International Standard

ISO 1928

Coal and coke — Determination of gross calorific value

Charbon et coke — Détermination du pouvoir calorifique supérieur

Fifth edition
2025-08

Reference number
ISO 1928:2025(en)

© ISO 2025



COPYRIGHT PROTECTED DOCUMENT

© ISO 2025

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
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword ..... **v**

1 Scope **1**

2 Normative references **1**

3 Terms, definitions and symbols **2**
3.1 Terms and definitions 2
3.2 Symbols 3

4 Principle **6**
4.1 Gross calorific value 6
4.2 Net calorific value 7

5 Reagents **7**

6 Apparatus **8**

7 Preparation of test sample **12**

8 Calorimetric procedure **13**
8.1 General 13
8.2 Preparing the combustion vessel for measurement 15
8.2.1 General procedure 15
8.2.2 Using a combustion aid 15
8.3 Assembling the calorimeter 16
8.4 Combustion reaction and temperature measurements 16
8.5 Analysis of products of combustion 17
8.6 Corrected temperature rise 17
8.6.1 Observed temperature rise, $t_f - t_i$ 17
8.6.2 Isoperibol and static-jacket calorimeters 17
8.6.3 Adiabatic calorimeters 18
8.6.4 Thermometer corrections 19
8.7 Reference temperature 19

9 Calibration **19**
9.1 Principle 19
9.2 Calibrant 19
9.2.1 Certification conditions 19
9.2.2 Calibration conditions 19
9.3 Valid working range of the effective heat capacity 20
9.4 Ancillary contributions 20
9.5 Calibration procedure 21
9.6 Calculation of effective heat capacity for the individual test 21
9.6.1 Constant mass-of-calorimeter-water basis 21
9.6.2 Constant total-calorimeter-mass basis 21
9.7 Precision of the mean value of the effective heat capacity 22
9.7.1 Constant value of ε 22
9.7.2 ε as a function of the observed temperature rise 22
9.8 Redetermination of the effective heat capacity 23

10 Gross calorific value **23**
10.1 General 23
10.2 Coal combustions 23
10.3 Coke combustions 24
10.4 Calculation of gross calorific value 24
10.4.1 General 24
10.4.2 Constant mass-of-calorimeter-water basis 25
10.4.3 Constant total-calorimeter-mass basis 26
10.4.4 ε as a function of the observed temperature rise 26
10.5 Expression of results 26

© ISO 2025 – All rights reserved

10.6 Calculation to other bases ... 27
11 Precision ... **27**
11.1 Repeatability limit ... 27
11.2 Reproducibility limit ... 27
12 Calculation of net calorific value ... **27**
12.1 General ... 27
12.2 Calculations ... 28
12.2.1 Calculation of net calorific value at constant pressure ... 28
12.2.2 Calculation of net calorific value at constant volume ... 29
13 Test report ... **30**
Annex A (informative) **Adiabatic calorimeters** ... **32**
Annex B (informative) **Isoperibol and static-jacket calorimeters** ... **36**
Annex C (informative) **Automated calorimeters** ... **41**
Annex D (informative) **Checklists for the design of combustion tests and their procedures** ... **44**
Annex E (informative) **Examples to illustrate some of the calculations used in this document** ... **49**
Annex F (informative) **Safe use, maintenance and testing of calorimeter combustion vessels** ... **55**
Bibliography ... **61**

© ISO 2025 – All rights reserved

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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

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.

This document was prepared by Technical Committee ISO/TC 27, *Coal and coke*, Subcommittee SC 5, *Methods of analysis*.

This fifth edition cancels and replaces the fourth edition (ISO 1928:2020), which has been technically revised.

The main changes are as follows:

— title changed from solid mineral fuels to coal and coke;

— updated symbols within formulae;

— allowance for alternative material for calorimeter can;

— expanded on some derivations and added units of measure to some equations;

— removed ambiguity around crucible masses;

— specified the analysis sample;

— more concise wording around the use of a combustion aid and determining a correction value;

— warnings now included in body of text;

— the addition of alternate ignition methods.

Any feedback or questions on this document shall be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

© ISO 2025 – All rights reserved

Coal and coke — Determination of gross calorific value

WARNING — Strict adherence to all of the provisions specified in this document is needed to ensure against explosive rupture of the combustion vessel, or a blow-out, provided that the combustion vessel is of proper design and construction and in good mechanical condition.

1 Scope

This document specifies a method for the determination of the gross calorific value of coal and coke at constant volume and at the reference temperature of 25 °C in a combustion vessel calorimeter calibrated by combustion of certified benzoic acid.

The result obtained is the gross calorific value of the analysis sample at constant volume with all the water of the combustion products as liquid water. In practice, fuel is burned at constant (atmospheric) pressure and the water is not condensed but is removed as vapour with the flue gases. Under these conditions, the operative heat of combustion is the net calorific value of the fuel at constant pressure. The net calorific value at constant volume can also be used; formulae are given for calculating both values.

General principles and procedures for the calibrations and the fuel tests are specified in the main text, whereas those pertaining to the use of a particular type of calorimetric instrument are described in Annexes A to C. Annex D contains checklists for performing calibration and fuel tests using specified types of calorimeters. Annex E gives examples illustrating some of the calculations. Annex F provides guidance around safe use, maintenance and testing of the calorimeter combustion vessel.

NOTE Descriptors: solid fuels, coal, coke, tests, determination, calorific value, rules of calculation, calorimetry.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 651:1975, *Solid-stem calorimeter thermometers*[1)]

ISO 652:1975, *Enclosed-scale calorimeter thermometers*[1)]

ISO 687, *Coke — Determination of moisture in the general analysis test sample*

ISO 1770:1981, *Solid-stem general purpose thermometers*[1)]

ISO 1771:1981, *Enclosed-scale general purpose thermometers*[1)]

ISO 5068-2, *Brown coals and lignites — Determination of moisture — Part 2: Indirect gravimetric method for moisture in the analysis sample*

ISO 11722, *Solid mineral fuels — Hard coal — Determination of moisture in the general analysis test sample by drying in nitrogen*

ISO 13909-4, *Hard coal and coke — Mechanical sampling — Part 4: Preparation of test samples of coal*

ISO 17247, *Coal and coke — Ultimate analysis*

ISO 18283, *Coal and coke — Manual sampling*

1) Withdrawn.

© ISO 2025 – All rights reserved

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1.1
gross calorific value at constant volume
absolute value of the specific energy of combustion for unit mass of a solid fuel burned in oxygen in a calorimetric combustion vessel under the conditions specified

Note 1 to entry: The products of combustion are assumed to consist of gaseous oxygen, nitrogen, carbon dioxide and sulfur dioxide, of liquid water (in equilibrium with its vapour) saturated with carbon dioxide under the conditions of the combustion vessel reaction, and of solid ash, all at the reference temperature.

Note 2 to entry: Gross calorific value is expressed in units of joules/gram.

3.1.2
gross calorific value at constant pressure
absolute value of the specific energy of combustion, for unit mass of a solid fuel burned in oxygen at constant pressure, instead of constant volume in a calorimetric combustion vessel

Note 1 to entry: The hydrogen in the fuel, reacting with gaseous oxygen to give liquid water, causes a decrease in the volume of the system. When the fuel carbon reacts with gaseous oxygen, an equal volume of gaseous carbon dioxide is formed and, hence, no change in volume occurs in combustion of the carbon. The oxygen and nitrogen in the fuel both give rise to an increase in volume.

3.1.3
net calorific value at constant volume
absolute value of the specific energy of combustion, for unit mass of a solid fuel burned in oxygen under conditions of constant volume and such that all the water of the reaction products remains as water vapour (in a hypothetical state at 0,1 MPa), the other products being as for the gross calorific value, all at the *reference temperature* (3.1.8)

3.1.4
net calorific value at constant pressure
absolute value of the specific heat (enthalpy) of combustion, for unit mass of the fuel burned in oxygen at constant pressure under such conditions that all the water of the reaction products remains as water vapour (at 0,1 MPa), the other products being as for the gross calorific value, all at the *reference temperature* (3.1.8)

3.1.5
adiabatic calorimeter
calorimeter that has a rapidly changing jacket temperature

Note 1 to entry: The inner calorimeter chamber and the jacket exchange no energy because the water temperature in both is identical during the test. The water in the external jacket is heated or cooled to match the temperature change in the calorimeter proper.

3.1.6
isoperibol calorimeter
<isothermal type> calorimeter that has a jacket of uniform and constant temperature

Note 1 to entry: These calorimeters have the inner chamber surrounded by a water jacket in which the temperature is maintained at ambient temperature. The outer jacket acts like a thermostat and the thermal conductivity of the interspace between the two chambers is kept as small as possible.

© ISO 2025 – All rights reserved

3.1.7
aneroid calorimeter
calorimeter system without fluid, where the calorimeter can, stirrer and water are replaced by a metal block and the combustion vessel itself constitutes the calorimeter

Note 1 to entry: Characteristically, these calorimeters have a small heat capacity, leading to large changes in temperature. Therefore, smaller masses of sample are used. A calorimeter of this kind requires more frequent calibrations.

3.1.8
reference temperature
international reference temperature for thermochemistry, 25 °C

Note 1 to entry: The temperature dependence of the calorific value of coal or coke is small, about 1 J/(g·K).

3.1.9
effective heat capacity of the calorimeter
amount of energy required to cause unit change in temperature of the calorimeter

3.1.10
corrected temperature rise
change in calorimeter temperature caused solely by the processes taking place within the combustion vessel

Note 1 to entry: The change in temperature can be expressed in terms of other units: resistance of a platinum or thermistor thermometer, frequency of a quartz crystal resonator, etc., provided that a functional relationship is established between this quantity and a change in temperature. The effective heat capacity of the calorimeter can be expressed in units of energy per such an arbitrary unit. Criteria for the required linearity and closeness in conditions between calibrations and fuel tests are given in 9.3.

3.2 Symbols

$c_{\mathrm{p,aq}}$	specific heat capacity of water at constant pressure
$c_{\mathrm{p,s}}$	specific heat capacity of the sample
$c_{\mathrm{p}}\mathrm{d}t$	heat capacity times the temperature change
$c_{\mathrm{p,cr}}$	specific heat capacity of the crucible
ΔC	is the difference in heat capacity ($m_{\mathrm{cr}} \times c_{p,\mathrm{cr}}$) of the crucible used in the calibrations and that used in combustion of the fuel
$\frac{\mathrm{d}q}{\mathrm{d}T}$	heat flow into the calorimeter
$(\mathrm{d}t/\mathrm{d}\tau)_{\mathrm{i}}$	the initial drift rate
G	specific rate constant, which is evaluated from the time-temperature measurements of the rating periods, the fore- and the after-period
g	drift rate ($\mathrm{d}t/\mathrm{d}\tau$) in the rating periods
g_{f}	final drift rate (drift rate in the after-period)
g_{i}	initial drift rate (drift rate in the fore-period)
K	is the Newton's law cooling constant
l_{wire}	length of ignition wire (fuse)
L	is the latent heat of vaporization of water at 25 °C and constant pressure (43 988 J/mol)

© ISO 2025 – All rights reserved

L_s	is the latent heat of vaporization at 25 °C and constant pressure of the water present in the analysis sample and formed from the hydrogen in it
M	moisture in the analysis sample
m_{aq}	mass of combustion vessel water
M_T	total moisture mass fraction of the fuel for which the calculation is required
m_{ba}	mass of benzoic acid
m_{cr}	mass of crucible
m_s	mass of sample
m_{fuse}	mass of wire (fuse)
m_1	mass of fuel sample burned
m_2	mass of combustion aid
p_O	initial pressure of oxygen
P_{st}	power of stirring
Q_{fuse}	contribution from combustion of the fuse
Q_{ign}	contribution from oxidation of the ignition wire
Q_N	contribution from formation of nitric acid (from liquid water and gaseous nitrogen and oxygen)
Q_S	correction for taking the sulfur from the aqueous sulfuric acid in the combustion vessel to gaseous sulfur dioxide
$q_{p,gr,d}$	gross calorific value at constant pressure of the dry (moisture-free) fuel
$q_{p,net,M}$	net calorific value at constant pressure for air-dried fuel with moisture mass fraction
$q_{p,net,d}$	net calorific value at constant pressure of the dry (moisture-free) fuel
q_{p,net,M_T}	net calorific value at constant pressure of the fuel with moisture mass fraction M_T
$q_{V,ba}$	certified gross calorific value at constant volume for benzoic acid
$q_{V,gr}$	gross calorific value at constant volume of the fuel as analysed
$q_{V,gr,d}$	gross calorific value at constant volume of the dry (moisture-free) fuel
$q_{V,gr,m}$	gross calorific value at constant volume of the fuel with moisture mass fraction M_T
$q_{V,net}$	net calorific value at constant volume
$q_{V,net,d}$	net calorific value at constant volume of the dry (moisture-free) fuel
$q_{V,net,M}$	net calorific value at constant volume for air-dried fuel with moisture mass fraction
q_{V,net,M_T}	net calorific value at constant volume of the fuel with moisture mass fraction M_T
$q_{V,2}$	gross calorific value at constant volume of a combustion aid
R	the universal gas constant, equal to 8,315 J/mol K

© ISO 2025 – All rights reserved

T	the reference temperature for calorific value, i.e. 298,15 K (25 °C)
Δn_g	contraction in volume of the gaseous phase for the combustion reaction, expressed in terms of moles per gram of sample, on an air-dried basis
t	calorimeter temperature
t_1	the correction of 1 applied after the ignition of the sample
Δm_{cr}	heat capacity from the mass of the crucible
Δt_{ex}	heat-leak correction, which is the contribution from the heat exchange
t_f	final temperature of the main period (equal to the reference temperature)
τ_a	time, a minutes after the end of the main period
$t_{f+\tau_a}$	temperature, a minutes after the end of the main period
$t_f - t_i$	observed temperature rise
Δt	observed temperature rise
t_i	initial temperature of the main period (at the time of firing the charge)
t_j	thermostat (jacket) temperature
$t_j - t$	thermal head
t_k	successive temperature readings, taken at 1 min intervals during the main period
t_m	the integrated mean temperature
t_0	is equal to t_i and is the temperature at the beginning of the main period
t_n	is the temperature reading, taken during the main period, at the nth one-minute interval, t_n (= t_f) being the reading taken at the end
t_{mf}	mean temperature in the after-period
t_{mi}	mean temperature in the fore-period
t_x	temperature at the time τ_x,
t_∞	is the temperature that the calorimeter eventually attains if left running for an extended period of time, which is the asymptotic temperature of an isoperibol calorimeter (at "infinite" time)
t_{ref}	reference temperature
V_1	is the volume of the barium hydroxide solution used
V_2	is the volume, of the hydrochloric acid solution used
$V_{aq,}$	volume of combustion vessel water, may be substituted, as appropriate, for m_{aq}
V_{cv}	combustion vessel volume
W_1	the work done against the atmosphere when the water is expanded at constant pressure to vapour at 25 °C

© ISO 2025 – All rights reserved

W_2 Δn_g multiplied by RT to interpret the volume change in terms of the associated work done by the atmosphere to maintain constant pressure

w_H hydrogen mass fraction of the sample less the hydrogen contained in the moisture mass fraction

$w_{H,d}$ hydrogen, mass fraction of the moisture-free fuel (includes the hydrogen from the water of hydration of the mineral matter as well as hydrogen in the coal substance)

$w_{N,d}$ nitrogen, mass fraction of the moisture-free fuel

$w_{O,d}$ oxygen, mass fraction of the moisture-free fuel

w_V the volatile-matter mass fraction of the sample with moisture mass fraction, M_T

w_A the ash mass fraction of the sample with moisture mass fraction, M_T

ε effective heat capacity of the calorimeter

$\hat{\varepsilon}$ best estimate (corresponds to "mean" value) of ε from linear regression of ε as a function of the observed temperature rise ($t_f - t_i$)

ε_* effective heat capacity of calorimeter on a "total-calorimeter-mass" basis

ε_n mean effective heat capacity of the calorimeter based on n determinations of ε

ε_O effective heat capacity of hypothetical calorimeter with no crucible in the combustion vessel

$\varepsilon_{O,n}$ mean effective heat capacity of the calorimeter based on n determinations of ε_O

θ corrected temperature rise

τ time

$\Delta\tau$ length of the main period

τ_f time at the end of the main period

τ_i time at the beginning of the main period

τ_x Dickinson extrapolation time

4 Principle

4.1 Gross calorific value

A measured portion of the general analysis sample is burned in high-pressure oxygen in a combustion vessel calorimeter under specified conditions. The effective heat capacity of the calorimeter is determined in calibration tests by combustion of certified benzoic acid under similar conditions, accounted for in the certificate. The corrected temperature rise is established from observations of temperature before, during, and after the combustion reaction takes place. The duration and frequency of the temperature observations depend on the type of calorimeter used. Water is added to the combustion vessel initially to give a saturated vapour phase prior to combustion, thereby allowing all the water formed from the hydrogen and moisture in the sample to be regarded as liquid water.

The gross calorific value is calculated from the corrected temperature rise and the effective heat capacity of the calorimeter, with allowances made for contributions from ignition energy, combustion of the fuse(s) and for thermal effects from side reactions such as the formation of nitric acid. Furthermore, a correction is applied to account for the difference in energy between the aqueous sulfuric acid formed in the combustion vessel reaction and gaseous sulfur dioxide, i.e. the required reaction product of sulfur in the fuel.

© ISO 2025 – All rights reserved