

---

---

**Reciprocating internal combustion  
engines — Exhaust emission  
measurement —**

**Part 1:  
Test-bed measurement systems of  
gaseous and particulate emissions**

*Moteurs alternatifs à combustion interne — Mesurage des émissions  
de gaz d'échappement —*

*Partie 1: Mesurage des émissions de gaz et de particules au banc d'essai*

ISO 8178-1:2020

<https://standards.iteh.ai/catalog/standards/iso/4c414d60-cdef-4c95-a588-9691b16677bd/iso-8178-1-2020>



**iTeh Standards**  
**(<https://standards.iteh.ai>)**  
**Document Preview**

ISO 8178-1:2020

<https://standards.iteh.ai/catalog/standards/iso/4c414d60-cdef-4c95-a588-9691b16677bd/iso-8178-1-2020>



**COPYRIGHT PROTECTED DOCUMENT**

© ISO 2020

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office  
CP 401 • Ch. de Blandonnet 8  
CH-1214 Vernier, Geneva  
Phone: +41 22 749 01 11  
Fax: +41 22 749 09 47  
Email: [copyright@iso.org](mailto:copyright@iso.org)  
Website: [www.iso.org](http://www.iso.org)

Published in Switzerland

# Contents

Page

|                                                                           |            |
|---------------------------------------------------------------------------|------------|
| <b>Foreword</b>                                                           | <b>vi</b>  |
| <b>Introduction</b>                                                       | <b>vii</b> |
| <b>1 Scope</b>                                                            | <b>1</b>   |
| <b>2 Normative references</b>                                             | <b>1</b>   |
| <b>3 Terms and definitions</b>                                            | <b>1</b>   |
| <b>4 Symbols and abbreviated terms</b>                                    | <b>8</b>   |
| 4.1 General symbols                                                       | 8          |
| 4.2 Symbols for fuel composition                                          | 10         |
| 4.3 Symbols and abbreviated terms for the chemical components             | 10         |
| 4.4 Abbreviated terms                                                     | 11         |
| <b>5 General measurement principles</b>                                   | <b>13</b>  |
| 5.1 Principle of emission measurement                                     | 13         |
| 5.1.1 Mass of constituent                                                 | 14         |
| 5.2 Exhaust sampling and dilution                                         | 15         |
| 5.2.1 General sampling requirements                                       | 15         |
| 5.2.2 Gas sampling                                                        | 15         |
| 5.2.3 Raw sampling for gaseous emissions                                  | 17         |
| 5.2.4 Dilute sampling for gaseous emissions                               | 18         |
| 5.2.5 Dilution system                                                     | 18         |
| 5.2.6 Dilute sampling for particulate emissions                           | 21         |
| 5.3 Measurement instruments                                               | 21         |
| 5.3.1 General                                                             | 21         |
| 5.3.2 Data recording and control                                          | 22         |
| 5.3.3 Performance specifications for measurement instruments              | 23         |
| <b>6 Engine and ambient related measurement equipment</b>                 | <b>25</b>  |
| 6.1 Dynamometer specification                                             | 25         |
| 6.2 Speed and torque sensors                                              | 25         |
| 6.2.1 Shaft work                                                          | 25         |
| 6.2.2 Speed sensors                                                       | 25         |
| 6.2.3 Torque sensors                                                      | 26         |
| 6.2.4 Engine accessories                                                  | 26         |
| 6.3 Pressure transducers, temperature sensors, and dew point sensors      | 26         |
| 6.4 Flow related measurements                                             | 26         |
| 6.4.1 Fuel flow                                                           | 27         |
| 6.4.2 Intake air flow                                                     | 27         |
| 6.4.3 Raw exhaust flow                                                    | 27         |
| 6.4.4 Indirect exhaust flow                                               | 28         |
| 6.4.5 Dilution air and diluted exhaust flow meters                        | 29         |
| 6.4.6 Sample flow meter for batch sampling                                | 30         |
| 6.4.7 Use of gas dividers                                                 | 31         |
| <b>7 Determination of the gaseous components</b>                          | <b>31</b>  |
| 7.1 General specifications                                                | 31         |
| 7.2 Gas drying                                                            | 31         |
| 7.3 Analysers                                                             | 31         |
| 7.3.1 General                                                             | 31         |
| 7.3.2 Carbon monoxide (CO) and carbon dioxide (CO <sub>2</sub> ) analysis | 31         |
| 7.3.3 Oxygen (O <sub>2</sub> ) analysis                                   | 31         |
| 7.3.4 Hydrocarbon (HC) analysis                                           | 32         |
| 7.3.5 Non-methane hydrocarbon (NMHC) analysis                             | 32         |
| 7.3.6 Oxides of nitrogen (NO <sub>x</sub> ) analysis                      | 33         |
| 7.3.7 Sulphur dioxide (SO <sub>2</sub> ) analysis                         | 34         |
| 7.3.8 Ammonia (NH <sub>3</sub> ) analysis                                 | 34         |

|          |                                                                              |           |
|----------|------------------------------------------------------------------------------|-----------|
| 7.3.9    | Dinitrogen oxide (N <sub>2</sub> O) analysis                                 | 34        |
| 7.3.10   | Formaldehyde (HCHO) analysis                                                 | 34        |
| 7.3.11   | Methanol (CH <sub>3</sub> OH) analysis                                       | 35        |
| 7.3.12   | Air-to-fuel measurement                                                      | 35        |
| 7.4      | Measurement system                                                           | 35        |
| 7.4.1    | General                                                                      | 35        |
| 7.4.2    | Analytical system                                                            | 35        |
| 7.4.3    | Ammonia analysis                                                             | 36        |
| 7.4.4    | Methane analysis                                                             | 41        |
| 7.4.5    | Methanol analysis                                                            | 45        |
| 7.4.6    | Formaldehyde analysis                                                        | 45        |
| <b>8</b> | <b>Particulate determination</b>                                             | <b>47</b> |
| 8.1      | Particulate mass                                                             | 47        |
| 8.1.1    | Particulate Sampling probes (PSP)                                            | 47        |
| 8.1.2    | Transfer tubes                                                               | 47        |
| 8.1.3    | Pre-classifier                                                               | 48        |
| 8.1.4    | Particulate sampling filters                                                 | 48        |
| 8.1.5    | Weighing chamber and analytical balance specifications                       | 49        |
| 8.2      | Particle number                                                              | 50        |
| 8.2.1    | Sampling                                                                     | 50        |
| 8.2.2    | Compensating for particle number sample flow — Full flow dilution systems    | 50        |
| 8.2.3    | Compensating for particle number sample flow — Partial flow dilution systems | 50        |
| 8.2.4    | Correction of PM measurement                                                 | 51        |
| 8.2.5    | Proportionality of partial flow dilution sampling                            | 52        |
| 8.3      | Particulate dilution sampling system equipment                               | 52        |
| 8.3.1    | General                                                                      | 52        |
| 8.3.2    | Partial flow dilution system                                                 | 52        |
| 8.3.3    | Full-flow dilution system                                                    | 54        |
| 8.3.4    | Particulate sampling system                                                  | 57        |
| 8.4      | Particle number measurement equipment                                        | 60        |
| 8.4.1    | System overview                                                              | 60        |
| 8.4.2    | General requirements                                                         | 60        |
| 8.4.3    | Specific requirements                                                        | 60        |
| 8.4.4    | Typical system description                                                   | 61        |
| <b>9</b> | <b>Calibration and verification</b>                                          | <b>66</b> |
| 9.1      | Calibration and performance checks                                           | 66        |
| 9.1.1    | General                                                                      | 66        |
| 9.1.2    | Summary of calibration and verification                                      | 66        |
| 9.1.3    | Verifications for accuracy, repeatability, and noise                         | 68        |
| 9.1.4    | Linearity check                                                              | 69        |
| 9.1.5    | Continuous gas analyser system-response and updating-recording verification  | 72        |
| 9.1.6    | Response time verification for compensation type analysers                   | 74        |
| 9.2      | Analytical gases                                                             | 75        |
| 9.2.1    | General                                                                      | 75        |
| 9.2.2    | Gas specifications                                                           | 75        |
| 9.2.3    | Concentration and expiration date                                            | 77        |
| 9.2.4    | Gas transfer                                                                 | 77        |
| 9.3      | Vacuum-side leak verification                                                | 77        |
| 9.3.1    | Scope and frequency                                                          | 77        |
| 9.3.2    | Measurement principles                                                       | 77        |
| 9.3.3    | Low-flow leak test                                                           | 77        |
| 9.3.4    | Dilution-of-span-gas leak test                                               | 78        |
| 9.3.5    | Vacuum-decay leak test                                                       | 78        |
| 9.4      | NO <sub>2</sub> -to-NO converter conversion verification                     | 79        |
| 9.4.1    | Scope and frequency                                                          | 79        |
| 9.4.2    | Measurement principles                                                       | 79        |

|                              |                                                                                                |            |
|------------------------------|------------------------------------------------------------------------------------------------|------------|
| 9.4.3                        | System requirements                                                                            | 79         |
| 9.4.4                        | Procedure                                                                                      | 79         |
| 9.5                          | Calibration and set up of gaseous measurements                                                 | 80         |
| 9.5.1                        | Scope and frequency                                                                            | 80         |
| 9.5.2                        | Calibration                                                                                    | 81         |
| 9.5.3                        | HC FID response optimization                                                                   | 81         |
| 9.5.4                        | HC FID CH <sub>4</sub> response factor determination                                           | 81         |
| 9.5.5                        | HC FID methane (CH <sub>4</sub> ) response verification                                        | 82         |
| 9.5.6                        | Non-stoichiometric raw exhaust FID O <sub>2</sub> interference verification                    | 82         |
| 9.5.7                        | Efficiency of the Non-Methane Cutter (NMC)                                                     | 84         |
| 9.5.8                        | CO and CO <sub>2</sub> Measurements                                                            | 87         |
| 9.5.9                        | NO <sub>x</sub> Measurement                                                                    | 89         |
| 9.5.10                       | Methanol response factor                                                                       | 99         |
| 9.6                          | Calibration of the particulate mass measuring system                                           | 100        |
| 9.6.1                        | General                                                                                        | 100        |
| 9.6.2                        | Checking the partial flow conditions                                                           | 100        |
| 9.6.3                        | PM balance verifications and weighing process verification                                     | 100        |
| 9.7                          | Calibration of the particle number measuring system                                            | 103        |
| 9.7.1                        | Calibration of the particle number counter                                                     | 103        |
| 9.7.2                        | Calibration/Validation of the volatile particle remover                                        | 104        |
| 9.7.3                        | Particle number system check procedures                                                        | 105        |
| 9.8                          | Calibration of the CVS full flow dilution system                                               | 105        |
| 9.8.1                        | General                                                                                        | 105        |
| 9.8.2                        | Calibration of the Positive Displacement Pump (PDP)                                            | 106        |
| 9.8.3                        | Calibration of the Critical Flow Venturi (CFV)                                                 | 108        |
| 9.8.4                        | Calibration of the subsonic venturi (SSV)                                                      | 110        |
| 9.8.5                        | CVS and batch sampler verification (Propane check)                                             | 112        |
| 9.8.6                        | Periodic calibration of the partial flow PM and associated raw exhaust gas measurement systems | 116        |
| 9.9                          | Calibration of the dynamometer                                                                 | 118        |
| 9.9.1                        | Torque calibration                                                                             | 118        |
| 9.10                         | Calibration of temperature, pressure and dew point sensors                                     | 119        |
| 9.11                         | Flow-related measurements                                                                      | 119        |
| 9.11.1                       | Fuel flow calibration                                                                          | 119        |
| 9.11.2                       | Intake air flow calibration                                                                    | 119        |
| 9.11.3                       | Exhaust flow calibration                                                                       | 119        |
| <b>Annex A (normative)</b>   | <b>1980 international gravity formula</b>                                                      | <b>120</b> |
| <b>Annex B (normative)</b>   | <b>Determination of system equivalence</b>                                                     | <b>121</b> |
| <b>Annex C (normative)</b>   | <b>Carbon flow check</b>                                                                       | <b>122</b> |
| <b>Annex D (normative)</b>   | <b>Statistical formulae</b>                                                                    | <b>126</b> |
| <b>Annex E (informative)</b> | <b>Examples of partial flow dilution systems</b>                                               | <b>134</b> |
| <b>Annex F (informative)</b> | <b>Examples of exhaust gas analysis system</b>                                                 | <b>144</b> |
| <b>Bibliography</b>          |                                                                                                | <b>148</b> |

## Foreword

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

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

The committee responsible for this document is ISO/TC 70, *Internal combustion engines*, Subcommittee SC 8, *Exhaust gas emission measurement*.

This fourth edition cancels and replaces the third edition (ISO 8178-1:2017), which has been technically revised.

The main changes compared to the previous edition are as follows:

- addition of provision to use alternative systems for ammonia analysis;
- improvement of weighing chamber and analytical balance specifications;
- insertion of general section on measurement instruments;
- revision of particle number measurement system requirements;
- addition concentration and expiration date for analytical gases;
- revision of the annex on carbon flow check;
- addition of the 1980 international gravity formula.

A list of all the parts in the ISO 8178 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

This document is intended for use as a measurement procedure to determine the gaseous and particulate emission levels of reciprocating internal combustion (RIC) engines for non-automotive use. Its purpose is to provide an engine's emissions characteristics which, through use of proper weighting factors and test cycles, can be used as an indication of that engine's emission levels under various applications and for different fuels. The emission results are expressed in units of grams per kilowatt-hour and represent the rate of emissions per unit of work accomplished.

Many of the procedures described in this document are detailed accounts of laboratory methods, since determining an emissions value requires performing a complex set of individual measurements, rather than obtaining a single measured value. Thus, the results obtained depend as much on the process of performing the measurements as they depend on the engine and test method.

Evaluating emissions from non-road engines is more complicated than the same task for on-road engines due to the diversity of non-road applications. For example, on-road applications primarily consist of moving a load from one point to another on a paved roadway. The constraints of the paved roadways, maximum acceptable pavement loads and maximum allowable grades of fuel, narrow the scope of on-road vehicle and engine sizes. Non-road engines and vehicles include a wider range of size, including the engines that power the equipment. Many of the engines are large enough to preclude the application of test equipment and methods that were acceptable for on-road purposes. In cases where the application of dynamometers is not possible, testing at site or under appropriate conditions can be a viable alternative.

In limited instances, the engine can be tested on the test bed in accordance with ISO 8178-2, to test in field conditions. This can only occur with the agreement of the parties involved. It should be recognized that data obtained under these circumstances may not agree completely with previous or future data obtained under the auspices of this document.

For engines used in machinery covered by additional requirements (e.g. occupational health and safety regulations, regulations for power plants), additional test conditions and special evaluation methods may apply.

Where it is not possible to use a test bed or where information is required on the actual emissions produced by an in-service engine, the site test procedures and calculation methods specified in ISO 8178-2 are appropriate.