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EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN ISO 21654

July 2021

ICS 75.160.10

Supersedes EN 15400:2011

English Version

Solid recovered fuels - Determination of calorific value (ISO 21654:2021)

Combustibles solides de récupération - Détermination
du pouvoir calorifique (ISO 21654:2021)

Feste Sekundärbrennstoffe - Bestimmung des
Brennwertes (ISO 21654:2021)

This European Standard was approved by CEN on 19 March 2021.

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COMITÉ EUROPÉEN DE NORMALISATION
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CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Contents	Page
European foreword.....	3

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SIST EN ISO 21654:2021
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European foreword

This document (EN ISO 21654:2021) has been prepared by Technical Committee ISO/TC 300 "Solid recovered materials, including solid recovered fuels" in collaboration with Technical Committee CEN/TC 343 "Solid Recovered Fuels" the secretariat of which is held by SFS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2022, and conflicting national standards shall be withdrawn at the latest by January 2022.

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

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INTERNATIONAL
STANDARD

ISO
21654

First edition
2021-06

**Solid recovered fuels — Determination
of calorific value**

*Combustibles solides de récupération — Détermination du pouvoir
calorifique*

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Reference number
ISO 21654:2021(E)

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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
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Principle	2
4.1 Gross calorific value.....	2
4.2 Net calorific value.....	3
5 Reagents	3
6 Laboratory conditions	4
7 Apparatus	5
7.1 General.....	5
7.2 Auxiliary equipment.....	7
7.3 Balances.....	7
8 Preparation of test sample	8
9 Calorimetric procedure	8
9.1 General.....	8
9.2 Preparing the combustion vessel for measurement.....	9
9.2.1 General procedure.....	9
9.2.2 Using combustion aids.....	10
9.3 Assembling the calorimeter.....	11
9.4 Combustion reaction and temperature measurements.....	11
9.5 Analysis of products of combustion.....	12
9.6 Corrected temperature rise θ	12
9.6.1 Observed temperature rise.....	12
9.6.2 Isoperibol and static-jacket calorimeters.....	12
9.6.3 Adiabatic calorimeters.....	14
9.6.4 Thermometer corrections.....	14
9.7 Reference temperature.....	14
10 Calibration	14
10.1 Principle.....	14
10.2 Calibration reference.....	15
10.2.1 Certification conditions.....	15
10.2.2 Calibration conditions.....	15
10.3 Valid working range of the effective heat capacity ϵ	15
10.4 Ancillary contributions.....	16
10.5 Calibration procedure.....	16
10.6 Calculation of effective heat capacity for the individual experiment.....	17
10.6.1 Constant mass-of-calorimeter-water basis.....	17
10.6.2 Constant total-calorimeter-mass basis.....	17
10.7 Precision of the mean value of the effective heat capacity ϵ	18
10.7.1 Constant value of ϵ	18
10.7.2 ϵ as a function of the observed temperature rise.....	19
10.8 Repetition of the determination of effective heat capacity.....	19
11 Gross calorific value	19
11.1 General.....	19
11.2 Combustion.....	20
11.3 Calculation of gross calorific value.....	20

ISO 21654:2021(E)

11.3.1	General.....	20
11.3.2	Constant mass-of-calorimeter-water basis.....	20
11.3.3	Constant total-calorimeter-mass basis.....	22
11.3.4	ϵ as a function of the observed temperature rise.....	23
11.4	Expression of results.....	23
11.5	Calculation to other bases.....	23
12	Precision	24
12.1	Repeatability limit.....	24
12.2	Reproducibility limit.....	24
13	Calculation of net calorific value at constant pressure	24
13.1	General.....	24
13.2	Calculations.....	24
14	Test report	25
Annex A (normative) Adiabatic combustion vessel calorimeters		27
Annex B (normative) Isooperibol and static-jacket combustion vessel calorimeters		31
Annex C (normative) Automated combustion vessel calorimeters		36
Annex D (normative) Removed ash contributors		39
Annex E (informative) Checklists for the design and procedures of combustion experiments		42
Annex F (informative) Examples to illustrate the main calculations used in this document if an automated (adiabatic) combustion vessel calorimeter is used for determinations		47
Annex G (informative) List of symbols used in this document		50
Annex H (informative) Flow chart for a routine calorific value determination		53
Annex I (informative) Interlaboratory test results		54
Annex J (informative) Additional terms for the basis of results expression		57
Annex K (informative) Environmental aspects		58
Bibliography		60

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).

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).

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 300, *Solid recovered fuels*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 343, *Solid Recovered Fuels*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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.

ISO 21654:2021(E)

Introduction

This document is based on EN 15400 [1].

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

General principles and procedures for the calibrations and the solid recovered fuels experiments are presented in the main part of this document, whereas those pertaining to the use of a particular type of calorimetric instrument are specified in [Annexes A](#) to [C](#). [Annex D](#) contains the formulae to calculate the removed ash contributors. [Annex E](#) contains checklists for performing calibration and fuel experiments using specified types of calorimeters. [Annex F](#) gives examples to illustrate some of the calculations.

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Solid recovered fuels — Determination of calorific value

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

1 Scope

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

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 10304-1, *Water quality — Determination of dissolved anions by liquid chromatography of ions — Part 1: Determination of bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulfate*

ISO 16993, *Solid biofuels — Conversion of analytical results from one basis to another*

ISO 21637, *Solid recovered fuels — Vocabulary*

ISO 21644, *Solid recovered fuels — Methods for the determination of biomass content*

ISO 21646,¹⁾ *Solid recovered fuels — Sample preparation*

ISO 21660-3, *Solid recovered fuels — Determination of moisture content using the oven dry method — Part 3: Moisture in general analysis sample*

EN 15358, *Solid recovered fuels — Quality management systems — Particular requirements for their application to the production of solid recovered fuels*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 21637 and the following apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

gross calorific value at constant volume

absolute value of the specific energy of combustion, in Joules, for unit mass of a solid recovered 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* (3.4).

1) Under preparation. Stage at the time of publication: ISO/DIS 21646:2021.

ISO 21654:2021(E)

3.2

net calorific value at constant volume

absolute value of the specific energy of combustion, in Joules, for unit mass of a solid recovered 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* (3.4)

3.3

net calorific value at constant pressure

absolute value of the specific heat (enthalpy) of combustion, in Joules, for unit mass of a solid recovered 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* (3.4)

3.4

reference temperature

international reference temperature for thermo-chemistry of 25 °C is adopted as the reference temperature for calorific values (see 9.7)

Note 1 to entry: The temperature dependence of the calorific value of solid recovered fuels is small [less than 1]/(g · K)].

3.5

effective heat capacity of the calorimeter

amount of energy required to cause unit change in temperature of the calorimeter

3.6

corrected temperature rise

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

Note 1 to entry: It is the total observed temperature rise corrected for heat exchange, stirring power etc. (see 9.6).

Note 2 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* (3.5) 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 experiments are given in 9.3.

Note 3 to entry: A list of the symbols used and their definitions is given in Annex G.

Note 4 to entry: Annex J explains additional relevant terms that could be of interest, more specifically in association to Annex D. The terms can provide some clarification in certain cases.

3.7

removed ash contributors**rac**

coarse inert material (i.e. metals, glass, stones, tiles, etc.) removed from the sample before preparation, in order to avoid damage to the preparation equipment

Note 1 to entry: The removed ash contributors (rac), after sample pre-drying, are taken into account for the calculation of the ash, carbon, hydrogen, nitrogen and sulfur content in the analysed sample.

Note 2 to entry: See Annex D for further information.

4 Principle

4.1 Gross calorific value

A weighed portion of the analysis sample of a solid recovered fuel 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 experiments by the 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 vessel initially to give a saturated vapour phase prior to combustion (see 9.2.1 and 10.2.2), 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 solid recovered fuel. The corresponding energy effect between aqueous and gaseous hydrochloric acid can be negligible for solid recovered fuels of mainly biomass origin.

The corresponding energy effect between aqueous and gaseous hydrochloric acid depends on the sample characteristics, e.g. the content of inorganic and organic chlorine, mineral composition and the actual pH-value in combustion vessel liquid. At the present time no values are available for this chlorine correction. Attention should be paid to the extremely high chlorine content in the test sample because e.g. PVC fractions can affect the calorific value significantly.

Automatic equipment may be used if the method is validated by parallel measurements. This automatic equipment shall fulfil all the requirements regarding sample size, heating procedure, temperature, atmosphere, and weighing accuracy. Deviations from this paragraph shall be reported and justified.

NOTE [Annex H](#) shows a flow chart for a routine determination of calorific value.

4.2 Net calorific value

The net calorific value at constant volume and the net calorific value at constant pressure of the solid recovered fuel are obtained by calculation from the gross calorific value at constant volume determined on the analysis sample. The calculation of the net calorific value at constant volume requires information about the moisture and hydrogen contents of the analysis sample. In principle, the calculation of the net calorific value at constant pressure also requires information about the oxygen and nitrogen contents of the sample.

NOTE [Annex H](#) shows a flow chart for a routine determination of calorific value.

5 Reagents

5.1 Oxygen, at a pressure high enough to fill the combustion vessel to 3 MPa, pure with an assay of at least 99,5 % volume fraction, and free from combustible matter.

NOTE Oxygen made by the electrolytic process can contain up to 4 % volume fraction of hydrogen.

5.2 Fuse

5.2.1 Ignition wire, of nickel-chromium 0,16 mm to 0,20 mm in diameter, platinum 0,05 mm to 0,10 mm in diameter, or another suitable conducting wire with well-characterized thermal behaviour during combustion.

5.2.2 Cotton fuse, of white cellulose cotton, or equivalent, if required (see NOTE 1 of 9.2.1).

5.3 Combustion aids, of known gross calorific value, composition and purity, e.g. benzoic acid, n-dodecane, paraffin oil, combustion bags or capsules.