2, alternatively another steady speed condition (with fuel consuming engine running under load) should be carried out.
6. TYPE IV TEST METHODS
- 6.1. The vehicles shall be tested according to Annex 7.

6.2. Before starting the test procedure (paragraph 5.1. of Annex 7), the vehicles shall be preconditioned as follows:

6.2.1. For OVC vehicles:

6.2.1.1. OVC vehicles without an operating mode switch: the procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving (on the test track, on a chassis dynamometer, etc.):

- at a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up, or
- if a vehicle cannot reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine just does not start up for a defined time/distance (to be specified between technical service and manufacturer), or
- with manufacturer's recommendation.

The fuel consuming engine shall be stopped within 10 seconds of it being automatically started.

6.2.1.2. OVC vehicles with an operating mode switch: the procedure shall start with the discharge of the electrical energy/power storage device of the vehicle while driving with the switch in pure electric position (on the test track, on a chassis dynamometer, etc.) at a steady speed of 70 per cent \pm 5 per cent from the maximum thirty minutes speed of the vehicle.

Stopping the discharge occurs:

- when the vehicle is not able to run at 65 per cent of the maximum thirty minutes speed, or
- when an indication to stop the vehicle is given to the driver by the standard on-board instrumentation, or
- after covering the distance of 100 km.

If the vehicle is not equipped with a pure electric mode, the electrical energy/power storage device discharge shall be conducted with the vehicle driving (on the test track, on a chassis dynamometer, etc.):

- at a steady speed of 50 km/h until the fuel consuming engine of the HEV starts up, or
- if a vehicle cannot reach a steady speed of 50 km/h without starting up the fuel consuming engine, the speed shall be reduced until the vehicle can run a lower steady speed where the fuel consuming engine does not start up for a defined time/distance (to be specified between technical service and manufacturer), or
- with manufacturer's recommendation.

The engine shall be stopped within 10 seconds of it being automatically started.

6.2.2. For NOVC vehicles:

6.2.2.1. NOVC vehicles without an operating mode switch: the procedure shall start with a preconditioning of at least two consecutive complete driving cycles (one Part One and one Part Two) without soak.

6.2.2.2. NOVC vehicles with an operating mode switch: the procedure shall start with a preconditioning of at least two consecutive complete driving cycles (one Part One and one Part Two) without soak, performed with the vehicle running in hybrid mode. If several hybrid modes are available, the test shall be carried out in the mode which is automatically set after turn on of the ignition key (normal mode).

6.3. The preconditioning drive and the dynamometer test shall be carried out according to paragraphs 5.2. and 5.4. of Annex 7:

6.3.1. For OVC vehicles: under the same conditions as specified by condition B of the Type I test (paragraphs 3.1.3. and 3.2.3.).

6.3.2. For NOVC vehicles: under the same conditions as in the Type I test.

7. TYPE V TEST METHODS

7.1. The vehicles shall be tested according to Annex 9.

7.2. For OVC vehicles:

It is allowed to charge the electrical energy/power storage device twice a day during mileage accumulation.

For OVC vehicles with an operating mode switch, mileage accumulation should be driven in the mode which is automatically set after turn on of the ignition key (normal mode).

During the mileage accumulation a change into another hybrid mode is allowed if necessary in order to continue the mileage accumulation after agreement of the technical service.

The measurements of emissions of pollutants shall be carried out under the same conditions as specified by condition B of the Type I test (paragraphs 3.1.3. and 3.2.3.).

7.3. For NOVC vehicles:

For NOVC vehicles with an operating mode switch, mileage accumulation shall be driven in the mode which is automatically set after turn on of the ignition key (normal mode).

The measurements of emissions of pollutants shall be carried out in the same conditions as in the Type I test.

8. TYPE VI TEST METHODS

8.1. The vehicles shall be tested according to Annex 8.

8.2. For OVC vehicles, the measurements of emissions of pollutants shall be carried out under the same conditions as specified for condition B of the Type I test (paragraphs 3.1.3. and 3.2.3.).

8.3. For NOVC vehicles, the measurements of emissions of pollutants shall be carried out under the same conditions as in the Type I test.

9. ON BOARD DIAGNOSTICS (OBD) TEST METHODS

9.1. The vehicles shall be tested according to Annex 11.

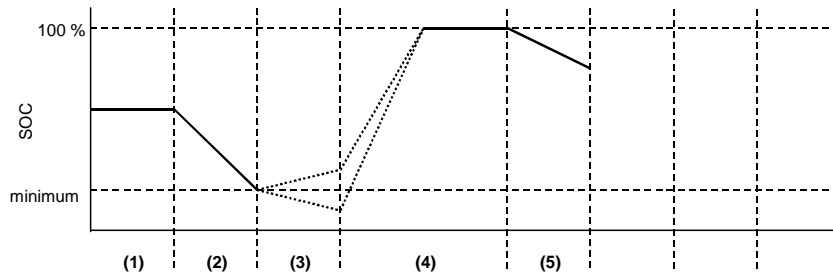
9.2. For OVC vehicles, the measurements of emissions of pollutants shall be carried out under the same conditions as specified for condition B of the Type I test (paragraphs 3.1.3. and 3.2.3.).

9.3. For NOVC vehicles, the measurements of emissions of pollutants shall be carried out under the same conditions as in the Type I test.

Annex 14, Appendix 1,

Electrical energy/power storage device State Of Charge (SOC) profile for OVC HEV Type I test

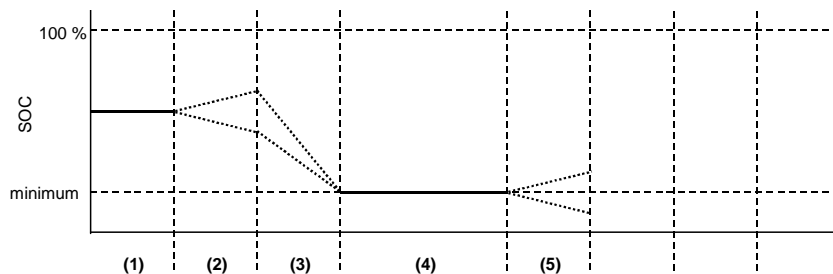
Condition A of the Type I test



Condition A:

- (1) initial electrical energy/power storage device state of charge
- (2) discharge according to paragraph 3.1.2.1. or 3.2.2.1.
- (3) vehicle conditioning according to paragraph 3.1.2.2. or 3.2.2.2.
- (4) charge during soak according to paragraphs 3.1.2.3. and 3.1.2.4., or paragraphs 3.2.2.3. and 3.2.2.4.
- (5) test according to paragraph 3.1.2.5. or 3.2.2.5.

Condition B of the Type I test



Condition B:

- (1) initial state of charge
- (2) vehicle conditioning according to paragraph 3.1.3.1. or 3.2.3.1.
- (3) discharge according to paragraph 3.1.3.2. or 3.2.3.2.
- (4) soak according to paragraph 3.1.3.3. or 3.2.3.3.
- (5) test according to paragraph 3.1.3.4. or 3.2.3.4.

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Annex 9

ROAD LOAD DETERMINATION

- **ISO 10521-1&2** as a basis
 - ISO o.k. => mark text green

1 Scope

This part of ISO 10521 specifies methods of determining the road load of road vehicles for subsequent test purposes, for example, fuel consumption tests or exhaust emission measurements. This Annex consists of two parts, part one determines the road load of a vehicle running on a level road under reference atmospheric conditions. It is achieved by the coastdown method, the torque meter method or the wind-tunnel/chassis-dynamometer method. Part two specifies methods of setting the target road load on chassis dynamometers for the purpose of a subsequent test, for example the fuel consumption test or the exhaust-emission measurement test.

This part of ISO 10521 is applicable to motor vehicles, as defined in ISO 3833, up to a gross vehicle mass of 3 500 kg.

Part 2 is applicable to chassis dynamometers that can set road load at a minimum of three speed points

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*

3 Terms and definitions

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

3.1

total resistance

total force-resisting movement of a vehicle, measured either by the coastdown method or by the windtunnel/ chassis-dynamometer method, including the friction forces in the drive-train

3.2

running resistance

torque-resisting movement of a vehicle, measured by the torquemeter installed in the drive-train of a vehicle, including the friction torque in the drive-train downstream of the torquemeter

3.3

road load

general meaning of the force or torque which opposes the movement of a vehicle, including total resistance and/or running resistance

3.4

aerodynamic drag

resistance of the air to the motion of a vehicle

3.5

rolling resistance

opposing force in the drive-train, axles and tyres to the motion of a vehicle

3.6

reference speed

a vehicle speed at which a chassis-dynamometer load is verified

3.7

reference atmospheric conditions

atmospheric conditions of the following values, to which the road-load measurement results are corrected:

a) atmospheric pressure: $p_0 = 100$ kPa, unless otherwise specified by regulations;

b) atmospheric temperature: $t_0 = 293$ K, unless otherwise specified by regulations;

c) dry air density: $\rho_0 = 1,189$ kg/m³, unless otherwise specified by regulations;

d) wind speed: 0 m/s.

3.8

stationary anemometry

measurement of wind speed and direction with an anemometer at a location and height above road level alongside the test road where the most representative wind conditions will be experienced

3.9

onboard anemometry

measurement of wind speed and direction with an anemometer appropriately installed to the test vehicle

3.10

wind correction

correction of the effect of wind on road load, which is achieved either by stationary or by onboard anemometry

3.11

aerodynamic stagnation point

point on the surface of a vehicle where the wind velocity is equal to zero

3.1 total resistance

total force-resisting movement of a vehicle movement, measured either by the coastdown method or by the wind-tunnel and chassis-dynamometer method, including the friction forces in the drive train

3.2 running resistance

torque-resisting movement of a vehicle, measured by the torquemeter installed in the drive-train of a vehicle, including the friction torque in the drive-train downstream of the torquemeter

3.3 road load

general meaning of force or torque which opposes the movement of a vehicle, including total resistance and/or running resistance

3.4 reference speed

vehicle speed at which a chassis-dynamometer load is verified

NOTE Reference speeds may be continuous speed points covering the complete speed range.

3.5 target road load

road load to be reproduced on the chassis dynamometer

3.6 chassis-dynamometer setting load

load to be set on the power-absorption unit of the chassis dynamometer

3.7 simulated road load

road load to be calculated from measured coastdown data using the least-square regression

NOTE See Annex A for the calculation procedure.

3.8 speed range

range of speed of chassis-dynamometer roller between 15 km/h and maximum reference speed plus 10 km/h, over which the coastdown test is conducted

3.9 chassis dynamometer of coefficient control

chassis dynamometer of which absorption characteristics are determined by giving coefficients of a road-load approximation polynomial

3.10 chassis dynamometer of polygonal control

chassis dynamometer of which absorption characteristics are determined by giving load values at several speed points

4 Required overall measurement accuracy

The required overall measurement accuracy shall be as follows:

- a) vehicle speed: $\pm 0,5$ km/h or ± 1 %, whichever is greater;
- b) time: ± 50 ms or $\pm 0,1$ %, whichever is greater;
- c) wheel torque: ± 3 N·m or $\pm 0,5$ %, whichever is greater;
- d) wind speed: $\pm 0,3$ m/s;
- e) wind direction: $\pm 3^\circ$;
- f) atmospheric temperature: ± 1 K;
- g) atmospheric pressure: $\pm 0,3$ kPa;
- h) vehicle mass: ± 10 kg;
- i) tyre pressure: ± 5 kPa;
- j) product of aerodynamic coefficient and frontal projected area (SCd): ± 2 %;
- k) chassis-dynamometer roller speed: $\pm 0,5$ km/h or ± 1 %, whichever is greater;
- l) chassis-dynamometer force:

Category 1 chassis dynamometer: ± 6 N, or

Category 2 chassis dynamometer: ± 10 N or $\pm 0,1$ % of full scale, whichever is greater.

NOTE The Category 2 chassis dynamometer usually has a greater load capacity, e.g. 130 kW or more.

Part one

5 Road-load measurement on road

5.1 Requirements for road test

5.1.1 Atmospheric conditions for road test

5.1.1.1 Wind

The average wind speed over the test road shall not exceed 10 m/s, nor wind gusts exceed 14 m/s. Relevant wind correction shall be conducted according to the applicable type of anemometry specified in Table 1. In order to decide the applicability of each anemometry type, the average wind speed shall be determined by continuous wind speed measurement, using a recognized meteorological instrument, at a location and height above the road level alongside the test road where the most representative wind conditions will be experienced.

NOTE Wind correction may be waived when the average wind speed is 3 m/s or less.

Table 1 — Applicable anemometry depending on average wind speed and cross-wind component

Type of anemometry	Wind speed in metres per second (m/s)		
	Average wind speed		
	Absolute wind speed $v \leq 5$	Absolute wind speed	
	Cross-wind component (v_c)	Cross-wind component (v_c)	$5 < v \leq 10$
	$v_c \leq 3$	$3 < v_c \leq 5$	
Stationary anemometry	Applicable	Not applicable	Not applicable
Onboard anemometry	Applicable	Applicable	Applicable

NOTE The stationary anemometry is recommended when the absolute wind speed is less than 1 m/s.

5.1.1.2 Atmospheric temperature

The atmospheric temperature shall be within the range of 274 to 308 K, inclusive.

5.1.2 Test road

The road surface shall be flat, clean, dry, free of obstacles or wind barriers that might impede the measurement of the running resistance and hard, and its texture and composition shall be representative of current urban and highway road surfaces. The test-road longitudinal slope shall not exceed $\pm 1\%$. The local inclination between any points 3 m apart shall not deviate more than $\pm 0,5\%$ from this longitudinal slope. The maximum cross-sectional camber of the test road shall be 1,5 %.

5.2 Preparation for road test

5.2.1 Vehicle preparation

5.2.1.1 Vehicle condition

The test vehicle shall be suitably run-in for the purpose of the subsequent test for at least 3000 km. The tyres shall be suitably broken-in for the purpose of the subsequent test, while still having a tread depth of not less than 50 % of the initial tread depth [at the beginning or end of test runs].

Unless any particular purpose is intended, the vehicle shall be in normal vehicle conditions, as specified by the manufacturer. That is, tyre pressure (see 5.2.1.2), wheel alignment, vehicle height, lubricants in the drivetrain and wheel-bearings, and brake adjustment to avoid unrepresentative parasitic drag.

The tyres shall be selected according to the characteristics used for the lab test. [no provisions in regional legislations except ECE (width/rolling resistance), but ECE procedure not practicable?]

During the road test, the engine bonnet/hood and all windows shall be closed so that they will not influence the road-load measurement. Any covers of the air ventilation system, headlamps, etc., shall be closed, and the air-conditioning switched off. [ECE: use worst aerodynamic bodywork type → general accessories discussion?]

The vehicle mass shall be adjusted to meet the requirement of the intended subsequent test, including the mass of the driver and instruments.

Special provisions for HEV/Hybrids → LabProcHEV Subgroup

5.2.1.2 Tyre-pressure adjustment

If the difference between the ambient and soak temperature is more than 5 K, the tyre pressure shall be adjusted as follows:

Soak the tyres for more than 4 h at 10 % above the target pressure. Just before testing, reduce the pressure down to the manufacturer's recommended inflation pressure, adjusted for difference between the soaking environment temperature and the ambient test temperature at a rate of 0,8 kPa per 1 K using the following formula:

$$\Delta P_r = 0,8 \cdot (T_{\text{soak}} - T_{\text{amb}})$$

where

ΔP_r is the tyre pressure adjustment, in kilopascals (kPa);

0,8 is the pressure adjustment factor, in kilopascals per kelvin (kPa/K);

T_{soak} is the tyre-soaking temperature, in kelvins (K);

T_{amb} is the test ambient temperature, in kelvins (K).

The vehicle tires shall be inflated to the vehicle manufacturer's minimum recommended inflation pressure, adjusted for changes in temperature between the tire temperature at the time of inflation and the test track ambient temperature. (For normal passenger vehicle tires this correction is approximately a 1 kPa increase for each degree Celsius that the tire temperature exceeds the track ambient temperature.)

OPTION—Where tire temperatures are not stable or when the test is not to be run immediately after vehicle preparation, the tires shall be inflated to the manufacturers minimum recommended tire pressure plus 10%.

The vehicle shall be parked near the test track area with the tires shielded from the sun for a minimum of 4 h.

5.2.2 Installation of instruments

Any instruments, especially for those installed outside the vehicle, shall be installed on the vehicle in such a manner as to minimize effects on the operating characteristics of the vehicle.

5.2.3 Vehicle preconditioning

Prior to the test, the vehicle shall be preconditioned appropriately, until stabilized and normal vehicle operating temperatures have been reached. It is recommended that the vehicle should be driven at the most appropriate reference speed for a period of 30 min. During this preconditioning period, the vehicle speed shall not exceed the highest reference speed.

Immediately prior to the test, the vehicle shall be brought to normal running temperature in an appropriate manner.

5.3 Measurement of total resistance by coastdown method

The total resistance shall be determined by either the multi-segment method (5.3.1), the average deceleration method (5.3.2) or the direct regression method (5.3.3).

Draft Proposal – Raw Version after Workshop 03.-06.08.2010 in Ingolstadt

5.3.1 Multi-segment method

5.3.1.1 Selection of speed points for road-load curve determination

In order to obtain a road-load curve as a function of vehicle speed, a minimum of four speed points, V_j ($j = 1, 2, \text{etc.}$) shall be selected. The highest speed point shall not be lower than the highest reference speed, and the lowest speed point shall not be higher than the lowest reference speed. The interval between each speed point shall not be greater than 20 km/h.

5.3.1.2 Data collection

During the test, a) and b) shall be measured and recorded at a maximum of 0,2 s intervals, and c) and d) at a maximum of 1,0 s intervals.

a) elapsed time;

b) vehicle speed;

c) wind speed;

d) wind direction.

NOTE The wind speed and the wind direction are measured by the stationary anemometry.

5.3.1.3 Vehicle coastdown

5.3.1.3.1 Following preconditioning, and immediately prior to each test measurement, drive the vehicle at the highest reference speed for, at most, 1 min, if necessary. Then accelerate the vehicle to 5 km/h more than the speed at which the coastdown time measurement begins ($V_j + \Delta V$) and begin the coastdown immediately.

5.3.1.3.2 During coastdown, the transmission shall be in neutral, and the engine shall run at idle. In the case of vehicles with manual transmission, the clutch shall be engaged. Movement of steering-wheel shall be avoided as much as possible, and the vehicle brakes shall not be operated until the end of the coastdown.

5.3.1.3.3 Repeat the test, taking care to begin the coastdown at the same speed and preconditions.

5.3.1.3.4 Although it is recommended that each coastdown run be performed without interruption, split runs are permitted if data cannot be collected in a continuous fashion for the entire speed range. For split runs, care shall be taken so that the vehicle condition be constant as much as possible at each split point.

5.3.1.4 Determination of total resistance by coastdown time measurement

5.3.1.4.1 Measure the coastdown time corresponding to the speed V_j as the elapsed time from the vehicle speed ($V_j + \Delta V$) to ($V_j - \Delta V$). It is recommended that ΔV be 10 km/h when the vehicle speed is more than 60 km/h, and 5 km/h when the vehicle speed is 60 km/h or less.

5.3.1.4.2 Carry out these measurements in both directions until a minimum of three consecutive pairs of figures have been obtained which satisfy the statistical accuracy p , in percent, defined below.

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

where

n is the number of pairs of measurements;

ΔT_j is the mean coastdown time at speed V_j , in seconds (s), given by the formula:

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

in which

ΔT_{ji} is the harmonized average coastdown time of the i th pair of measurements at speed V_j , in seconds (s) given by the formula:

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

and in which

ΔT_{jai} and ΔT_{jbi} are the coastdown times of the i th measurement at speed V_j in each direction, respectively, in seconds (s);

s is the standard deviation, in seconds (s), defined by the formula:

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

t is the coefficient given in Table 2.

Table 2

n	t	$\frac{t}{\sqrt{n}}$
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	2.2	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

5.3.1.4.3 If, during a measurement in one direction, the driver is forced to change the vehicle direction sharply, this measurement and the paired measurement in the opposite direction shall be rejected.

5.3.1.4.4 The total resistances, F_{ja} and F_{jb} at speed V_j in each direction, in newtons, are determined by the formulae:

$$F_{ja} = -\frac{1}{3.6} \times (m - m_r) \times \frac{2 \times \Delta v}{\Delta T_{ja}}$$

$$F_{jb} = -\frac{1}{3.6} \times (m - m_r) \times \frac{2 \times \Delta v}{\Delta T_{jb}}$$

where

m is the test vehicle mass including the driver and instruments, in kilograms (kg);

m_r is the equivalent effective mass of all the wheels and vehicle components rotating with the wheels during coastdown on the road, in kilograms (kg); m_r should be measured or calculated by an appropriate technique. As an alternative, m_r may be estimated as 3 % of the unladen vehicle mass;

ΔT_{ja} and ΔT_{jb} are the mean coastdown times in each direction, respectively, corresponding to speed V_j , in seconds (s), given by the formulae:

$$\Delta T_{ja} = \frac{1}{n} \sum_{i=1}^n \Delta T_{jai}$$

$$\Delta T_{jb} = \frac{1}{n} \sum_{i=1}^n \Delta T_{jbi}$$

5.3.1.4.5 The total-resistance curve shall be determined as follows. Fit the following regression curve to the data sets (V_j, F_{ja}) and (V_j, F_{jb}) corresponding to all the speed points V_j ($j = 1, 2$, etc.) and direction (a, b) to determine f_0 , f_1 and f_2 :

$$F_a = f_{0a} + f_{1a} V + f_{2a} V^2$$

$$F_b = f_{0b} + f_{1b} V + f_{2b} V^2$$

where

F_a and F_b are the total resistances in each direction, in newtons (N);

f_{0a} and f_{0b} are the constant terms in each direction, in newtons (N);

f_{1a} and f_{1b} are the coefficients of the first-order term of the vehicle speed in each direction, in newtons hour per kilometre (N·h/km); f_1 may be assumed to be zero, if the value of $f_1 V$ is no greater than 3 % of F at the reference speed(s); in this case, the coefficients f_0 and f_2 shall be recalculated;

f_{2a} and f_{2b} are the coefficients of the second-order term of the vehicle speed in each direction, in newtons hour squared per kilometre squared [(N⊕(h/km)²)];

V is the vehicle speed, in kilometres per hour (km/h).

Then calculate the coefficients f_0 , f_1 and f_2 in the total-resistance equation using the following formulae:

$$f = \frac{f_{0a} + f_{0b}}{2}$$

$$f = \frac{f_{1a} + f_{1b}}{2}$$

$$f = \frac{f_{2a} + f_{2b}}{2}$$

where f_0 , f_1 and f_2 are the average coefficients in the following average total-resistance equation:

$$F_{\text{avg}} = f_0 + f_1 V + f_2 V^2$$

and in which F_{avg} is the average total resistance, in newtons (N).

NOTE As a simple alternative to the above calculation, the following formula may be applied to compute the average total resistance, where the harmonized average of the alternate coastdown time is used instead of the average of alternate total resistance.

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

where ΔT_j is the harmonized average of alternate coastdown time measurements at speed V_j , in seconds (s), given by the formula:

$$\Delta T_j = \frac{2}{(1 / \Delta T_{ja}) + (1 / \Delta T_{jb})}$$

and in which ΔT_{ja} and ΔT_{jb} are the coastdown time at speed V_j in each direction, respectively, in seconds (s).

Then, calculate the coefficients f_0 , f_1 and f_2 in the total-resistance equation with the regression analysis.

5.3.2 Average deceleration method

As an alternative to the determination in 5.3.1, the total resistance may also be determined by the procedures described in 5.3.2.1 to 5.3.2.4.

5.3.2.1 Selection of speed points for road-load curve determination

Speed points shall be selected as specified in 5.3.1.1.

5.3.2.2 Data collection

Data shall be measured and recorded as specified in 5.3.1.2.

5.3.2.3 Vehicle coastdown

Vehicle coastdown shall be conducted as specified in 5.3.1.3.

5.3.2.4 Determination of total resistance by coastdown measurement

5.3.2.4.1 Record the speed-versus-time data during coastdown from vehicle speed $(V_j + \Delta V)$ to $(V_j - \Delta V)$, where ΔV is more than 10 km/h.

5.3.2.4.2 Fit the following function to the group of data by polynomial regression to determine the coefficients A_0 , A_1 , A_2 and A_3 :

$$V_a(t) = A_{0a} + A_{1a}t + A_{2a}t^2 + A_{3a}t^3$$

$$V_b(t) = A_{0b} + A_{1b}t + A_{2b}t^2 + A_{3b}t^3$$

where

$V_a(t)$, $V_b(t)$ is the vehicle speed, in kilometres per hour (km/h);

t is the time, in seconds (s);

A_{0a} , A_{1a} , A_{2a} , A_{3a} , A_{0b} , A_{1b} , A_{2b} and A_{3b} are the coefficients.

5.3.2.4.3 Determine the deceleration, γ_j , in metres per second squared, at the speed V_j as follows:

$$\gamma_j = \frac{1}{3.6} \times (A_{1j} + 2 \times A_{2j}t_j + 3 \times A_{3j}t_j^2)$$

where t_j is the time at which the vehicle speed given by the function in 5.3.2.4.2 is equal to V_j .

5.3.2.4.4 Repeat the measurements in both directions, until a minimum of four consecutive pairs of the data have been obtained which satisfy the statistical accuracy p , in percent, below. The validity of the data shall be decided in accordance with 5.3.1.4.3.

$$p = \frac{ts}{\sqrt{n}} \times \frac{100}{\Gamma_j} \leq 3\%$$

where

n is the number of pairs of measurements;

Γ_j is the mean average deceleration at the speed V_j , in metres per second squared (m/s²), given by the formula:

$$\Gamma_j = \frac{1}{n} \sum_{i=1}^n \Gamma_{ji}$$

in which

$$\Gamma_j = \frac{1}{2} \times (\gamma_{ai} + \gamma_{bi})$$

and in which

γ_{ai} and γ_{bi} are the decelerations of the i th measurement at the speed V_j defined in 5.3.2.4.3 for each direction, respectively, in metres per second squared (m/s²);

s is the standard deviation, in metres per second squared (m/s²), defined by the formula:

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (\Gamma_{ji} - \Gamma_j)^2}$$

t is the coefficient given in Table 2.

5.3.2.4.5 Determine the total resistance F_j at the speed V_j by the following formula, using m and mr as defined in 5.3.1.4.4.

$$F_j = (m + mr) \Gamma_j$$

5.3.2.4.6 Total-resistance curve determination

Determine the total-resistance curve as specified in 5.3.1.4.5.

5.3.3 Direct regression method

As an alternative to the determination in 5.3.1.4.5, the total resistance may also be determined by the following mathematical approach.

5.3.3.1 Selection of speed range for road-load curve determination

The test speed range (i.e. the maximum speed and the minimum speed) shall be so determined that it covers the range of the reference speeds, over which total resistance is measured. If the test is carried out in a manner of split runs, each split speed range shall be determined accordingly.

5.3.3.2 Data collection

Data shall be measured and recorded as specified 5.3.1.2.

5.3.3.3 Vehicle coastdown

Vehicle coastdown shall be conducted as specified in 5.3.1.3.

5.3.3.4 Determination of total resistance by coastdown measurement

The coefficients f_0 , f_1 and f_2 shall be calculated by approximating the relation between V and t to tangent with Equation (4), of which the mathematical process is as follows.

5.3.3.4.1 Express F using Formulae (1) and (2):

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

$$F = -\frac{1}{3.6} \times (m + mr) \times \frac{dV}{dt} \quad (2)$$

where

F is the total resistance, in newtons (N);

f_0 is the constant term, in newtons (N);

f_1 is the coefficient of the first-order term, in newtons hour per kilometre [N⊙(h/km)];

f_2 is the coefficient of the second-order term, in newtons hour squared per kilometre squared [N⊙(h/km)²];

m is the test vehicle mass including the driver and instruments, in kilograms (kg);

mr is the equivalent effective mass of all the wheels and vehicle components rotating with the wheels during coastdown on the road, in kilograms (kg); mr should be measured or calculated by an appropriate technique; as an alternative, mr may be estimated as 3 % of the unladen vehicle mass;

V is the vehicle speed, in kilometres per hour (km/h).

5.3.3.4.2 Equation (3) is derived from Equations (1) and (2).

$$-\frac{3.6 \times dt}{m + mr} = \frac{dV}{f_0 + f_1 V + f_2 V^2} \quad (3)$$

5.3.3.4.3 Yield Equation (4) from Equation (3).

$$V = \frac{\sqrt{4 \times f_0 f_2 - f_1^2}}{2 \times f_2} \tan \left[-\frac{3.6 \times \sqrt{4 \times f_0 f_2 - f_1^2}}{2 \times (m + mr)} xt - C_0 \right] - \frac{f_1}{2 \times f_2} \quad (4)$$

where

t is the time, in seconds (s);

C_0 is the integration constant.

5.3.3.4.4 Replace Equation (4) with (5).

$$V = A \tan(Bt + C) + D \quad (5)$$

5.3.3.4.5 Calculate A , B , C and D in the approximate Equation (5) by the least-squares method, and then determine the coefficients f_0 , f_1 and f_2 by the following formulae:

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

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

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

NOTE If coastdowns are carried out in the manner of split runs, the total resistance, F , can be calculated as follows.

Calculate the road-load force for each reference speed included in the actual coastdown speed range. Then put each split data into one set, and calculate one road-load force equation for respective directions.

5.3.3.4.6 Total-resistance curve determination

Determine the total-resistance curve as specified in 5.3.1.4.5.

5.4 Onboard-anemometer based coastdown method

As an alternative to the determination in 5.3.1, 5.3.2 or 5.3.3, the total resistance may also be determined by the procedure described in 5.4.1 to 5.4.5. This method is applicable to a wind speed range up to 10 m/s on a test road as given in Table 1.

5.4.1 Selection of speed range for road-load curve determination

Select the test speed range as specified in 5.3.3.1.

5.4.2 Data collection

The following data shall be measured and recorded at a maximum of 0,2 s intervals during the test.

- a) elapsed time;
- b) vehicle speed;
- c) wind speed and direction.

NOTE The wind speed and the wind direction are measured by the onboard anemometry.

5.4.3 Vehicle coastdown

Vehicle coastdown shall be conducted as specified in 5.3.1.3.1 to 5.3.1.3.4 with an onboard anemometer installed on the vehicle. The anemometer shall be installed in a position such that the effect on the operating characteristics of the vehicle is minimized. It is recommended to install the anemometer at the aerodynamic stagnation point of the vehicle's front and approximately 2 m in front of it. Before the coastdown, the anemometer shall be installed on the vehicle and calibrated appropriately, as specified by the manufacturer.

An example of the anemometer calibration procedure is given in Annex A.

5.4.4 Determination of coefficients

Calculate each coefficient by the following equation with multi-regression analysis, using coastdown time and wind data.

$$-\frac{1}{3.6} \times (m + mr) \times \frac{dV}{dt} = a_{\text{mech}} + b_{\text{mech}}V + c_{\text{mech}}V^2 + \frac{1}{2} \times \rho S v_r^2 \times (a_0 + a_1\theta + a_2\theta^2 + a_3\theta^3 + a_4\theta^4)$$

where

m is the test vehicle mass including driver and instruments, in kilograms (kg);

mr is the equivalent effective mass of all the wheels and vehicle components rotating with the wheels during coastdown on the road, in kilograms (kg); mr should be measured or calculated by an appropriate technique; as an alternative, mr may be estimated as 3 % of the unladen vehicle mass;

dV/dt is the acceleration, in kilometres per hour per second [(km/h)/s];

a_{mech} is the coefficient of mechanical drag, in newtons (N);

b_{mech} is the coefficient of mechanical drag, in newtons per kilometre per hour [N/(km/h)];

c_{mech} is the coefficient of mechanical drag, in newtons per kilometre squared per hour squared [N/(km/h)²];

V is the vehicle speed, in kilometres per hour (km/h);

V_r is the relative wind speed, in kilometres per hour (km/h);

ρ is the air density, in kilograms per cubic metre (kg/m³);

S is the projected frontal area of the vehicle, in square metres (m²);

a_n ($n = 0$ to 4) is the coefficient for aerodynamic drag as a function of yaw angle, in degrees⁻ⁿ;

θ is the yaw-angle apparent wind relative to the direction of vehicle travel, in degrees.

NOTE If the wind speed is close to 0, the equation theoretically cannot separate c_{mech} and $(1/2) \times a_0 \rho S$ appropriately. Therefore, a constrained analysis, where a_0 is fixed if it is previously determined, for example in a wind tunnel, or c_{mech} is assumed to be zero, may be employed.

5.4.5 Determination of total resistance

Calculate the total resistance, F , where all the wind effects are eliminated, by the following equation with the coefficients obtained in 5.4.4.

$$F = a_{\text{mech}} + b_{\text{mech}}V + \left[c_{\text{mech}} + \frac{1}{2} \times a_0 \rho S \right] V^2$$

5.5 Measurement of running resistance by torquemeter method

As an alternative to the coastdown methods, the torquemeter method may also be used, in which the running resistance is determined by measuring the torque as described in 5.5.1 to 5.5.3.

5.5.1 Installation of torquemeter

The torquemeter(s) shall be installed on the drive-train of the test vehicle. It is preferable to have wheel torquemeters on each driven wheel.

5.5.2 Vehicle running and data sampling

5.5.2.1 Start of data collection

The data collection may be started following preconditioning and stabilization of the vehicle at the speed V_{ji} , where the running resistance is to be measured.

5.5.2.2 Data collection

Record at least 10 data sets of speed, torque and time over a period of at least 5 s.

5.5.2.3 Speed deviation

The speed deviation from the mean speed shall be within the values in Table 3.

Table 3

Time period s	Speed deviation km/h
5	± 0,2
10	± 0,4
15	± 0,6
20	± 0,8
25	± 1,0
30	± 1,2

5.5.3 Calculation of mean speed and mean torque

5.5.3.1 Calculation process

Calculate the mean speed V_{jm} , in kilometres per hour (km/h), and mean torque C_{jm} in newton metres (N·m), over a time period, as follows:

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

and

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

where

V_{ji} is the vehicle speed of the i th data set, in kilometres per hour (km/h);

k is the number of data sets;

C_{ji} is the torque of the i th data set, in newton metres (N·m);

C_{js} is the compensation term for the speed drift, in newton metres (N·m), which is given by the following formula; C_{js} shall be not greater than 5 % of the mean torque before compensation, and may be neglected if $\langle j \rangle$ is no greater than $\pm 0,005 \text{ m/s}^2$:

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

in which

m and m_r are the test vehicle mass and the equivalent effective mass, respectively, both in kilograms (kg), defined in 5.3.1.4.4;

r_j is the dynamic radius of the tyre, in metres (m), given by the formula:

$$r_j = \frac{1}{3.6} \times \frac{v_j m}{2 \times \pi N}$$

and in which

N is the rotational frequency of the driven tyre, in revolutions per second (s⁻¹);

α_j is the mean acceleration, in metres per second squared (m/s²), which shall be calculated by the formula:

$$\alpha_j = \frac{1}{3.6} \times \frac{k \sum_{i=1}^k t_i v_{ji} - \sum_{i=1}^k t_i \sum_{i=1}^k v_{ji}}{\sum_{i=1}^k t_i^2 - \left[\sum_{i=1}^k t_i \right]^2}$$

and in which t_i is the time at which the i th data set was sampled, in seconds (s).

5.5.3.2 Accuracy of measurement

Carry out these measurements in both directions until a minimum of four consecutive figures have been obtained which satisfy accuracy p , in percent (%), below. Calculate the mean speed V_j , in kilometres per hour (km/h), and mean torque C_{jm} in newton metres, over a time period as follows. The validity of the data shall be decided in accordance with 5.3.1.4.3.

$$\rho = \frac{ts}{\sqrt{k}} \times \frac{100}{C_j} \leq 3\%$$

where

k is the number of data sets;

C_j is the running resistance at the speed V_j , in newton metres (N·m), given by the formula:

$$\overline{C_j} = \frac{1}{k} \sum_{i=1}^k C_{jmi}$$

in which C_{jmi} is the average torque of the i th pair of data sets at the speed V_j , in newton metres (N·m), given by the formula:

$$C_{jmi} = \frac{1}{2} \times (C_{jmai} + C_{jm bi})$$

and in which

C_{jmai} and $C_{jm bi}$ are the mean torques of the i th data sets at the speed V_j determined in 5.5.3.1 for each direction respectively, in newton metres (N·m);

s is the standard deviation, in newton metres (N·m), defined by the formula:

$$s = \sqrt{\frac{1}{k-1} \sum_{i=1}^k (C_{jmi} - \overline{C_j})^2}$$

k is the coefficient given by replacing n in Table 2 with k .

5.5.3.3 Validity of the measured average speed

The average speed V_{jmi} , shall not deviate by more than ± 2 km/h from its mean, $\overline{V_j}$, V_{jmi} and V_j shall be calculated as follows:

$$\overline{V_j} = \frac{1}{k} \sum_{i=1}^k V_{jmi}$$

and

$$V_{jmi} = \frac{1}{2} \times (V_{jmai} + V_{jm bi})$$

where V_{jmai} and $V_{jm bi}$ are the mean speeds of the i th pair of data sets at the speed V_j determined in 5.5.3.1 for each direction respectively, in kilometres per hour (km/h).

5.5.4 Running resistance curve determination

The following regression curve shall be fitted to all the data pairs (V_{jm}, C_{jma}) and (V_{jm}, C_{jmb}) for both directions at all speed points V_j ($j = 1, 2$, etc.) described in 5.3.1.1, to determine c_{0a} , c_{0b} , c_{1a} , c_{1b} , c_{2a} and c_{2b} :

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

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

where

C_a and C_b are the running resistances in each direction, in newton metres (N·m);

c_{0a} and c_{0b} are the constant terms in each direction, in newton metres (N·m);

c_{1a} and c_{1b} are the coefficients of the first-order term in each direction, in newton metres hour per kilometre [N·m(h/km)]; c_1 may be assumed to be zero, if the value of $c_1 V$ is no greater than 3 % of C at the reference speed(s); In this case, the coefficients c_0 and c_2 shall be recalculated;

c_{2a} and c_{2b} are the coefficients of the second-order term in each direction, in newton metres hour squared per kilometre squared [N·m(h/km)²];

V is the vehicle speed, in kilometres per hour (km/h).

Then calculate the coefficients c_0 , c_1 and c_2 in the total torque equation using the following formulae:

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

$$c_1 = \frac{c_{1a} + c_{1b}}{2}$$

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

where

c_0 , c_1 and c_2 are the average coefficients in the following average total torque equation:

$$C_{avg} = c_0 + c_1 V + c_2 V^2$$

and in which C_{avg} is the average running resistance, in newton metres (N·m).

5.6 Correction to standard atmospheric conditions

5.6.1 Correction factors

5.6.1.1 Determination of correction factor for air resistance

Determine the correction factor for air resistance K_2 as follows:

$$K_2 = \frac{T}{293} \times \frac{100}{p} \quad \text{[Check with reference ambient conditions of Lab]}$$

where

T is the mean atmospheric temperature, in kelvins (K);

p is the mean atmospheric pressure, in kilopascals (kPa).

5.6.1.2 Determination of correction factor for rolling resistance

The correction factor, K_0 , for rolling resistance, in reciprocal kelvins, may be determined, based on the empirical data for the particular vehicle and tyre test, or may be assumed as follows:

$$K_0 = 8.1 \times 10^{-3} \times K^{-1}$$

(R101: $K_r = 3.6 \times 10^{-3} \times ^\circ\text{C}^{-1}$;

R83: $K_r = 8.64 \times 10^{-3} \times ^\circ\text{C}^{-1}$

US: $K_r = 8.6 \times 10^{-3} \times ^\circ\text{C}^{-1}$

5.6.1.3 Wind correction

Wind correction, for absolute wind speed alongside the test road, shall be made by subtracting the difference that cannot be cancelled by alternate runs from the constant term f_0 given in 5.3.1.4.5, or from c_0 given in 5.5.4. This wind correction shall not apply in the onboard-anemometer-based coastdown method (5.4) as the wind correction is made during the series of data sampling and subsequent analysis. The wind correction resistance w_1 for the coastdown method (5.3) or w_2 for the torquemeter method shall be calculated by the formulae:

$$w_1 = 3.6^2 \cdot f_2 v^2 w$$

or

$$w_2 = 3.6 \cdot c_2 v^2 w$$

where

w_1 is the wind correction resistance, in newtons (N);

f_2 is the coefficient of the aerodynamic term determined in 5.3.1.4.5;

w is the average wind speed alongside the test road during the test, in metres per second (m/s);

or

w_2 is the wind correction resistance, in newtons (N);

c_2 is the coefficient of the aerodynamic term determined in 5.5.4.

5.6.2 Road-load curve correction

5.6.2.1 The fitting curve determined in 5.3.1.4.5, 5.3.2.4.6 or 5.3.3.4.6 shall be corrected to reference conditions as follows:

$$F^* = \{(f_0 - w_1) + f_1 V\} \cdot \{1 + K_0 (T - 293)\} + K_2 f_2 V^2$$

where

F^* is the corrected total resistance in newtons (N);

f_0 is the constant term, in newtons (N);

f_1 is the coefficient of the first-order term, in newtons hour per kilometre [N⊕(h/km)];

f_2 is the coefficient of the second-order term, in newtons hour squared per kilometre squared $[N \cdot (h/km)^2]$;

K_0 is the correction factor for rolling resistance, as defined in 5.6.1.2;

K_2 is the correction factor for air resistance, as defined in 5.6.1.1;

V is the vehicle speed, in kilometres per hour (km/h);

w_1 is the wind correction resistance, as defined in 5.6.1.3.

5.6.2.2 The fitting curve determined in 5.4.5 shall be corrected to reference conditions as follows:

$$F^* = (a_{\text{mech}} + b_{\text{mech}} V + c_{\text{mech}} V^2) \times \{1 + K_0 \times (T - 293)\} + \frac{1}{2} \times K_2 a_0 \rho S V^2$$

where

F^* is the corrected total resistance, in newtons (N);

a_{mech} is the coefficient of mechanical drag, in newtons (N);

b_{mech} is the coefficient of mechanical drag, in newtons per kilometre per hour $[N/(km/h)]$;

c_{mech} is the coefficient of mechanical drag, in newtons per kilometre squared per hour squared $[N/(km/h)^2]$;

ρ is the air density, in kilograms per cubic metre (kg/m³);

S is the projected frontal area of the vehicle, in square metres (m²);

a_0 is the coefficient for aerodynamic drag, as a function of yaw angle;

K_0 is the correction factor for rolling resistance, as defined in 5.6.1.2;

K_2 is the correction factor for air resistance as defined in 5.6.1.1;

V is the vehicle speed, in kilometres per hour (km/h).

5.6.2.3 The fitting curve determined as described in 5.5.4 shall be corrected to reference conditions as follows:

$$C^* = \{(c_0 - w_2) + c_1 V\} \times \{1 + K_0 \times (T - 293)\} + K_2 c_2 V^2$$

where

C^* is the corrected total running resistance, in newton metres (N·m);

c_0 is the constant term, in newton metres (N·m);

c_1 is the coefficient of the first-order term, in newton metres hour per kilometre $[N \cdot m \cdot (h/km)]$;

c_2 is the coefficient of the second-order term, in newton metres hour squared per kilometre squared $[N \cdot m \cdot (h/km)^2]$;

K_0 is the correction factor for rolling resistance as defined in 5.6.1.2;

K_2 is the correction factor for air resistance as defined in 5.6.1.1;

V is the vehicle speed, in kilometres per hour (km/h);

w_2 is the wind correction resistance as defined in 5.6.1.3.

6 Road-load measurement by wind tunnel/chassis dynamometer

6.1 Aerodynamic drag measurement in wind tunnel

6.1.1 Requirements for wind tunnel

The wind-tunnel design, the test methods and the corrections shall be sufficient to provide a SCd [(see 4)] representative of the on-road SCd value.

6.1.2 Testing procedure

6.1.2.1 The test vehicle shall be positioned according to the specifications of the wind-tunnel laboratory, so as to ensure that the air stream is parallel to the longitudinal axis of the test vehicle. The test-vehicle ground clearance shall be checked according to the vehicle manufacturer's specification, and shall be adjusted if required. The engine bonnet/hood, all windows, any covers of the air ventilation system, headlamps, etc., shall be closed. The test vehicle shall be immobilized in a way that minimizes the effect on the airflow.

The vehicle shall be prepared as described in section 5.2. of this annex

6.1.2.2 The measurement shall be conducted according to the specification of the wind-tunnel laboratory.

It is recommended to use the test section wind speed of 140 km/h, but the lowest wind speed shall be 80 km/h.

Two measurements shall be conducted. If the difference in the resultant SCd values is greater than 1 %, the test vehicle set-up and the wind-tunnel set-up shall be checked and corrected if necessary. Two further tests shall then be performed. This procedure shall be repeated until a difference of no more than 1 % between two values is obtained.

6.1.3 Test result

Determine the test result (SCd), in square metres, by averaging a pair of the measurement values.

6.2 Rolling resistance determination with chassis dynamometer

6.2.1 Testing device

The chassis dynamometer shall have the following characteristics:

- single roller (double single rollers for permanent four-wheel-drive vehicles);
- roller diameter: no less than 1,2 m;

- roller surface: smooth steel, or other equivalent materials, or textured and shall be kept clean. In cases where a textured surface is used, this fact shall be noted in the test report, and the surface texture shall be 180 µm deep (80 grit)

The external vehicle-cooling fan shall have the following characteristics:

- blower nozzle area: surface: greater than 0,4 m²
- cooling wind speed: ± 2 km/h of roller speed.

6.2.2 Testing procedure

The rolling resistance of the front and rear wheels shall be measured separately. When a double-single-axis type chassis dynamometer is used for a permanent four-wheel-drive vehicle, the resistance of both axles may be measured simultaneously. During the test, the vehicle shall be cooled with an external cooling fan.

NOTE This procedure is based on force measurement at several steady speed points and not under deceleration.

6.2.2.1 Adjust the vehicle conditions as specified in 5.2.1.1.

6.2.2.2 Adjust the test room temperature to $293K^{+6}_{-2}$ K. Warm up the chassis dynamometer according to the chassis-dynamometer specification. Measure the chassis-dynamometer running losses.

6.2.2.3 Place the non-driving wheels in the normal front-driving direction on the chassis dynamometer first.

- a) restrain the vehicle, taking care not to apply an abnormal load on the measured axle;
- b) warm up the axle until the chassis-dynamometer force is stabilized, or up to a maximum of 30 min at the highest reference speed;
- c) measure the axle rolling resistance for this speed;
- d) decrease the speed to the immediate lower reference speed;
- e) measure the axle rolling resistance for this new speed;
- f) repeat c) to e) for each reference speed;
- g) once the loads have been measured for each reference speed, repeat the entire measurement procedure from c) to f);
- h) if the difference is greater than 4 % at any reference speed, the test vehicle set-up and the chassis dynamometer set-up shall be checked and corrected, if necessary. Two further tests shall then be performed. This procedure shall be repeated until a difference of no more than 4 % between two values at any reference speed, is obtained;
- i) once two satisfactory measurements have been obtained, the final result shall be the average of the two measurements for each reference speed.

6.2.2.4 Place the driving axle on the chassis dynamometer.

- a) restrain the vehicle, taking care not to apply an abnormal load on the measured axle;

- b) adjust the chassis-dynamometer load to an appropriate value;
- c) warm up the axle until the chassis-dynamometer force is stabilized, or up to a maximum of 30 min at the highest reference speed, running the engine on the appropriate gear;
- d) return the engine to idle, shift the transmission into neutral, and re-engage the clutch in the case of a manual transmission vehicle;
- e) stabilise the speed at the highest reference speed;
- f) measure the axle rolling resistance for this speed;
- g) decrease the speed to the immediate lower reference speed;
- h) measure the axle rolling resistance for this new speed;
- i) repeat e) to h) for each reference speed;
- j) once the loads have been measured for each reference speed, repeat the entire measurement procedure from e) to i);
- k) if the difference is greater than 4 % at any reference speed, the test vehicle set-up and the chassis dynamometer set-up shall be checked and corrected, if necessary. Two further tests shall then be performed. This procedure shall be repeated until a difference of no more than 4 % between two values at any reference speed is obtained;
- l) once two satisfactory measurements have been obtained, the final result shall be the average of the two measurements for each reference speed.

6.2.3 Test results

For each reference speed V_j , calculate the total rolling resistance using the following formula:

$$R_{rt,j} = R_{rf,j} + R_{rr,j} - 2 \times R_{rloss,j}$$

where

$R_{rt,j}$ is the total rolling resistance, in newtons (N);

$R_{rf,j}$ is the rolling resistance of the front wheel, in newtons (N);

$R_{rr,j}$ is the rolling resistance of the rear wheel, in newtons (N);

$R_{rloss,j}$ is the loss of the chassis dynamometer, in newtons (N).

The $R_{rt,j}$ result should be corrected. Examples of the correction procedures are given in Annex B.

6.3 Total-resistance calculation

The total road-load resistance is calculated for each reference speed V_j by the following formula, using SCd obtained in 6.1 and $R_{rt,j}$ in 6.2:

$$F_j = \frac{1}{3.6^2} \times \frac{\rho S C_d V_j^2}{2} + R_{rt,j}$$

where

F_f is the total road-load resistance, in newtons (N);

ρ is the air density, in kilograms per cubic metre (kg/m³);

S is the projected frontal area of the vehicle, in square metres (m²);

C_d is the aerodynamic coefficient;

V is the vehicle speed, in kilometres per hour (km/h).

6.4 Total-resistance curve determination

If necessary, the total-resistance curve shall be determined by fitting the following regression curve with the least-squares method:

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

where

F is the total resistance, in newtons (N);

f_0 is the constant term, in newtons (N);

f_1 is the coefficient of the first-order term, in newtons hour per kilometre (N·h/km);

f_2 is the coefficient of the second-order term, in newtons hour squared per kilometre squared [(N·h/km)²];

V is the vehicle speed, in kilometres per hour (km/h).

6.5. It is recommended that the value of the total rolling resistance measured with chassis dynamometers should be corrected. Examples of three correction methods may be found in Annex B to ISO 10521-1.

Annex A

(informative)

Examples of onboard-anemometer calibration procedure

A.1 Introduction

This annex gives an example of a calibration procedure for a type of onboard-anemometer to be used in 5.4.

The onboard-anemometer-based coastdown method requires instrumentation that measures the apparent relative air speed and apparent yaw angle encountered by the vehicle during a coastdown test. The method described below requires that the calibration data collection assume a minimum variation in the true wind speed and true wind attack angle, during each pair of opposite direction drives.

A.2 Instrumentation and theory

A meteorological anemometer is installed on a mast, approximately 2 m in front of the vehicle at the approximately aerodynamic stagnation height, level with the vehicle front bumper. Typically, this device produces an anemometer-propeller rotational signal which is proportional to the apparent relative air speed, as well as a static signal that indicates the angular direction of the anemometer vane with respect to some reference position. These signals are assumed to correlate with the observed changes in vehicle deceleration, such that the coefficients S , a_0 , a_1 , a_2 , a_3 and a_4 can be determined in the following aerodynamic drag (F_{aero}) equation, which is consistent with that described in 5.4.4.

$$F = -\frac{1}{2} \rho V^2 \left(a + a_1 \left(\frac{V}{V_0} \right) + a_2 \left(\frac{V}{V_0} \right)^2 + a_3 \left(\frac{V}{V_0} \right)^3 + a_4 \left(\frac{V}{V_0} \right)^4 \right)$$

A "zero yaw offset" must be calculated by a method described in this Annex, because the aerodynamic centreline of the anemometer may not be assumed to coincide exactly with the aerodynamic centre-line of the vehicle.

The following procedure outlines a method by which the anemometer signals can be correlated to vehicle deceleration:

A.3 Assumptions and procedural suggestions

A.3.1 Symbols

Symbols and the meanings in A.3 are as follows:

V is the vehicle speed, in kilometres per hour (km/h);

V_a is the apparent air speed, in the direction of the vehicle movement without respect to wind, in kilometres per hour (km/h);

V_w is the true wind speed, in kilometres per hour (km/h);

\angle is the true direction of the wind, with respect to the direction of the track, in degrees;

\angle_0 is the zero yaw offset angle, in degrees;

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γ_{true} is the true yaw angle, in degrees;

$\gamma_{apparent}$ is the apparent yaw angle, in degrees;

V_{true} is the true relative air speed, in kilometres per hour (km/h);

$V_{apparent}$ is the apparent relative air speed, in kilometres per hour (km/h);

k_y is the yaw correction coefficient;

k_a is the coefficient relating V_{true} to $V_{apparent}$;

k_a^* is the coefficient relating V to V_a ;

k_r is the minimum velocity at which the anemometer will respond, in kilometres per hour (km/h);

k_u is a unitless coefficient relating yaw angle to relative air speed.

A.3.2 Graphical description of the pertinent parameters

The apparent air speed (V_a) is lower than the vehicle speed (V) due to the presence of the vehicle. Because of this retardative effect, the measured relative air speed ($V_{apparent}$) and the true relative air speed (V_{true}) are shown graphically in Figures A.1 and A.2.

Figure A.1 — Direction against the wind **Figure A.2 — Direction with the wind**

A.3.3 Equation assumption

When it is assumed that the variation in the true wind attack angle during each pair of opposite direction drives is a minimum, V_a can be calculated with $V_{apparent}$ and $\gamma_{apparent}$ as follows:

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(+)

$V_{apparent} \sin \gamma_{apparent} = V \sin \gamma_{true}$

$V_{apparent} \cos \gamma_{apparent} = V \cos \gamma_{true}$

$\cos \gamma_{true} = \frac{V_{apparent} \cos \gamma_{apparent}}{V}$

$\sin \gamma_{true} = \frac{V_{apparent} \sin \gamma_{apparent}}{V}$

$V_{true} = \frac{V_{apparent}}{\cos \gamma_{true}}$

$V_a = \frac{V_{true}}{k_a}$

$V_r = \frac{V_a}{k_r}$

$V_r = \frac{V_{apparent}}{k_r \cos \gamma_{apparent}}$

$V_r = \frac{V_{apparent}}{k_r \cos \gamma_{apparent}}$

$V_r = \frac{V_{apparent}}{k_r \cos \gamma_{apparent}}$

$V_r = \frac{V_{apparent}}{k_r \cos \gamma_{apparent}}$

~~k~~

Figure A.3 — Relationship between V and V_a

~~$$l_{\text{true}} = k_{\text{y}} \cdot (l_{\text{apparent}} \mp l_0), \text{ in a direction against the wind (A.1)}$$~~ ~~$\lambda_{\text{true}} = k_y \cdot (\lambda_{\text{apparent}} + \lambda_0)$, in a direction with the wind (A.2)~~~~$$V_{\text{true}} = k_a V_{\text{apparent}} + k_r - 1 \uparrow k_u \downarrow \text{true (A.3)}$$~~

~~A.3.4 Calibration procedure~~

If kr is known previously by an appropriate technique, the calibration data collection may be done with a run at a constant speed. In this case, 80 km/h is recommended as the vehicle speed.

The average values of \bar{V} and $\bar{V}_{apparent}$ are calculated for each direction. Then, solve k_y , k_a , k_u and \bar{V}_0 in Equations (A.1), (A.2) and (A.3) by the least-squares or iteration technique, while the value of k_r is assumed from the relationship between V and V_a as described in Figure A.2.

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Annex B

(informative)

Examples of dynamometer-measured rolling-resistance-correction method

B.1 Introduction

It is recommended that the value of the total rolling resistance measured with chassis dynamometers should be corrected. This annex describes three correction methods as examples.

B.2 Method 1

In this method, tyre rolling resistance is separated from other mechanical losses, and the correction factor for only the tyre rolling resistance is determined. Also, in this method, the correction factor for the tyre rolling resistance is determined by comparing the change of rolling resistance value on the road and the change of the tyre rolling resistance value on the chassis dynamometer, under two different test conditions. For the comparison test, the factor that affects only the tyre rolling resistance, for example the tyre inflation pressure or the axle load, shall be altered.

NOTE The loss of the wheel bearing is included in the tyre rolling resistance in this method. However, generally it is sufficiently small in comparison with the other mechanical losses, and may be neglected.

B.2.1 Under the two conditions, determine the total resistance curve from road data to calculate the following equation coefficients:

2

$$F_1 = f_{0,1} + f_{1,1}V + f_{2,1}V^2$$

2

$$F_2 = f_{0,2} + f_{1,2}V + f_{2,2}V^2$$

where

F_1, F_2 are the total resistances under the first and second conditions, in newtons (N);

$f_{0,1}, f_{0,2}$ are the constant terms under the first and second conditions, in newtons (N);

$f_{1,1}, f_{1,2}$ are the coefficients of the first-order term under the first and second conditions, in newtons hour per kilometre [N·(h/km)];

$f_{2,1}, f_{2,2}$ are the coefficients of the second-order term of vehicle speed under the first and second conditions, in newtons hour squared per kilometre squared [(N·(h/km)²);

V is the vehicle speed, in kilometres per hour (km/h).

Notice that the rolling resistance consists of only the constant and the first-order terms. This simplification presumes that the contribution from the rolling resistance to f_2 is negligible. The following equations express the simplified result.

$$F_{roll1,j} = f_{0,1} + f_{1,1}V_j$$

$$F_{roll2,j} = f_{0,2} + f_{1,2}V_j$$

where $F_{roll1,j}$ and $F_{roll2,j}$ are the rolling resistances measured on the road under the first and second conditions, in newtons (N).

B.2.2 Substitute the formula specified in 6.2.3 with the following formulae:

$$(\rightarrow)$$

$$(\rightarrow)$$

$$\pm$$

$$t, 3, ft, rt, fm, rm,$$

$*$

$$t, j, 3, f, r, fm, 2 \text{ loss}, fm, rm,$$

$$j, j, j, j, j, j$$

$$j, j, j, j, j, j, j$$

$$Rr, K, Rr, Rr, Rr, Rr$$

$$Rr, K, Rr, Rr, Rr, Rr, Rr, Rr$$

$$= - + + + +$$

$$= - + \uparrow \downarrow + + +$$

where

$R_{n,j}^*$ is the corrected total rolling resistance, in newtons (N);

$K_{3,j}$ is the correction factor for the tyre rolling resistance;

$R_{ft,j}$ is the front tyre rolling resistance measured on a chassis dynamometer, in newtons (N);

$R_{rt,j}$ is the rear tyre rolling resistance measured on a chassis dynamometer, in newtons (N);

$R_{fm,j}$ is the front mechanical loss, except for the tyre rolling resistance, in newtons (N);

$R_{rm,j}$ is the rear mechanical loss, except for the tyre rolling resistance, in newtons (N);

$R_{ft,j}$ is the front total rolling resistance, including the loss of the chassis dynamometer, in newtons (N);

$R_{rt,j}$ is the rear total rolling resistance, including the loss of the chassis dynamometer, in newtons (N);

$R_{loss,j}$ is the loss of the chassis dynamometer, in newtons (N).

B.2.3 Set the front axle of the vehicle on the chassis dynamometer, and measure the front rolling resistances under the two different conditions, which are expressed by the following equations:

$R_{f1,j} = R_{ft1,j} + R_{fm1,j} + R_{loss,j}$ for the first condition

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$R_{ft2,j} = R_{ft1,j} + R_{fm2,j} + R_{loss,j}$ for the second condition

where

$R_{ft1,j}$ and $R_{ft2,j}$ are the front-tyre rolling resistances, measured on a chassis dynamometer including the loss of the chassis dynamometer, in newtons (N);

$R_{fm1,j}$ and $R_{fm2,j}$ are the front mechanical losses, except for the tyre rolling resistance, in newtons (N).

B.2.4 Disconnect the front joint between the wheel and axle shaft or driveshaft, and then measure the tyre rolling resistances, including the loss of chassis dynamometer, $R_{ft1,j} + R_{loss,j}$ and $R_{ft2,j} + R_{loss,j}$ on the chassis dynamometer.

B.2.5 Calculate the mechanical losses, except for tyre, $R_{fm1,j}$ and $R_{fm2,j}$, as the difference of B.2.3 and B.2.4.

B.2.6 Remove the vehicle from the chassis dynamometer, and then measure the loss of the chassis dynamometer, $R_{loss,j}$.

B.2.7 Calculate the front-tyre rolling resistances, $R_{ft1,j}$ and $R_{ft2,j}$, from B.2.3, B.2.5 and B.2.6.

B.2.8 Set the rear axle of the vehicle on the chassis dynamometer, and measure the rolling resistances under the two different conditions, which are expressed by the following equations

$$R_{r1,j} = R_{rt1,j} + R_{rm1,j} + R_{loss,j}$$

for the first condition

$$R_{r2,j} = R_{rt2,j} + R_{rm2,j} + R_{loss,j}$$

for the second condition where

$R_{rt1,j}$ and $R_{rt2,j}$ are the rear-tyre rolling resistances, measured on a chassis dynamometer including the loss of the chassis dynamometer, in newtons (N);

$R_{rm1,j}$ and $R_{rm2,j}$ are the rear mechanical losses, except for the tyre rolling resistance, in newtons (N).

B.2.9 Disconnect the rear joint between wheel and axle shaft or driveshaft, and then measure the rolling resistances including the loss of chassis dynamometer, $R_{rt1,j} + R_{loss,j}$ and $R_{rt2,j} + R_{loss,j}$ on the chassis dynamometer.

B.2.10 Calculate the mechanical losses except for tyre, $R_{rm1,j}$ and $R_{rm2,j}$, as the difference of B.2.8 and B.2.9.

B.2.11 Calculate the rear-tyre rolling resistances, $R_{rt1,j}$ and $R_{rt2,j}$, from B.2.6, B.2.8 and B.2.10.

B.2.12 Determine the correction factor for each reference speed, V_j , by the following equation:

$$K_{3,j} = \frac{f_{0,1} + f_{1,1} V_j + f_{0,2} + f_{1,2} V_j}{R_{ft1,j} + R_{rt1,j} + R_{ft2,j} + R_{rt2,j}}$$

The correction factor may be applied to future measurements of similar sized vehicles and tyres on the same chassis dynamometer.

NOTE If a dual-axis chassis dynamometer is used for Method 1, the front and the rear resistances can be measured at the same time.

B.3 Method 2

In this method, the total rolling resistance values measured on the chassis dynamometer are compared to the total resistance values obtained on the road using, in this example, the coastdown method described in 5.3.

B.3.1 Determine the total resistance curve from road data to estimate the following equation coefficients:

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

where

F is the total resistance, in newtons (N);

f_0 is the constant term, in newtons (N);

f_1 is the coefficient of the first-order term, in newtons hour per kilometre [N⊙(h/km)];

f_2 is the coefficient of the second-order term of vehicle speed, in newtons hour squared per kilometre squared [N⊙(h/km)²];

V is the vehicle speed, in kilometres per hour (km/h).

Assume the following equation, on the presumption that the contribution to f_2 which comes from the rolling resistance is negligible:

$$F_{roll,j} = f_0 + f_1 V_j$$

where $F_{roll,j}$ is the rolling resistance measured on the road, in newtons (N).

B.3.2 The corrected total rolling resistance is expressed by the following formula using the chassis dynamometer measurement data as specified in 6.2.

* ()

$$R_{t,j} = K_{4,j} - R_{f,j} + R_{r,j} \frac{1}{2} - R_{loss,j}$$

where

$R_{t,j}$

* is the corrected total rolling resistance, in newtons (N);

$K_{4,j}$ is the correction factor for the tyre rolling resistance;

$R_{f,j}$ is the rolling resistance of the front wheel dynamometer, including the loss of the chassis dynamometer, in newtons (N);

$R_{r,j}$ is the rolling resistance of the rear wheel dynamometer, including the loss of the chassis dynamometer, in newtons (N);

$R_{loss,j}$ is the loss of the chassis dynamometer, in newtons (N).

B.3.3 Determine the correction factor for each reference speed, V_j , using the following equation, because $F_{roll,j}$ is equal to $R_{rt,j}$:

$$K_{4,j} = (f_0 + f_1 V_j) (R_{rt,j} + R_{rr,j} - R_{loss,j})$$

The correction factor may be applied to future measurements of similar sized vehicles and tyres on the same chassis dynamometer.

B.4 Method 3

The total rolling resistance values measured on the dynamometer shall be compared to the total resistance values obtained on the road using, in this example, the coastdown method described in 5.3. The SCd value is measured in a wind tunnel to separate the on-road rolling resistance from the total on-road resistance.

B.4.1 Determine the total resistance curve from road data to estimate the following equation coefficients:

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

where

F is the total resistance, in newtons (N);

f_0 is the constant term, in newtons (N);

f_1 is the coefficient of the first-order term, in newtons hour per kilometre (N·h/km);

f_2 is the coefficient of the second-order term of vehicle speed, in newtons hour squared per kilometre squared [N·h²/(km)²];

V is the vehicle speed, in kilometres per hour (km/h).

B.4.2 Measure SCd of the vehicle using the method described in 6.1, in order to calculate the values of the on-road rolling resistance at each reference speed. Then, assume the following equation:

$$F_{roll,j} = K_{5,j} (F - F_{SCd})$$

$$F_{roll,j} = f_0 + f_1 V_j + f_2 V_j^2$$

$$F_{roll,j} = f_0 + f_1 V_j + f_2 V_j^2$$

$$F_{roll,j} = f_0 + f_1 V_j + f_2 V_j^2 + SCd V_j$$

where $F_{roll,j}$ is the value of the calculated on-road rolling resistance, for each reference speed, V_j .

B.4.3 The corrected total rolling resistance is expressed by the following formula, using the chassis dynamometer measurement data as specified in 6.2.

$$R_{rt,j}^* = K_{5,j} (R_{rt,j} + R_{rr,j} - R_{loss,j})$$

$$R_{rt,j}^* = K_{5,j} (R_{rt,j} + R_{rr,j} - R_{loss,j})$$

where

$$R_{rt,j}^*$$

$R_{rt,j}^*$ is the corrected total rolling resistance, in newtons (N);

$K_{5,j}$ is the correction factor for the tyre rolling resistance;

$R_{f,j}$ is the rolling resistance of the front-wheel dynamometer, including the loss of the chassis dynamometer, in newtons (N);

$R_{r,j}$ is the rolling resistance of the rear-wheel dynamometer, including the loss of the chassis dynamometer, in newtons (N);

$R_{loss,j}$ is the loss of the chassis dynamometer, in newtons (N).

B.4.4 Determine the correction factor for each reference speed V_j by the following equation, because $F_{roll,j}$ is equal to $R_{rt,j}$:

2.2 (-)

5, 0 1 1 2 f, r, loss,

4

$$K_j = \frac{f + fV + fV^2}{SCdV - R_{rt,j} - R_{r,j} - R_{loss,j}}$$

—€

The correction factor may be applied to future measurements of similar sized vehicles and tyres on the same chassis dynamometer.

1 Scope

This part of ISO 10521 specifies methods of setting the target road load on chassis dynamometers for the purpose of a subsequent test, for example the fuel consumption test or the exhaust emission measurement test.

The road load setting method on chassis dynamometers depends on the road load measurement method, such as the coastdown method, the torque meter method or the wind-tunnel and chassis-dynamometer method. This part of ISO 10521 gives detailed instructions on the methods of the chassis-dynamometer setting procedure for road load value, obtained by the various measurement methods specified in ISO 10521-1.

This part of ISO 10521 is applicable to chassis dynamometers that can set road load at a minimum of three speed points, and to motor vehicles as defined in ISO 3833 up to a gross vehicle mass of 3500 kg.

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 10521-1:2006, *Road vehicles — Road load — Part 1: Determination under reference atmospheric conditions*

3 Terms and definitions

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

3.1 total resistance

total force-resisting movement of a vehicle movement, measured either by the coastdown method or by the wind-tunnel and chassis-dynamometer method, including the friction forces in the drive train

3.2 running resistance

torque-resisting movement of a vehicle, measured by the torquemeter installed in the drive-train of a vehicle, including the friction torque in the drive-train downstream of the torquemeter

3.3 road load

general meaning of force or torque which opposes the movement of a vehicle, including total resistance and/or running resistance

3.4 reference speed

vehicle speed at which a chassis-dynamometer load is verified

NOTE Reference speeds may be continuous speed points covering the complete speed range.

3.5 target road load

road load to be reproduced on the chassis dynamometer

3.6 chassis-dynamometer setting load

load to be set on the power-absorption unit of the chassis dynamometer

3.7 simulated road load

road load to be calculated from measured coastdown data using the least-square regression

NOTE See Annex A for the calculation procedure.

3.8 speed range

range of speed of chassis-dynamometer roller between 15 km/h and maximum reference speed plus 10 km/h, over which the coastdown test is conducted

3.9 chassis dynamometer of coefficient control

chassis dynamometer of which absorption characteristics are determined by giving coefficients of a road-load approximation polynomial

3.10 chassis dynamometer of polygonal control

chassis dynamometer of which absorption characteristics are determined by giving load values at several speed points

4 Required overall measurement accuracy

The required overall measurement accuracy shall be as follows:

a) chassis-dynamometer roller speed: $\pm 0,5$ km/h or ± 1 %, whichever is greater;

b) chassis-dynamometer force:

Category 1 chassis dynamometer: ± 6 N, or

Category 2 chassis dynamometer: ± 10 N or $\pm 0,1$ % of full scale, whichever is greater;

NOTE Category 2 chassis dynamometer usually has greater load capacity, e.g. 130 kW or more.

c) time: ± 50 ms or $\pm 0,1$ %, whichever is greater;

d) wheel torque: ± 3 N⊙m or $\pm 0,5$ %, whichever is greater;

e) atmospheric temperature: ± 1 K;

f) tyre pressure: ± 5 kPa.

Part 2 - Reproduction on chassis dynamometer

5 Preparation for chassis-dynamometer test

5.1 Setting parameter

The following parameters shall be determined prior to the test, in accordance with the purpose of the subsequent test:

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a) target road load;

b) speed range;

c) reference speed.

5.2 Laboratory condition

5.2.1 Roller

The chassis-dynamometer roller shall be clean, dry and free from anything which might cause tyre slippage. In the case of chassis dynamometers with multiple rollers, the chassis dynamometers shall be run in the same coupled or uncoupled state as the subsequent emission test, fuel consumption test, etc., and the chassis dynamometer speed shall be measured from the roller coupled to the power-absorption unit.

5.2.2 Room temperature

The laboratory atmospheric temperature shall be within 293 K to 303 K as the standard condition, unless otherwise required by the subsequent test.

5.3 Preparation of chassis dynamometer

5.3.1 Inertia-mass setting

Set the equivalent inertia mass of the chassis dynamometer in accordance with the vehicle mass or vehicle mass category.

5.3.2 Preconditioning of chassis dynamometer

Precondition the chassis dynamometer in accordance with the dynamometer manufacturer's recommendations, or as appropriate, so that the friction loss of the chassis dynamometer can be stabilized.

5.4 Vehicle preparation

5.4.1 Tyre-pressure adjustment

The tyre pressure shall be adjusted to the recommended values for the subsequent test. These values shall correspond to those recommended for the range of vehicle speeds encountered during the subsequent emission test, fuel consumption test, etc., in conjunction with roller geometry of the chassis dynamometer to be used. If small diameter roller(s) are being used, the tyre pressure may be increased so as to ensure a safe test. This pressure increase should be typically 50 %.

5.4.2 Vehicle setting

The tested vehicle shall be installed on the chassis-dynamometer roller in a straight position and restrained in a safe manner. In the case of a single roller, the tyre contact point shall be within ± 25 mm or ± 2 % of the roller diameter, whichever is smaller, from the top of the roller.

5.4.3 Vehicle preconditioning

The power-absorption unit of the chassis dynamometer shall be set in the way specified in 6.1.1.1 or 6.2.1.1, so that an adequate load will be applied to the test vehicle during preconditioning.

Prior to the test, the vehicle shall be preconditioned appropriately until normal vehicle operating temperatures have been reached. It is recommended that the vehicle should be driven at the most

appropriate reference speed for a period of 30 min. During this preconditioning period, the vehicle speed shall not exceed the highest reference speed.

6 Load setting on the chassis dynamometer

6.1 Chassis-dynamometer setting by coastdown method

This method is applicable when the road load is determined using the coastdown method, or the wind-tunnel and chassis-dynamometer method as specified in Part one ISO 40624-1:2006, 5.3, 5.4 or Clause 6.

6.1.1 Load setting of chassis dynamometer

6.1.1.1 Initial load setting

For a chassis dynamometer of coefficient control, the chassis-dynamometer power-absorption unit shall be adjusted with the arbitrary initial coefficients, A_d , B_d and C_d , of the following equation:

$$F_d = A_d + B_d V + C_d V^2$$

where

F_d is the chassis-dynamometer setting load, in newtons (N);

V is the speed of the chassis-dynamometer roller, in kilometres per hour (Km/h).

The following are the recommended coefficient assumptions to be used for the initial load setting:

a) $A_d = 0,5 \times A_t$, $B_d = 0,2 \times B_t$, $C_d = C_t$, in the case of single-axis chassis dynamometers, or

$A_d = 0,1 \times A_t$, $B_d = 0,2 \times B_t$, $C_d = C_t$, in the case of dual-axis chassis dynamometers,

where A_t , B_t and C_t are the coefficients for the target road load;

b) empirical values, such as those used for the setting for a similar type of vehicle.

For a chassis dynamometer of polygonal control, adequate load values at each speed point shall be set to the chassis-dynamometer power-absorption unit.

6.1.1.2 Coastdown

Perform the coastdown test on the chassis dynamometer once with the procedure given in Part one ISO 40624-1:2006, 5.3.1.3.1 and 5.3.1.3.2. Then proceed to 6.1.1.3.

6.1.1.3 Verification

6.1.1.3.1 Calculate the target road-load value using the target road-load coefficient A_t , B_t and C_t for each reference speed V_j .

$$R_j = A_t + B_t V_j + C_t V_j^2$$

where

R_j is the target road load at reference speed V_j , in newtons (N);

V_j is the j th reference speed, in kilometres per hour (km/h).

6.1.1.3.2 Calculate the error, ε_j , in percent of the simulated road load F_{sj} , which is calculated using the method specified in A.1, for target road load F_{tj} at each reference speed V_j , using the following equation.

$$\varepsilon_j = \frac{F_{sj} - F_{tj}}{F_{tj}} \times 100$$

NOTE F_{mj} , obtained in A.1.1, may be used in the above equation instead of F_{sj} .

Verify whether errors at all reference speeds satisfy the following error criteria in two consecutive coastdown runs, unless otherwise specified by regulations.

$\varepsilon_j \leq 3\%$ for $V_j \geq 50$ km/h

$\varepsilon_j \leq 5\%$ for 20 km/h $< V_j < 50$ km/h

$\varepsilon_j \leq 10\%$ for $V_j \leq 20$ km/h

If an error at any reference speed does not satisfy the criteria, then proceed to 6.1.1.4 for the adjustment of the chassis-dynamometer setting load.

6.1.1.4 Adjustment

Adjust the chassis dynamometer setting load in order to minimise the error in accordance with the procedure specified in B.1.

Then repeat 6.1.1.2 and 6.1.1.3.

6.2 Chassis-dynamometer setting using torquemeter method

This method is applied when the road load is determined using the torquemeter method, as specified in Part one ISO 10521-4:2006, 5.5.

6.2.1 Load setting of chassis dynamometer

6.2.1.1 Initial load setting

For a chassis dynamometer of coefficient control, the chassis-dynamometer power-absorption unit shall be adjusted with the arbitrary initial coefficients, A_d , B_d and C_d , of the following equation:

$$F_d = A_d + B_d V + C_d V^2$$

where

F_d is the chassis-dynamometer setting load, in newtons (N);

V is the speed of the chassis-dynamometer roller, in kilometres per hour (km/h).

The following are the recommended coefficient assumptions to be used for the initial load setting.

a) $A_d = 0,5 \cdot at/r'$, $B_d = 0,2 \cdot bt/r'$, $C_d = ct/r'$, in the case of single-axis chassis dynamometers, or

$A_d = 0,1 \cdot at/r'$, $B_d = 0,2 \cdot bt/r'$, $C_d = ct/r'$, in the case of dual-axis chassis dynamometers.

where

a_t , b_t and c_t are the coefficients for the target torque;

r' is the dynamic radius of the tyre on the chassis dynamometer, in metres (m), that is obtained by averaging the r_2 values calculated in A.2.1;

b) empirical values, such as those used for the setting for a similar type of vehicle.

For a chassis dynamometer of polygonal control, adequate load values at each speed point shall be set to the chassis-dynamometer power-absorption unit.

6.2.1.2 Wheel torque measurement

Perform the torque measurement test on the chassis dynamometer with the procedure defined in Part one ISO 40521-4:2006, 5.5.2. The torquemeter(s) shall be identical with the one(s) used in the preceding road test.

6.2.1.3 Verification

6.2.1.3.1 Calculate the target road-load value using the target torque coefficients a_t , b_t , and c_t for each reference speed V_j :

$$F_{tj} = \frac{a_t + b_t V_j + c_t V_j^2}{r'}$$

where

F_{tj} is the target road load at reference speed V_j , in newtons (N);

V_j is the j th reference speed, in kilometres per hour (km/h);

r' is the dynamic radius of the tyre on the chassis dynamometer, in metres (m), that is obtained by averaging the r_2 values calculated in A.2.1.

6.2.1.3.2 Calculate the error, ϵ_j , in percent of simulated road load F_{sj} , which is calculated with the method specified in A.2, for target road load F_{tj} at each reference speed V_j :

$$\epsilon_j = \frac{F_{sj} - F_{tj}}{F_{tj}} \times 100$$

NOTE C_j m/ r_2 obtained in A.2.1 and 6.2.1.3.1, respectively, may be used in the above equation instead of F_{sj} .

Verify whether errors at all reference speeds satisfy the following error criteria in two consecutive coastdown runs, unless otherwise specified by regulations.

$\epsilon_j \leq 3\%$ for $V_j \geq 50$ km/h

$\epsilon_j \leq 5\%$ for 20 km/h $< V_j < 50$ km/h

$\epsilon_j \leq 10\%$ for $V_j \leq 20$ km/h

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If the error at any reference speed does not satisfy the criteria, then proceed to 6.2.1.4 for the adjustment of the chassis-dynamometer setting load.

6.2.1.4 Adjustment

Adjust the chassis-dynamometer setting load in order to minimise the error in accordance with the procedure specified in B.2. Then repeat 6.2.1.2 and 6.2.1.3.

Appendix Annex A

(normative)

Calculation of road load for the dynamometer test

A.1 Calculation of simulated road load for the coastdown method

When the road load is measured by the coastdown method as specified in ISO 10521-1:2006, 5.3 or 5.4, calculation of the simulated road load F_{sj} for each reference speed V_j , in kilometres per hour, shall be conducted as described in A.1.1 to A.1.3.

A.1.1 Calculate the measured road load using the following formula:

where

F_{mj} is the measured road load for each reference speed V_j , in newtons (N);

m_d is the equivalent inertia-mass of the chassis dynamometer, in kilograms (kg);

m_{2r} is the equivalent effective mass of drive wheels and vehicle components rotating with the wheels during coastdown on the dynamometer, in kilograms (kg); m_{2r} may be measured or calculated by an appropriate technique. As an alternative, m_{2r} may be estimated as 3 % of the unladen vehicle mass for a permanent four-wheel-drive vehicle, and 1,5 % of the unladen vehicle mass for a two-wheel-drive vehicle;

T_j is the coastdown time corresponding to speed V_j , in seconds (s).

A.1.2 Calculate the coefficients A_s , B_s and C_s of the following approximate equation by the least-square regression using the calculated F_{mj} :

2

$$F_s = A_s + B_s V + C_s V^2$$

A.1.3 Determine the simulated road load for each reference speed V_j using the following equation, using the calculated A_s , B_s and C_s :

2

$$F_{sj} = A_s + B_s V_j + C_s V_j^2$$

A.2 Calculation of simulated road load for the torquemeter method

When the road load is measured by the torquemeter method as specified in ISO 10521-1:2006, 5.5, calculation of the simulated road load F_{sj} for each reference speed V_j , in kilometres per hour, shall be conducted as described in A.2.1 to A.2.3.

A.2.1 Calculate the mean speed $V_j m$, in kilometres per hour, and the mean torque $C_j m$, in newton metres, for each reference speed V_j using the following formulae:

where

V_{ji} is the vehicle speed of the i th data set, in kilometres per hour (km/h);

k is the number of data sets;

and

C_{ji} is the torque of the i th data set, in newton metres (N⊗m);

C_{jc} is the compensation term for the speed drift, in newton metres, which is given by the following formula:

C_{jc} shall be no greater than 5 % of the mean torque before compensation, and may be neglected if $|a_j|$ is no greater than 0,005 m/s².

$$C_{jc} = (m_d + m_{r2}) \times |a_j| r_{2j}$$

in which

m_d and m_{r2} are the equivalent inertia mass of the chassis dynamometer and the equivalent effective mass of drive wheels and vehicle components rotating with the wheel during coastdown on the chassis dynamometer, respectively, both in kilograms (kg), as defined in A.1;

a_j is the mean acceleration, in metres per second squared (m/s²), which shall be calculated by the formula:

and in which t_i is the time at which the i th data set was sampled, in seconds (s).

r_{2j} is the dynamic radius of the tyre, in metres (m), given by the formula:

and in which N is the rotational frequency of the driven tyre, in revolutions per second (s⁻¹).

A.2.2 Calculate the coefficients a_s , b_s and c_s of the following approximate equation by the least-square regression using the calculated V_{ji} and the C_{ji} .

A.2.3 Determine the simulated road load for each reference speed V_j using the following equation, using the calculated a_s , b_s and c_s :

Appendix Annex B

(normative)

Adjustment of chassis-dynamometer setting load

B.1 Adjustment of chassis-dynamometer setting load by coastdown method

When the load setting on the chassis dynamometer is performed by the coastdown method, the chassisdynamometer setting load shall be adjusted using the following equations:

*

$$Fd_j = Fdj \downarrow Fj$$

$$= Fdj \downarrow Fsj + Rj$$

$$= Ad + Bd Vj + Cd Vj \downarrow As + Bs Vj + Cs Vj + At + Bt Vj + Ct Vj$$

$$= Ad + At \downarrow As + Bd + Bt \downarrow Bs Vj + Cd + Ct \downarrow Cs Vj$$

$$4 Ad = Ad + At \downarrow As$$

$$4 Bd = Bd + Bt \downarrow Bs$$

$$4 Cd = Cd + Ct \downarrow Cs$$

where

Fd_j

* is the new chassis-dynamometer setting load, in newtons (N);

Fj is the adjustment road load, which is equal to $Fsj \downarrow Rj$, in newtons (N);

Fsj is the simulated road load at reference speed Vj , in newtons (N);

Rj is the target road load at reference speed Vj , in newtons (N);

Ad

*, Bd

* and Cd

* are the new chassis-dynamometer setting coefficients.

B.2 Adjustment of chassis-dynamometer setting load by torquemeter method

When the load setting on the chassis dynamometer is performed by the torquemeter method, the chassisdynamometer load setting shall be adjusted using the following equation:

*

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$$F_{dj} = F_{dj} + f_{ej} r_2$$

$$= F_{dj} + f_{sj} r_2 + f_{tj} r_2$$

$$= A_d + B_d V_j + C_d V_j + a_s + b_s V_j + c_s V_j r_2 + a_t + b_t V_j + c_t V_j r_2$$

$$= A_d + a_t + a_s r_2 + B_d + b_t + b_s r_2 V_j + C_d + c_t + c_s r_2 V_j$$

$$4 A_d = A_d + (a_t + a_s) r_2$$

$$4 B_d = B_d + (b_t + b_s) r_2$$

$$4 C_d = C_d + (c_t + c_s) r_2$$

where

$$F_{dj}$$

* is the new chassis-dynamometer setting load, in newtons (N);

f_{ej} is the adjustment torque, which is equal to $f_{sj} + f_{tj}$, in newton metres (N·m);

f_{sj} is the simulated torque at reference speed V_j , in newton metres (N·m);

f_{tj} is the target torque at reference speed V_j , in newton metres (N·m);

$$A_d$$

$$*, B_d$$

$$* \text{ and } C_d$$

* are the new chassis-dynamometer setting coefficients;

r_2 is the dynamic radius of the tyre on the chassis dynamometer, in metres (m), that is obtained by averaging the r_{2j} values calculated in A.2.1.