



BSI Standards Publication

Carbon dioxide capture — Key performance parameters and characterization methods of absorption liquids for post-combustion CO₂ capture

National foreword

This British Standard is the UK implementation of ISO 27927:2025.

The UK participation in its preparation was entrusted to Technical Committee PSE/265, Carbon Capture Transportation and Storage.

A list of organizations represented on this committee can be obtained on request to its committee manager.

Contractual and legal considerations

This publication has been prepared in good faith, however no representation, warranty, assurance or undertaking (express or implied) is or will be made, and no responsibility or liability is or will be accepted by BSI in relation to the adequacy, accuracy, completeness or reasonableness of this publication. All and any such responsibility and liability is expressly disclaimed to the full extent permitted by the law.

This publication is provided as is, and is to be used at the recipient's own risk.

The recipient is advised to consider seeking professional guidance with respect to its use of this publication.

This publication is not intended to constitute a contract. Users are responsible for its correct application.

© The British Standards Institution 2025
Published by BSI Standards Limited 2025

ISBN 978 0 539 22447 4

ICS 13.020.40

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 August 2025.

Amendments/corrigenda issued since publication

Date	Text affected
------	---------------



**International
Standard**

ISO 27927

**Carbon dioxide capture — Key
performance parameters and
characterization methods of
absorption liquids for post-
combustion CO₂ capture**

*Captage du dioxyde de carbone — Paramètres clés de
performance et méthodes de caractérisation des liquides
d'absorption pour le captage du CO₂ post-combustion*

**First edition
2025-09**

Reference number
ISO 27927:2025(en)

Full document details: BS ISO 27927:2025

© ISO 2025  **Documents**
Document Sharing Hub



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	iv
Introduction	v
1 Scope	1
2 Normative references	2
3 Terms, definitions, abbreviated terms and symbols	2
3.1 Terms and definitions	2
3.2 Abbreviated terms	6
3.3 Symbols	6
4 Evaluation of performance parameters	8
4.1 General	8
4.2 Primary performance parameters	9
4.2.1 Rich and lean CO ₂ loading	9
4.2.2 Absorbent concentration	10
4.2.3 CO ₂ absorption capacity	11
4.2.4 Heat of absorption	11
4.2.5 Absorption rate	12
4.2.6 Absorbent volatility	13
4.3 Secondary performance parameters	13
4.3.1 Cyclic loading	13
4.3.2 Absorbent loss rate	13
4.4 Physical and chemical properties	14
5 General for the characterization of absorption liquids	14
5.1 Laboratory measurements and field testing	14
5.2 General requirement	15
6 Instrument and characterization methods	16
6.1 General	16
6.2 Instrument classification	16
6.3 Calibration of instrument	16
6.4 Evaluation of measurement uncertainty	16
6.5 Competence in characterization methods	17
Annex A (informative) Methods for sampling absorption liquids used in post-combustion CO₂ capture demonstration system	18
Annex B (informative) Summary for the characterization methods of primary performance parameters of absorption liquids used in post-combustion CO₂ capture	22
Annex C (informative) Characterization methods for evaluating carbon dioxide loading	24
Annex D (informative) Characterization methods for evaluating absorbent concentration	30
Annex E (informative) Characterization methods for evaluating CO₂ absorption capacity	40
Annex F (informative) Characterization methods for evaluating heat of absorption	46
Annex G (informative) Characterization methods for evaluating absorption rate	50
Annex H (informative) Characterization methods for evaluating absorbent volatility	58
Annex I (informative) Characterization methods for evaluating physical and chemical properties of absorption liquids	66
Bibliography	68

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 265, *Carbon dioxide capture, transportation and geological storage*.

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.

Introduction

Carbon dioxide capture and storage (CCS) is a suite of technologies to reduce carbon dioxide (CO₂) emissions into the atmosphere, as a central aspect of reducing overall greenhouse gas emissions that are causing climate change. CCS is widely recognized to play a crucial role in achieving deep and large-scale decarbonization in a short time frame in the power and industrial sectors. Among several CO₂ capture pathways, post-combustion CO₂ capture (PCC) is the most mature and viable, capable of reducing CO₂ emissions from combustion processes in the energy-related and industrial sectors. Chemical absorption using reactive liquids is a proven technology and has been widely developed in numerous PCC facilities. Various absorption liquids, such as amines, potassium carbonate, aqueous ammonia solutions, amino-acid salt solutions and mixtures of these reactants, have been adopted for PCC applications.

The performance of absorption liquids is one of the key factors influencing the cost and the energy consumption in a PCC process, thereby influencing its commercial application and its net greenhouse gas impact. Understanding the key performance parameters and physical and chemical properties of absorption liquid is essential, not only for screening of promising absorption liquids, but also for process engineering design and evaluating PCC plant performance during operation.

Specifically, accurate monitoring of CO₂ loading and absorbent concentration in the absorption liquid will guide parametric measurement, optimization, commissioning and operation of the PCC plant. Understanding the absorption capacity helps in selecting the appropriate absorption liquid for CO₂ capture, and optimizing the process conditions using information from vapour-liquid equilibria. A larger cyclic loading of CO₂ in the absorption liquid means that less absorption liquid needs to be circulated, leading to lower energy consumption for pumping, heating and cooling. Absorbent volatility is one of the factors leading to absorbent loss. The heat of absorption of CO₂ is a primary factor influencing the energy required for regenerating absorption liquids. The viscosity of absorption liquids can affect absorber flooding, and electricity consumption for pumping. A higher viscosity of the absorption liquid also reduces the heat transfer coefficient for the heat exchanger, meaning more heat exchanger area is required to achieve the same heat duty. It also decreases the absorption and mass transfer between gas and liquid. The absorption rate of absorption liquids impacts the capital costs of the PCC process. A higher absorption rate of the absorption liquids enables a shorter packing height in CO₂ capture, which reduces the sizes of the absorber and desorber. The density and viscosity are physical and chemical properties of absorption liquids. The thermal conductivity and specific heat capacity are important thermophysical properties to understand the heat transfer process in absorption liquid-based CO₂ capture process.

Given the large and diverse impact of absorption liquids on various aspects of PCC plant performance, an ISO standard for evaluating and characterizing the key performance parameters of absorption liquids is required and that would complement the standards for CO₂ capture, ISO 27919-1 and ISO 27919-2. Previously, ISO 27919-1 was developed as a guideline for measuring, evaluating and reporting the performance of a PCC plant integrated into a power plant. It provides a general methodology for calculating specific key performance indicators for the PCC process within the entire power system. ISO 27919-2 was developed to specify an evaluation procedure to ensure and maintain the stable performance of the PCC process integrated into a power plant during operation, from a commissioning perspective.

The measurement and evaluation of the key physical and chemical characteristics of absorption liquids, as defined in this document, are essential. This will benefit technology developers for the subsequent PCC process design, optimization, performance monitoring and plant operation.

Carbon dioxide capture — Key performance parameters and characterization methods of absorption liquids for post-combustion CO₂ capture

1 Scope

This document provides definitions, guidelines and supportive information for the key performance parameters and their characterization methods of absorption liquids used in post-combustion CO₂ capture. It covers common methodologies to measure and calculate specific key performance parameters of the absorption liquids.

The absorption liquids for post-combustion CO₂ capture covered by this document are chemically reactive liquids, such as amine solutions, potassium carbonate solutions, aqueous ammonia, amino-acid salt solutions and mixtures of these reactants. Other absorption liquids based on different principles for CO₂ capture are not covered.

The key performance parameters considered in this document relate to the design and operation of absorption liquid-based post-combustion CO₂ capture processes, as well as equipment such as absorber and desorber columns, reboilers and other heat exchangers.

The key performance parameters are:

- primary parameters, such as rich and lean CO₂ loading, absorbent concentration, absorption capacity, heat of absorption, absorption rate and absorbent volatility;
- secondary parameters, such as cyclic loading, that are directly derived from the primary parameters, or combined with other physical measurements, as in the case for the absorbent loss rate.

In addition, physical and chemical properties such as density, viscosity, pH, thermal conductivity and specific heat capacity are described. These properties are essential for understanding the key performance parameters of the absorption liquids.

This document also:

- establishes key performance parameters (see [Clause 4](#)), physical and chemical properties of absorption liquids, and their calculation methods, and provides a common way of reporting them;
- specifies the general requirements for the absorption liquid characterization in laboratory measurement and field testing (see [Clause 5](#));
- provides the requirements for the instrumentation to be installed or used, and guidelines for the characterization methods (see [Clause 6](#));
- provides information on the characterization methods of absorption liquids, describing all stages of test preparation, set-up and execution (see [Annexes A to I](#)), as well as guidance on sampling absorption liquids.

NOTE While key performance parameters of absorption liquids are important process indicators for post-combustion CO₂ capture, factors such as process design, equipment design and manufacturing, economics and safety are also considered for a comprehensive evaluation of post-combustion CO₂ capture technology.

The document does not provide guidelines for benchmarking or comparing absorption liquids for post-combustion capture processes, nor does it offer methods to assess different technologies or projects, or specify methodologies for process engineering design. Additionally, the document is not intended to compel technology owners to disclose any intellectual properties related to their proprietary absorption liquids.

The document does not cover all available and emerging characterization methods for the key performance parameters considered in this document.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, abbreviated terms and symbols

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 Terms and definitions

3.1.1

absorbent

substance able to take up liquid or gas

Note 1 to entry: the absorbent for post-combustion CO₂ capture is the substance able to take up CO₂ mainly through chemical reactions in liquid solution.

[SOURCE: ISO 27919-1:2018, 3.1.1, modified — "absorb" has been replaced with "take up" in the definition and Note 1 to entry has been added.]

3.1.2

absorbent concentration

amount of *absorbent* (3.1.1) present in a specific amount of absorption liquid, excluding water or other non-reactive substances in the absorption liquid

Note 1 to entry: Absorbent concentration may be expressed in units of kilograms of absorbent per kilogram of absorption liquid (kg·kg⁻¹), or moles of absorbent per litre of absorption liquid (mol·l⁻¹).

3.1.3

absorbent loss rate

speed at which the *absorbent* (3.1.1), excluding water or other non-reactive substances in the absorption liquids, that is lost from the CO₂ capture process due to factors such as evaporation, leaks and degradation

3.1.4

absorption liquid

liquid that is capable of removing carbon dioxide gas from the feed gas in a gas-liquid absorption process

Note 1 to entry: The absorption liquid contains both the *absorbent* (3.1.1) and solvent; the solvent can be water or other non-reactive substances.

3.1.5

absorption rate

mass transfer rate

speed at which the absorption process proceeds

Note 1 to entry: The absorption rate is quantified by the absorption rate coefficient or mass transfer coefficient, which is a proportionality factor in the rate law of chemical kinetics that relates to the concentration or partial pressure of gas phase species.

Note 2 to entry: The absorption rate can be expressed as the liquid-side mass transfer concentration driving force in the unit of mol·s⁻¹·m⁻²·Pa⁻¹.

3.1.6

accuracy

accuracy of measurement

measurement accuracy

closeness of agreement between a measured quantity value and a true quantity value of a measurand

[SOURCE: ISO/IEC Guide 99:2007, 2.13, modified — "accuracy" has become the preferred term.]

3.1.7

alkalinity

capacity of aqueous media to react with hydrogen ions

[SOURCE: ISO 6707-1:2020, 3.7.3.62]

3.1.8

carbon dioxide capture and storage

CCS

process consisting of the separation of CO₂ from industrial and energy-related sources, transportation and injection into a geological formation, resulting in long term isolation from the atmosphere

Note 1 to entry: CCS is often referred to as carbon capture and storage. This terminology is not encouraged because it is inaccurate: the objective is the capture of carbon dioxide and not the capture of carbon. Tree plantation is another form of carbon capture that does not describe precisely the physical process of removing CO₂ from industrial emission sources.

Note 2 to entry: The term "sequestration" is also used alternatively to "storage". The term "storage" is preferred since "sequestration" is more generic and can also refer to biological processes (absorption of carbon by living organisms).

Note 3 to entry: Long term means the minimum period necessary for geological storage of CO₂ to be considered an effective and environmentally safe climate change mitigation option.

Note 4 to entry: The term carbon dioxide capture, utilization (or use) and storage (CCUS) includes the concept that isolation from the atmosphere can be associated with a beneficial outcome. CCUS is embodied within the definition of CCS to the extent that long term isolation of the CO₂ occurs through storage within geological formations. CCU is carbon capture and utilization (or use) without storage within geological formations.

Note 5 to entry: CCS should also ensure long term isolation of CO₂ from oceans, lakes, potable water supplies and other natural resources.

[SOURCE: ISO 27917:2017, 3.1.1]

3.1.9

carbon dioxide loading

CO₂ loading

quantity of carbon dioxide absorbed in a specific amount of absorption liquids

Note 1 to entry: Carbon dioxide loading may be expressed in units of moles of CO₂ per mole of *absorbent* (3.1.1) (mol·mol⁻¹) or moles of CO₂ per kilogram of absorption liquid (mol·kg⁻¹).

3.1.10

CO₂ absorption capacity

maximum quantity of carbon dioxide absorbed in a specific amount of absorption liquids in a vapor liquid equilibrium state, under a certain temperature and CO₂ partial pressure

3.1.11

CO₂ flux

rate of CO₂ absorption (3.1.13) or mass transfer per unit area, which is linked to the concentration or partial pressure driving force for absorption or mass transfer

Note 1 to entry: CO₂ flux is expressed in mol·s⁻¹·m⁻².

3.1.12

chemical absorption

process in which CO₂ is absorbed by chemical reaction

[SOURCE: ISO 27919-1:2018, 3.1.8]

3.1.13

CO₂ absorption

process through which CO₂ is separated from the feed gas through contact with absorption liquids

3.1.14

CO₂ desorption

process through which absorption liquids release CO₂ after changing the conditions of the liquid (e.g. temperature, pressure)

3.1.15

cyclic loading

net quantity of CO₂ produced from a complete absorption and desorption cycle in a specific amount of absorption liquids

Note 1 to entry: The value of cyclic loading equals to the *CO₂ loading* ([3.1.9](#)) after absorption minus the CO₂ loading after desorption.

Note 2 to entry: Cyclic loading may be expressed in units of moles of CO₂ per mole of *absorbent* ([3.1.1](#)) (mol·mol⁻¹) or moles of CO₂ per kilogram of absorption liquid (mol·kg⁻¹).

3.1.16

mass density

ρ

common density (mass per unit volume)

Note 1 to entry: The unit of the mass density is kg·m⁻³ (or g·cm⁻³).

[SOURCE: ISO 16413:2020, 3.1.19]

3.1.17

dynamic viscosity

viscosity

η

ratio between the applied shear stress and rate of shear of a liquid

Note 1 to entry: It is a measure of the resistance to flow or deformation of a liquid.

Note 2 to entry: The term dynamic viscosity is also used in a different context to denote a frequency-dependent quantity in which shear stress and shear rate have a sinusoidal time dependence.

Note 3 to entry: Dynamic viscosity is expressed in pascal multiplied by seconds (Pa·s).

[SOURCE: ISO 3104:2023, 3.2, modified — Note 3 to entry has been replaced.]

3.1.18

heat of absorption

change of enthalpy in absorption liquids resulting from the absorption process

Note 1 to entry: The heat of absorption is often expressed in kJ·mol⁻¹ CO₂, or kJ·kg⁻¹ CO₂.

3.1.19

lean liquid

absorption liquid with a lower *carbon dioxide loading* ([3.1.9](#)) after the carbon dioxide desorption process

3.1.20

measurement uncertainty

uncertainty of measurement

uncertainty

non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

Note 1 to entry: Measurement uncertainty includes components arising from systematic effects, such as components associated with corrections and the assigned quantity values of physical properties, as well as the definitional uncertainty. Sometimes estimated systematic effects are not corrected for; associated measurement uncertainty components are incorporated.

Note 2 to entry: The parameter may be, for example, a standard deviation called standard measurement uncertainty (or a specified multiple of it), or the half-width of an interval, having a stated coverage probability.

Note 3 to entry: Measurement uncertainty comprises, in general, many components. Some of these may be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from a series of measurements and can be characterized by standard deviations. The other components, which may be evaluated by Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

Note 4 to entry: In general, for a given set of information, it is understood that the measurement uncertainty is associated with a stated quantity value attributed to the measurand. A modification of this value results in a modification of the associated uncertainty.

Note 5 to entry: “Type A evaluation of measurement uncertainty” is an evaluation of a component of measurement uncertainty by a statistical analysis of measured quantity values obtained under defined measurement conditions. “Type B evaluation of measurement uncertainty” is an evaluation of a component of measurement uncertainty determined by means other than a Type A evaluation of measurement uncertainty”.

[SOURCE: ISO/IEC Guide 99:2007, 2.26, modified — “measurement standards” has been changed to “physical properties” in Note 1 to entry and Note 5 to entry has been added.]

3.1.21

partial pressure

pressure due to a specified component of a gaseous mixture

Note 1 to entry: Partial pressure is expressed in pascal (Pa).

[SOURCE: ISO 3529-1:2019, 3.1.5, modified — Note 1 to entry has been added.]

3.1.22

pH

measure of the activity of the hydrogen ion

Note 1 to entry: Essentially, pH is a measure of acidity or *alkalinity* ([3.1.7](#)).

[SOURCE: ISO/IEEE 11073-10422:2017, 3.1.17, modified — the definition has been split into the definition and Note 1 to entry.]

3.1.23

rich liquid

absorption liquid with a higher *carbon dioxide loading* ([3.1.9](#)) after the carbon dioxide absorption process

3.1.24

specific heat capacity

amount of energy required to raise 1 kg of material by the temperature of 1 K

Note 1 to entry: The specific heat capacity is expressed in $\text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$.

3.1.25

thermal conductivity

quotient of the amount of heat flow per unit of time through a unit of surface area perpendicular to the heat flow in a solid material, divided by the temperature difference per unit length (temperature gradient)

Note 1 to entry: The SI unit of thermal conductivity is $\text{W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$.

[SOURCE: ISO 4825-1:2023, 3.3]

3.1.26

volatility

tendency of a substance to evaporate

Note 1 to entry: The volatility of an *absorbent* (3.1.1) is often expressed as the Henry's law constant which represents the vapor-liquid partition of the absorbent in terms of the ratio of the vapor pressure to its liquid mole fraction at a given temperature.

Note 2 to entry: Volatility is expressed in pascal (Pa).

3.2 Abbreviated terms

CCS carbon dioxide capture and storage

PCC post-combustion CO_2 capture

3.3 Symbols

The following mathematical symbols are preparatory for revising variables and formulae in [Clause 4](#) based on the ISO directives and relevant standards.

α	Carbon dioxide loading per mole of absorbent	$\text{mol}\cdot\text{mol}^{-1}$
α'	Carbon dioxide loading per kilogram of absorption liquid	$\text{mol}\cdot\text{kg}^{-1}$
α_{lean}	Carbon dioxide loading per mole of absorbent of the lean absorption liquid	$\text{mol}\cdot\text{mol}^{-1}$
α'_{lean}	Carbon dioxide loading per kilogram of absorption liquid of the lean absorption liquid	$\text{mol}\cdot\text{kg}^{-1}$
α_{rich}	Carbon dioxide loading per mole of absorbent of the rich absorption liquid	$\text{mol}\cdot\text{mol}^{-1}$
α'_{rich}	Carbon dioxide loading per kilogram of absorption liquid of the rich absorption liquid	$\text{mol}\cdot\text{kg}^{-1}$
$\Delta\alpha$	Cyclic loading of CO_2 per mole of absorbent	$\text{mol}\cdot\text{mol}^{-1}$
$\Delta\alpha'$	Cyclic loading of CO_2 per kilogram of absorption liquid	$\text{mol}\cdot\text{kg}^{-1}$
c_p	Specific heat capacity	$\text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$
ρ	Density	$\text{kg}\cdot\text{m}^{-3}$
η	Dynamic viscosity	$\text{Pa}\cdot\text{s}$
λ	Thermal conductivity	$\text{W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$
γ_{abs}	Absorbent activity coefficient at the reference state of infinite dilution of absorbent in absorption liquid	—
γ_{lossrate}	Absorbent loss rate	$\text{kg}\cdot\text{tonne}^{-1}$

C_{abs}	Absorbent concentration in molar	$\text{mol}\cdot\text{l}^{-1}$
C'_{abs}	Absorbent concentration in mass fraction	$\text{kg}\cdot\text{kg}^{-1}$
D_{CO_2}	Diffusion coefficient of CO_2 in absorption liquid	$\text{m}^2\cdot\text{s}^{-1}$
d_h	Hydraulic diameter of the mass transfer measurement device	m
ΔH	Heat of absorption	$\text{kJ}\cdot\text{mol}^{-1} \text{CO}_2$
$\Delta H'$	Heat of absorption	$\text{kJ}\cdot\text{kg}^{-1} \text{CO}_2$
H_{abs}	Henry's law volatility constant	Pa
k_g	Gas-side mass transfer coefficient	$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$
k'_g	Liquid-side mass transfer coefficient	$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$
K_G	Overall mass transfer coefficient	$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$
m_{abs}	Mass of absorbent in absorption liquid	kg
m_l	Mass of absorption liquid	kg
$m_{\text{CO}_2}^l$	Mass of CO_2 absorbed in absorption liquid	kg
$m_{\text{CO}_2(\text{eq})}^l$	Mass of CO_2 absorbed at equilibrium	kg
m_{CO_2}	Mass of CO_2 produced	tonne
m_{final}	Mass of absorbent in absorption liquid after a period of PCC operation	kg
m_{initial}	Mass of absorbent in absorption liquid at the start of measurement in PCC operation	kg
N_{CO_2}	CO_2 flux	$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$
$n_{\text{CO}_2}^l$	Amount of moles of CO_2 absorbed in liquid phase	mol
$n_{\text{CO}_2\text{lean}}^l$	Amount of moles of CO_2 absorbed in liquid phase in the lean absorption liquid	mol
$n_{\text{CO}_2\text{rich}}^l$	Amount of moles of CO_2 absorbed in liquid phase in the rich absorption liquid	mol
$n_{\text{CO}_2(\text{eq})}^l$	Amount of moles of CO_2 absorbed in liquid phase at equilibrium	mol
n_{abs}	Total amount of moles of absorbent in absorption liquid	mol
P_{abs}	Partial pressure of an absorbent in vapour phase	Pa
$P_{\text{CO}_2, \text{g}}$	CO_2 partial pressure in the gas phase	Pa
$P_{\text{CO}_2}^*$	Equilibrium CO_2 partial pressure of the absorption liquid	Pa
Q	Amount of heat produced in the absorption liquid in the CO_2 absorption process	kJ
R	Universal gas constant	$\text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$
S_h	Sherwood number	—
T	Temperature	K

V_l	Volume of absorption liquid without CO ₂ absorbed	l
x_{abs}	Mole fraction of unreacted absorbents in absorption liquid	—
X	Absorption capacity in moles per kilogram of absorption liquid	mol·kg ⁻¹
X'	Absorption capacity in kilograms per kilogram of absorption liquid	kg·kg ⁻¹

4 Evaluation of performance parameters

4.1 General

[Clause 4](#) provides the key performance parameters of absorption liquids used in PCC applications.

The key performance parameters of absorption liquids are as follows.

- a) The primary performance parameters are those derived directly from measurements:
 - rich and lean CO₂ loading;
 - absorbent concentration;
 - absorption capacity;
 - heat of absorption;
 - absorption rate;
 - absorbent volatility.
- b) The secondary performance parameters are those derived from primary parameters:
 - cyclic loading;
 - absorbent loss rate.
- c) The primary and secondary parameters are essential for characterizing absorption liquids used in PCC. Characterization of the absorption liquid also includes the following physical and chemical properties, which are dependent on CO₂ loading and absorbent concentration:
 - density;
 - viscosity;
 - specific heat capacity;
 - thermal conductivity;
 - pH.

A block diagram demonstrating the key performance parameters and properties considered in this work and their application is shown in [Figure 1](#). The parameters are used in research and development in laboratories, and field testing at PCC plants.

Field testing demonstrates both the long-term performance of absorption liquids within the PCC process and ultimately validates a novel CO₂ capture technology utilizing these absorption liquids. Monitoring the following parameters and properties are useful in field testing:

- rich and lean CO₂ loading;
- absorbent concentration;
- absorbent volatility;

- cyclic loading;
- absorbent loss rate;
- pH;
- density;
- viscosity.

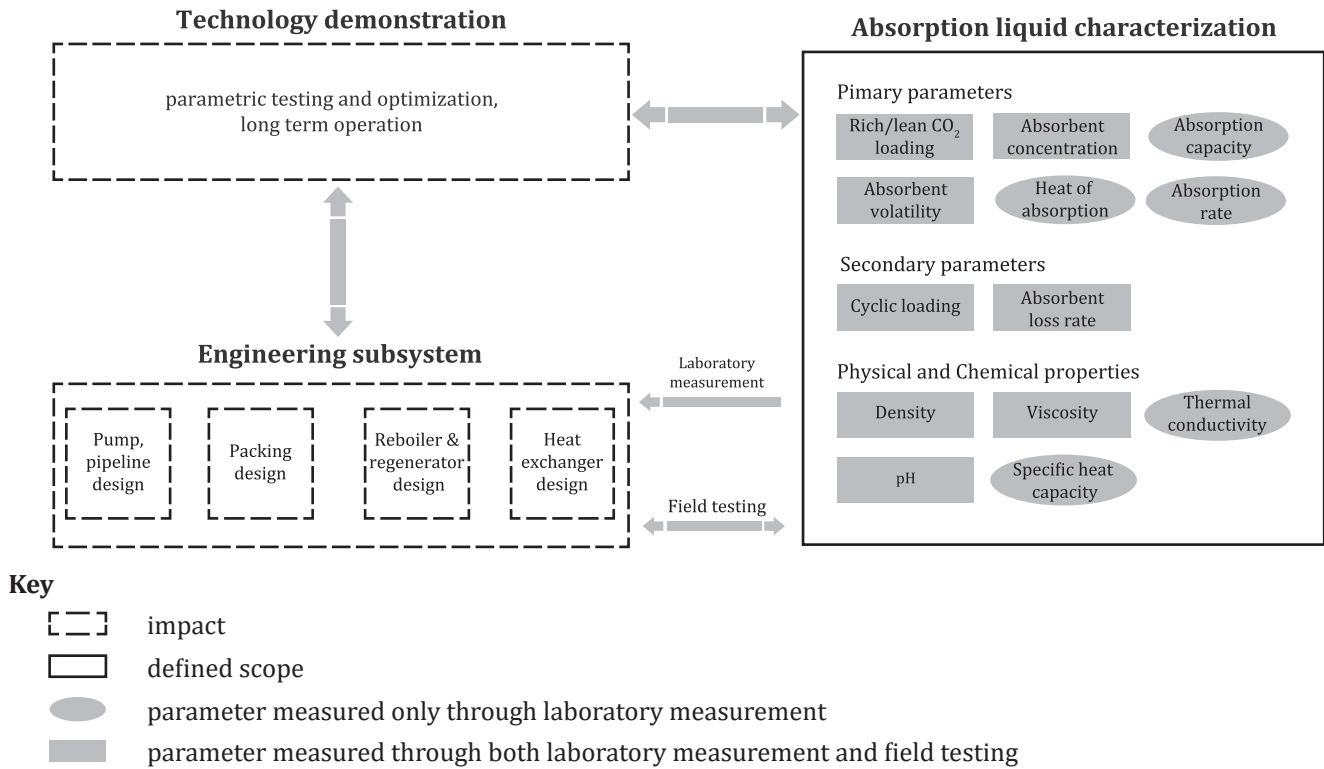


Figure 1 — Block diagram of key performance parameters of absorption liquids considered in this document (in the solid frame)

NOTE The rectangular block with grey fill indicates parameters that can be measured through both the laboratory measurement and field testing. The oval block with grey fill indicates parameters that can be measured solely through the laboratory measurement. Long term operation usually refers to field testing campaigns lasting a minimum period of 1 000 hours.

4.2 Primary performance parameters

4.2.1 Rich and lean CO₂ loading

The carbon dioxide loading (CO₂ loading) α [mol·mol⁻¹], is defined as the ratio of moles of all CO₂ absorbed to the moles of absorbent in absorption liquid:

$$\alpha = \frac{n_{\text{CO}_2}^{\text{l}}}{n_{\text{abs}}} \quad (1)$$

where

$n_{\text{CO}_2}^{\text{l}}$ is the total number of moles of CO₂ absorbed in a specific amount of absorption liquid [mol];

n_{abs} is total number of moles of absorbent in a specific amount of absorption liquid [mol].

When information about the composition and concentration of the absorption liquid is unknown or undisclosed, the CO₂ loading can also be expressed as α' [mol·kg⁻¹], which is the ratio of moles of all CO₂ absorbed to the mass of the absorption liquid. This mass includes both the absorbent and solvent, such as water or other non-reactive substances.

$$\alpha' = \frac{n_{\text{CO}_2}^{\text{l}}}{m_{\text{l}}} \quad (2)$$

where m_{l} is the mass of absorption liquid [kg].

When complete information on an absorption liquid, including its composition and concentration, is difficult to obtain, the alkalinity of the absorption liquid can serve as an alternative indicator of absorbent concentration. This approach is introduced in [Clause D.2](#).

The rich CO₂ loading α_{rich} [mol·mol⁻¹] or α'_{rich} [mol·kg⁻¹] is defined as the CO₂ loading after the CO₂ absorption process. In the laboratory measurement, and field testing at a PCC plant as shown in [Figure A.1](#), the rich CO₂ loading can be obtained from the measurement of a liquid sample taken at the solvent stream flowing out from the absorber bottom:

$$\alpha_{\text{rich}} = \frac{n_{\text{CO}_2\text{rich}}^{\text{l}}}{n_{\text{abs}}} \quad (3)$$

$$\alpha'_{\text{rich}} = \frac{n_{\text{CO}_2\text{rich}}^{\text{l}}}{m_{\text{l}}} \quad (4)$$

where $n_{\text{CO}_2\text{rich}}^{\text{l}}$ is the total number of moles of CO₂ absorbed in a specific amount of absorption liquid after CO₂ absorption [mol].

The lean CO₂ loading α_{lean} [mol·mol⁻¹] or α'_{lean} [mol·kg⁻¹] is defined as the CO₂ loading after the CO₂ desorption process. In the laboratory measurement, and field testing at a PCC plant, as shown in [Figure A.1](#), the lean CO₂ loading is obtained from the measurement of a liquid sample taken at the solvent stream flowing out from the desorber bottom:

$$\alpha_{\text{lean}} = \frac{n_{\text{CO}_2\text{lean}}^{\text{l}}}{n_{\text{abs}}} \quad (5)$$

$$\alpha'_{\text{lean}} = \frac{n_{\text{CO}_2\text{lean}}^{\text{l}}}{m_{\text{l}}} \quad (6)$$

where $n_{\text{CO}_2\text{lean}}^{\text{l}}$ is the total number of moles of CO₂ absorbed in a specific amount of absorption liquid after CO₂ desorption [mol].

See [Annex A](#) for additional information on the sampling of absorption liquid for rich and lean CO₂ loading measurements. The characterization methods for evaluating rich, lean and other CO₂ loadings are provided in [Annex C](#) for further information.

4.2.2 Absorbent concentration

The absorbent concentration is a key parameter monitored during the commissioning and operation of PCC plants. The absorbent concentration can be expressed in terms of molar concentration or mass fraction.

The absorbent concentration in molarity C_{abs} [mol·l⁻¹], is defined as the ratio of moles of absorbent to the volume of absorption liquid, which includes both the absorbent and solvent, such as water or other non-reactive substances:

$$C_{\text{abs}} = \frac{n_{\text{abs}}}{V_1} \quad (7)$$

where V_1 is the volume of absorption liquid without CO₂ absorbed [l].

The absorbent concentration in mass fraction C'_{abs} [kg·kg⁻¹], is defined as the ratio of mass of absorbent to the mass of absorption liquid:

$$C'_{\text{abs}} = \frac{m_{\text{abs}}}{m_1} \quad (8)$$

where m_{abs} is the mass of absorbent in absorption liquid [kg].

In addition, see [Annex A](#) for information on the sampling of absorption liquid for absorbent concentration measurement. [Annex D](#) provides absorbent concentration characterization methods, including the alkalinity method, total organic carbon method, ion chromatography and liquid chromatography with mass spectrometry.

4.2.3 CO₂ absorption capacity

The CO₂ absorption capacity X [mol·kg⁻¹] of absorption liquids refers to the moles of CO₂ absorbed in a certain mass of absorption liquid, under conditions of CO₂ partial pressure and temperature, when gas and liquid phases reach equilibrium:

$$X = \frac{n_{\text{CO2(eq)}}^1}{m_1} \quad (9)$$

where $n_{\text{CO2(eq)}}^1$ is the number of moles of CO₂ absorbed in the liquid phase when the gas and liquid phases reach equilibrium [mol].

The absorption capacity can also be expressed as X' [kg·kg⁻¹] absorption liquid:

$$X' = \frac{m_{\text{CO2(eq)}}^1}{m_1} \quad (10)$$

where $m_{\text{CO2(eq)}}^1$ is the mass of CO₂ absorbed in absorption liquid when the gas and liquid phases reach equilibrium [kg].

The characterization method using a vapour-liquid equilibrium apparatus in the laboratory for measuring CO₂ absorption capacity is provided in [Annex E](#) for further information.

4.2.4 Heat of absorption

The heat of absorption ΔH (kJ·mol⁻¹) or $\Delta H'$ (kJ·kg⁻¹), is the total amount of heat produced per unit of CO₂ absorbed during the CO₂ absorption reaction. The value of heat of absorption can vary depending on the CO₂ loading.

$$-\Delta H = \frac{Q}{m_{\text{CO2}}^1} \times 0,044 \quad (11)$$

$$-\Delta H' = \frac{Q}{m_{\text{CO}_2}^1} \quad (12)$$

where

Q is the amount of heat produced in absorption liquid in the CO_2 absorption process [kJ];

$m_{\text{CO}_2}^1$ is the mass of CO_2 absorbed in absorption liquid [kg].

The characterization methods for evaluating the heat of absorption are provided in [Annex F](#) for further information.

4.2.5 Absorption rate

The absorption rate of CO_2 in the absorption liquid can be represented by the liquid-side mass transfer coefficient k'_g [$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$], which represent the liquid-side mass transfer concentration driving force.

The value of k'_g can vary under different CO_2 loadings and temperatures. It relates to the overall mass transfer coefficient K_G and gas-side mass transfer coefficient k_g as follows:

$$\frac{1}{k'_g} = \frac{1}{K_G} - \frac{1}{k_g} \quad (13)$$

where

K_G is the overall mass transfer coefficient, which incorporates the processes of physical and chemical absorption of CO_2 in absorption liquid [$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$];

k_g is the gas-side mass transfer coefficient, representing gas-side mass transfer concentration driving force [$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}\cdot\text{Pa}^{-1}$].

$$K_G = \frac{N_{\text{CO}_2}}{(P_{\text{CO}_2,\text{g}} - P_{\text{CO}_2}^*)_{\log \text{ mean}}} \quad (14)$$

where

N_{CO_2} is the CO_2 flux [$\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$];

$P_{\text{CO}_2,\text{g}}$ is the CO_2 partial pressure in the gas phase [Pa];

$P_{\text{CO}_2}^*$ is the equilibrium CO_2 partial pressure in the absorption liquid at the measured temperature and CO_2 gas phase pressure conditions [Pa].

k_g is calculated using:

$$k_g = \frac{S_h \times D_{\text{CO}_2}}{R \times T \times d_h} \quad (15)$$

where

S_h is the Sherwood number;

D_{CO_2} is the diffusion coefficient of CO_2 in absorption liquid [$\text{m}^2\cdot\text{s}^{-1}$];

R is the universal gas constant [$\text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$];

T is the temperature [K];

d_h is the hydraulic diameter of the mass transfer measurement device [m].

The characterization methods for evaluating k'_g are provided in [Annex G](#) for further information.

4.2.6 Absorbent volatility

The absorbent volatility describes the tendency for the absorbent to evaporate from the absorption liquid at a given temperature. It is determined by the vapour-liquid partitioning of the absorbent. The Henry's Law volatility constant (H_{abs} , expressed in Pa) is a primary indicator of absorbent volatility, which is referenced to the state of infinite dilution of absorbent in absorption liquid. H_{abs} is expressed as the ratio of absorbent vapour pressure to the unreacted absorbent mole fraction in the absorption liquid. The Henry's law constant is referenced to the state of infinite dilution of absorbent in absorption liquid at a given temperature:

$$H_{\text{abs}} = \frac{P_{\text{abs}}}{x_{\text{abs}} \times \gamma_{\text{abs}}} \quad (16)$$

where

P_{abs} is the vapour pressure of absorbent over absorption liquid at a given temperature [Pa];

x_{abs} is the mole fraction of unreacted absorbents in absorption liquid, typically present in a dilute concentration;

γ_{abs} is the absorbent activity coefficient defined at the reference state of infinite dilution of absorbent in absorption liquid.

NOTE The activity coefficient used in [Formula \(16\)](#) to account for the deviation of a mixture of chemical substances from the ideal behaviour can be found in ISO 80000-9.

At dilute absorbent concentrations, the absorbent activity coefficient is close to unity. Therefore, the Henry's Law volatility constant can be evaluated as follows:

$$\lim_{x_{\text{abs}} \rightarrow 0} H_{\text{abs}} = \frac{P_{\text{abs}}}{x_{\text{abs}}} \quad (17)$$

The characterization methods for evaluating H_{abs} are provided in [Annex H](#) for further information.

4.3 Secondary performance parameters

4.3.1 Cyclic loading

The cyclic loading of CO₂ in absorption liquid $\Delta\alpha$ [mol·mol⁻¹] as the ratio of moles of all CO₂ absorbed to the moles of absorbent in absorption liquid, or $\Delta\alpha'$ [mol·kg⁻¹] as the ratio of moles of all CO₂ absorbed to the mass of the absorption liquid, is calculated based on the difference of the CO₂ loading in the rich liquid and that in the lean liquid. The cyclic loading of absorption liquid is dependent on the properties of absorption liquid and process configuration of a PCC plant.

$$\Delta\alpha = \alpha_{\text{rich}} - \alpha_{\text{lean}} \quad (18)$$

Or

$$\Delta\alpha' = \alpha'_{\text{rich}} - \alpha'_{\text{lean}} \quad (19)$$

4.3.2 Absorbent loss rate

The absorbent loss rate γ_{lossrate} [kilogram per tonne⁻¹ of CO₂] is calculated by a decrease in the absorbent amount during an operation period of the PCC plant for producing a certain amount of CO₂ (m_{CO_2}). A mass of

absorbent means the amount of active absorbent, obtained by subtracting water, degraded absorbents, other byproducts or non-reactive substances from the absorption liquid inventory:

$$\gamma_{\text{lossrate}} = \frac{m_{\text{initial}} - m_{\text{final}}}{m_{\text{CO}_2}} \quad (20)$$

where

m_{initial} is the mass of absorbent in absorption liquid inventory at the start of the measurement period of PCC plant operation [kg];

m_{final} is the mass of absorbent in absorption liquid inventory at the end of measurement period of PCC plant operation [kg];

m_{CO_2} is the mass of CO₂ produced in a measurement period of PCC plant operation [tonne].

NOTE 1 The absorbent loss in PCC processes can result from multiple mechanisms. These include the intrinsic properties of the absorbent, such as susceptibility to oxidative degradation, thermal degradation, emissions etc. Additionally, factors related to process and equipment setup, as well as operational and maintenance activities, result in non-negligible consumption of absorbent in the absorption liquid inventory.

NOTE 2 During the measurement period, operational and maintenance activities that cause substantial absorbent loss, such as filter exchange, pump maintenance, etc., are not implemented.

4.4 Physical and chemical properties

The density (ρ), viscosity (η), thermal conductivity (λ), specific heat capacity (c_p) of absorption liquids are physical properties. The pH of absorption liquid is a physico-chemical property. These five properties, which are important in laboratory measurements and field testing, have been carefully selected. They are related to the chemical reactions involved in CO₂ capture, CO₂ mass transfer between gas and liquid phases, absorption liquid circulation, heating and cooling, and other relevant processes.

Besides temperature and pressure, it is noted that the values of physical and chemical properties are dependent on CO₂ loading and absorbent concentration.

Their measurement methods can be found in the relevant standards as detailed in [Annex I](#). The methods for density measurement are outlined in ISO 15212-1 and ISO 15212-2, ISO 3507, ISO 387 and ISO 10790. The methods for viscosity measurement are outlined in ISO 12058-1, ISO 2555, ISO 6721-10 and ISO 1628-1. The methods for thermal conductivity measurement are outlined in ISO 22007-2 and ISO 22007-3. The methods for specific heat capacity measurement are outlined in ISO 11357-4, ASTM E2716-23 and ASTM E1269-11. The method for pH measurement is outlined in ISO 10523. Additional information on the sampling of absorption liquid for measurement can be found in [Annex A](#).

5 General for the characterization of absorption liquids

5.1 Laboratory measurements and field testing

Laboratory measurement refers to the process of obtaining quantitative data through experimental procedures conducted in a controlled environment, typically a laboratory. This process involves using specialized instruments and techniques, to assess and quantify performance parameters, physical and chemical properties of the absorption liquid.

NOTE Laboratories conforming with ISO/IEC 17025 are considered competent.

Field testing refers to the process of evaluating either the performance parameters or the physical and chemical properties, or both, of the absorption liquid in a pilot or demonstration scale operational environment, such as with real flue gas, rather than in a laboratory setting.

5.2 General requirement

The characterization methods for laboratory measurement and field testing should be designed with the appropriate goal in mind to ensure that proper procedures achieve the required operating mode. The following actions should be either considered or conducted, or both, during laboratory measurement and field testing:

- a) **Impartiality:** Activities relating to laboratory measurement and field testing shall be undertaken impartially and structured and managed so as to safeguard impartiality.
- b) **Scope:** Items relating to the laboratory measurement and field testing should be defined in advance. These should include specific objectives, personnel, schedule and characterization methods, including the method and procedure, equipment and reporting.
- c) **Personnel:** The responsibilities of personnel and the organization conducting the laboratory measurement or field testing should be agreed upon by the relevant parties. Representatives of all parties involved should be present to verify that activities are conducted according to the procedure and guidelines.
- d) **Schedule:** The schedule of activity and the detail of laboratory measurement and field testing procedures should be agreed upon by the relevant parties as early as practically possible.
- e) **Characterization method:** Procedures of the characterization method should be prepared and agreed upon by the relevant parties before beginning either the laboratory measurement or field testing, or both. Sufficient time should be provided for the selection of characterization methods, where appropriate. Verification and validation of methods and procedures should be carried out as extensively as necessary to meet the needs of laboratory measurement and field testing activities.
- f) **Deviation:** Any deviation from the laboratory measurement or field testing method and procedure should be identified and recorded. The involved parties should agree on a resolution for each recorded deviation to avoid aborting the test run.
- g) **Uncertainty:** Uncertainty analysis prior to the laboratory measurement or field testing should be confirmed. This includes evaluating all deviations of the parameters derived from measured values according to JCGM 100. Target uncertainty agreement can be ensured by selecting the instruments with the appropriate accuracy grade and confirming the accuracy grade of each instrument system.

NOTE 1 For further information on measurement uncertainty, see ISO/IEC Guide 98-3, ISO 21748, ISO 5725-1, ISO 5725-2, ISO 5725-3, ISO 5725-4 and ISO 5725-6.

- h) **Reporting:** The results of laboratory measurement or field testing shall be provided accurately, clearly, unambiguously and objectively, typically in a report format. The report shall include all information agreed upon with the customer, necessary for the interpretation of the results, and required by the method used. All issued reports shall be retained as technical records.
- i) **Location for field testing:** The location for field testing should be determined at the design stage, and selected to provide the lowest level of measurement uncertainty. The preferred location is at the test boundary, but it is possible to move the location if it is the best place for determining the required parameters.
- j) **Reference condition for field testing:** All effort should be made to conduct the field testing as close as possible to the reference conditions of the plant. The reference condition is defined by the plant operator as a stable operating condition of the power plant (or other plant) with the rated load operation or the ordinary load operation. Operating parameters should be within the ranges considered within the 'Allowable maximum deviation from plant reference conditions' column.

NOTE 2 ISO 27919-1 provides general requirements of the reference condition for field testing.

The results of the laboratory measurement and field testing can be used to evaluate the key performance parameters defined in [Clause 4](#). Additional information on the general requirements of measurements can be found in ISO 27919-1.

6 Instrument and characterization methods

6.1 General

This clause presents the requirements for the instrumentation to be installed or used in the laboratory measurement and field testing at a PCC plant. It provides guidelines for the measurement methods listed in the Annexes.

The recommended instrumentation can become more rigorous and accurate as technology advances. Under the mutual agreement of all parties involved in the tests, more advanced instruments may supersede the recommended instruments, providing that the application of such instruments have demonstrated accuracy and reliability.

The sampling points in the PCC plant for the characterization of key performance parameters are summarized in [Annex A](#).

Instrument and characterization methods should be selected and defined according to internationally recognized practices. Examples of such practices are provided in [Annexes B](#) to [I](#).

6.2 Instrument classification

Instruments are classified according to how the measured variables are used and how they affect the final results:

- a) primary variables: these are variables used in calculations of test results; they are further classified into:
 - class 1 primary variables: those which have a relative sensitivity coefficient of 0,2 % or greater, requiring more accurate instruments with more redundancy than Class 2;

NOTE The relative sensitivity coefficient is defined as a relative change in the result divided by the relative change in a parameter (or variable) evaluated near a desired testing point and expressed as a percentage.

 - class 2 primary variables: those which have a relative sensitivity coefficient of less than 0,2 %;
- b) secondary variables: variables that are measured but do not enter into the calculation of the test results; they are measured throughout a test period to ensure that the required test condition was not violated.

6.3 Calibration of instrument

Primary instrumentation calibration should be performed before the test. Calibration guidelines are referred to in the Annexes for the characterization methods of relevant performance parameters. Any calibration after the test is decided under mutual agreement between the parties involved during the test. The degree of calibration is chosen in reasonable relationship with the influence of the reading based on the instrument classification.

6.4 Evaluation of measurement uncertainty

The measurement of each quantity used for the calculation of the laboratory measurement or field testing result is subject to some degree of error, and the result is subject to a degree of uncertainty depending on the combined effect of measurement uncertainties as indicated in ISO/IEC Guide 98-3:2008, 5.1.3.

The measuring uncertainty and calculation procedure of the overall test result uncertainty should be clearly reported, including all inputs and assumptions, formulation, and calculation procedure. The measuring uncertainty and the overall test results uncertainties can be calculated from the uncertainties of the individual measurement as per ISO/IEC Guide 98-3, ISO/IEC 17025, ISO 21748 and the referred standards for instrumentation and measurements of this document.

For pre-test uncertainty analysis, the level of uncertainty for each individual measurement needs to be chosen in a reasonable relationship with the influence of the reading based on the overall uncertainty requirement and instrument classification.