FORCE Technology

Technical report

Quality control of automatic monitoring systems on carbon capture plants

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Summary

The industry for carbon capture, utilisation and storage (CCUS) is experiencing rapid development, and this has created an increasing need for reliable and continuous monitoring of the quality and purity of the captured CO_2. While the recipients of captured CO_2 have established specifications for impurity concentrations, there is currently no internationally recognised framework describing how monitoring systems used for CO_2 quality measurements should be quality assured.

This technical report proposes a framework for quality control of monitoring systems used on carbon capture plants by adapting principles and procedures from the established field of air emissions monitoring. In particular, the report draws upon the quality assurance approach described in EN 14181 and related standards.

The report identifies key considerations for monitoring locations, sampling systems and monitoring equipment, emphasising the challenges associated with measuring impurities in pressurised and liquefied CO_2 streams. Recommendations are provided regarding representative sampling, pressure reduction systems, equipment suitability and uncertainty evaluation.

The proposed framework aims to support confidence in measurement results, facilitate transparency throughout the CCUS value chain and contribute to the development of future standards and best practices for CO_2 quality monitoring.

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Abbreviations

AMS	Automated Measuring System. Measuring system permanently installed on site for continuous monitoring of emissions or measurement of peripheral parameters.
AST	Annual Surveillance Test. Yearly test of AMS to ensure that the calibration function used is still valid.
CEMS	Continuous Emissions Monitoring System. Another term for AMS. This expression is more often used outside Denmark.
GC	Gas chromatograph
MPU	Maximum permissible uncertainty
SRM	Standard Reference Method. Reference measurement method prescribed by European or national legislation.
QAL1	Quality Assurance Level 1. Quality assurance of the specific monitoring equipment. It is accomplished as a type-approval.
QAL2	Quality Assurance Level 2. Determination of calibration functions for the individual parameters after installation of AMS on a plant.
QAL3	Quality Assurance Level 3. The plant’s continuous control of the installed AMS.

Introduction

The growing industry for carbon capture, utilisation and storage (CCUS) has created an increasing demand for quantitative purity measurements of the captured CO_2 along with procedures for conducting effective quality control.

The CCUS industry is a constantly evolving industry in which relevant standards, procedures and methods are developed and published rapidly. However, the CCUS industry lacks standards which describe the procedure for performing quality control of automatic monitoring systems (AMS) of the captured CO_2 from a carbon capture plant. This calls for a standard or guideline, as recipients of the captured CO_2 require assurance for a certain level of purity, as outlined in the different CO_2 specifications (Table 1, Appendix A).

Within the focus area of emissions to air, well-established standards and procedures for quality control of automatic monitoring systems (described in EN 14181) exist, including national implementation guidelines (e.g. the Danish method implementation document, MEL-16 [1], [2]). EN 14181 clearly describes the requirements for four levels of Quality Assurance (QAL1, QAL2, QAL3 and AST), as briefly described in the box below, along with Standard Reference Methods (SRM) applied to control and calibration of the AMS.

Brief description of the four levels of Quality Assurance. For a more detailed description, see Appendix B Table 2.

Quality Level	Description
QAL	Includes three levels of quality assurance (QAL1, QAL2, QAL3). Covers certification and documentation that the AMS can meet the maximum permissible uncertainty (MPU), calibration of the AMS, along with ongoing quality control of the AMS.
AST	Annual verification of the calibration function and measurement performance

The main difference between the CCUS industry and the area of emission control is that within the area of emission control, the limiting values are set by the relevant environmental authorities, while the required purity levels of the captured CO_2 are set by the CCUS industry itself, e.g. the recipients, and currently not by an authority. This document only considers the purity of the captured CO_2 and does not focus on the emissions from the carbon capture plant.

The aim of this technical report is to provide relevant stakeholders, such as plant owners, operators of infrastructure, technology suppliers and recipients of CO_2, with a suggestion for a potential procedure for performing quality control of AMS for CO_2 related to existing standards. The document outlines the current situation and describes how a system for quality control can be constructed to minimise risks in the continuous operation of the CCUS-value chain and thereby minimise the uncertainties currently related to the industry. This technical report concerns continuous measurements of the captured CO_2 and should be seen as a proposal on how to incorporate third-party measurements to ensure the quality of the installed monitoring equipment controlling the quality of the captured CO_2. This proposal is highly based on the standards and methods already established for industrial plants with AMS installed.

The work with this technical report is embedded in the research and development project: “Denmark as a CO_2 Hub – Scaling and market development” co-financed by performance contract funds from the Danish Agency of Higher Education and Science, as a part of coupling the potential needs for the growing industry.

The report contains references to a variety of standards and method implementation documents, and Table 3 in Appendix C presents an overview of the standards used, along with brief descriptions of their contents.

Third-party verification

Currently, there is no European or international standard describing quality assurance of monitoring equipment for monitoring the quality of the captured CO_2 from carbon capture plants or along the CCUS-value chain. The need for quality assurance of the instrumentation used to determine the captured CO_2 quality is mentioned in several of the standards concerning CO_2 capture and transport, e.g. ISO 27913, but without mentioning details describing the process of quality assurance. Two recently updated standards (ISO 27928 and ISO 27929) mention third-party verification of CO_2 cargo transported by ship, along with a potential requirement for quality certificates and periodic quality control of monitoring equipment [3], [4]. ISO 27928 further presents methods applicable for conducting performance tests of the monitoring systems [3].

Air emissions are highly regulated, and methods are specified by authorities and international standards, which, in this case, can serve as inspiration when proposing control and monitoring systems for the quality of the captured CO_2. The international standards related to quality assurance of AMS for emissions to air are: EN 14181, EN 15267-3, EN/ISO 14956, EN 13284-2, EN 16911-2, EN 17255-1, EN 17255-4, EN 14884 and ISO 15259. These standards are all implemented in the Danish method implementation document describing quality assurance of AMS, MEL-16 [1].

The primary standard describing quality assurance of AMS, EN 14181 [2], constitutes the basis for this technical report. With some adjustments, a lot of the procedures and calculations described in the standard will be applicable to quality assurance of other automatic monitoring systems for captured CO_2. To avoid reproducing large parts of the standard, this report describes the key points and cases which deviate from the standard.

Requirements for monitoring location

In the field of air emissions, requirements for the monitoring location are described in EN 14181 [2] referring to ISO 15259 [5]. For Denmark, the standard is implemented in the Danish guideline MEL-22 [6], which is used as a basis when considering requirements for sampling and monitoring location for quality control of the purity of the captured CO_2.

Following a carbon capture plant, the physical state of CO_2 can be gaseous, compressed and/or cooled, resulting in a liquid phase. Gaseous CO_2 can further be pressurised, resulting in the pressure being significantly higher than atmospheric pressure. ISO 15259 is not applicable to pressurised gas and can therefore most likely not be applied directly to measurements performed in captured CO_2 [5].

Like the monitoring equipment used for air emissions monitoring, monitoring equipment used for measuring CO_2 purity is not suitable for measuring liquids and gases at high pressure. Consequently, the CO_2 stream is expected to undergo pressure reduction and, where necessary, vaporisation prior to measurements. This will apply to both the AMS installed at the carbon capture plant and the monitoring principles used for quality assurance of the AMS.

For the same reason, it is expected that an installed AMS will mainly be of the extractive type, where gas is taken from a sampling point and analysed outside the main pipe. In this context, pressure reduction must be performed to protect the monitoring equipment from excessive pressure. Pressure reduction can be performed using a pressure regulator with flash evaporation, causing a phase change of the CO_2 from liquid to gas phase.

The design of the pressure-reducing sampling system should ensure that there is no loss or condensation of the components to be measured. This will often require heating the pressure regulator, as a strong pressure drop can result in a significant temperature decrease in the gas, causing the CO_2 or some impurities to condense or freeze. ISO 27921 states the importance of ensuring that samples taken from the CO_2 stream are representative of the entire stream, as pressurisation prior to monitoring can cause partitioning of impurities in gaseous and solid phases, leading to false composition results [7], since the impurities do not distribute evenly between the two phases.

To ensure comparable conditions, an additional sampling point with pressure reduction identical to the one used for the AMS should be installed. This sampling point can then be used for parallel measurements during AMS quality assurance or for taking additional samples to test the quality of the captured CO_2.

Alternatively, it may be possible to use a side stream after the pressure regulator used for the AMS, so measurements are made directly from the same pressure-reduced gas stream. If this option is used, it must be ensured that the pressure regulator can handle the increased flow to be reduced and possibly heated. Likewise, it must be ensured that the side stream does not affect the AMS or vice versa.

In general, it is recommended not to combine the sampling point for AMS and the parallel measurements, in order to ensure independent sample points and avoid the risk of interference.

If a plant installs a different type of AMS which can monitor the pressurised or liquified CO_2, this will require further adaptation of the methods described below, as it is not given that the methods are applicable to all measuring principles.

Requirements for monitoring equipment

A standard measurement method for determining the impurity concentrations in a CO_2 matrix has, up until now, only existed for food-grade standards [8]. However, ISO 27928:2025 introduces a method based on the guidelines set by the ISO 6974 series for natural gas [3]. This method is based on GC with various detectors measuring the major impurities in the captured CO_2. Besides the analytical procedure related to the monitoring method, there are currently no other requirements for the monitoring equipment [3], [9]. However, a European standard draft describing analytical methods and quality assurance checks for CO_2 streams is currently under consultation [10].

On the other hand, there is a fully established system describing the standards and requirements for monitoring air emissions, so these will be presented below for comparison and inspiration.

Section 5.1 of EN 14181 states that the AMS used should be certified in accordance with EN 15267-1, EN 15267-2 and EN 15267-3, but in cases where no certified AMS is available, a non-certified AMS may be used [2]. Depending on the parameters to be measured and the required levels, it may be difficult to find a certified AMS suitable for the purpose, as the listed standards apply to flue gas and ventilation air as the measurement matrix rather than pressurised CO_2.

When considering the purity of a CO_2 gas stream, it can be difficult to find a certified AMS. The currently available and certified AMS are produced for monitoring air emissions and may not be able to measure the parameters listed in the CO_2 specifications or at the relevant levels. Monitoring equipment specifically produced to measure in a CO_2 gas matrix is available, but, to our knowledge, not certified.

When using non-certified AMS, it is recommended to perform at least a calculation of the uncertainty of the AMS as described in ISO 14956 to ensure that the AMS is suitable for measuring the desired parameters [11]. Calibration, inspection of measurement performance and drift check are also recommended by ISO 27928:2025 (Annex A.4) [3]. Further information on possible analysers for use in the captured CO_2 can be found in this white paper: Methods for measuring impurities in CO_2 [12].

Further attention should be drawn to cases where samples are taken and transported to an external laboratory, as materials for storage and transport may impact the samples. This may be caused either by impurities adsorbing to the walls of the container or by diffusion of gas through the material, e.g. O_2, which can cause great impact on the impurity composition within the sample.

Quality requirements for AMS

AMS for assessing the quality of captured CO_2 is currently unavailable, as the standards that define the quality requirements for the monitoring equipment are lacking. However, a standard draft currently for consultation is expected to cover the quality requirements [10]. Therefore, the requirements presented here are based on the quality requirements for air emission AMS.

In EN 14181, the maximum permissible uncertainty (MPU) for an analyser is used to test the variability of the quality assurance measurements performed [2]. For AMS used for air emission measurements, this value is sometimes called the quality requirement and is typically set by legislation as a percentage of the emission limit value. The term quality requirement is used in this technical report as a synonym for the MPU of an analyser.

There are no authority-regulated requirements for captured CO_2, so the current quality requirements are set by the recipients of the captured CO_2. The parameters to be measured in the captured CO_2 are based on the requirements related to its intended use and/or transport and storage. These requirements can replace the emission limit values for calculating the quality requirement, as they serve the same function (to limit the content of a substance in flue gas or captured CO_2).

For AMS on industrial plants, the percentage of an emission limit value used as a quality requirement is usually set in regulations or an environmental permit. This is currently not relevant to captured CO_2 from a carbon capture plant, so the percentage must be set differently. This technical report does not provide specific guidance on a particular percentage, but the following factors may be considered. A schematic representation of the terms mentioned above is available in Figure 1.

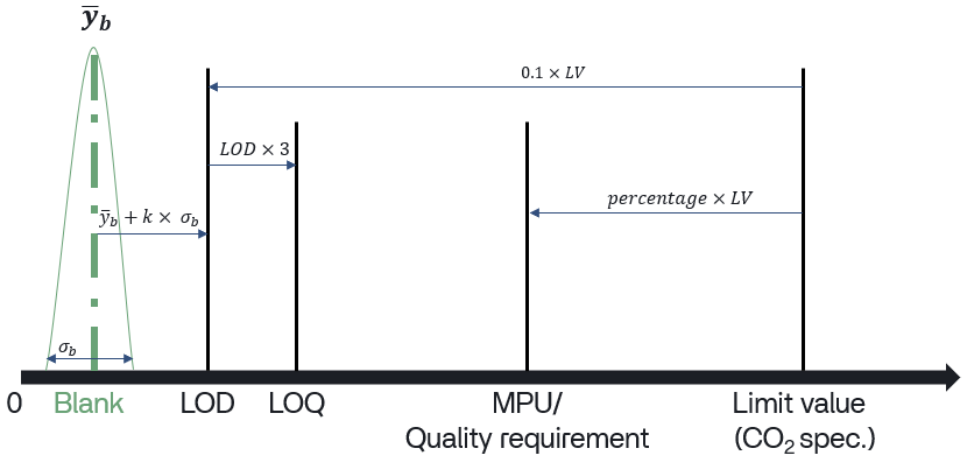

Figure 1: Schematic representation of the relations between the Limit of Detection (LOD), the Limit of Quantification (LOQ), the maximum permissible uncertainty (MPU)/quality requirement and the limit value set by the CO_2 specifications.

The general uncertainty of the monitoring equipment, relative to the quantification limit and specification requirements, can be used to assess what is realistic to set as a percentage or quality requirement. If the equipment's uncertainty and quantification limit are far from the requirement for the measured component, a lower percentage can be chosen to ensure that the analyser does not fluctuate excessively between measurements. Conversely, an analyser with high uncertainty or a quantification limit close to the requirement for the measured component will have difficulty passing quality assurance if the percentage is set too low. This must be weighed against how critical a given component is for the recipient of the captured CO_2. The draft version of the European standard currently for consultation introduces categories for the impurities in CO_2, grouping the impurities according to effect, measurement frequency and analysis methods [10].

For example, the water content in the captured CO_2 is considered critical to avoid corrosion. Therefore, generally, low requirements are set for its content. For a critical component, a low percentage of the content requirement should also be set as a quality requirement to ensure that content limits are not exceeded even if the analyser indicates everything is fine. At the same time, it must be assumed that the content requirements set by a recipient include a certain safety margin, which may mean that a low percentage of the requirement is not necessary. The process of setting the quality requirement can therefore be greatly facilitated through dialogue with the relevant recipient of the captured CO_2 to ensure that the quality requirements taken into account both the analyser's characteristics and the recipient's safety considerations.

Calibration of AMS and annual control – QLA2 and AST

Currently, the CCUS industry lacks standards that fully describe the procedure for performing annual verification and calibration of the AMS. However, standards and procedures are available for air emissions, and these are used as a baseline for the following recommendations.

EN 14181 includes a description of how to establish a calibration function for an AMS (QAL2 in Section 6) and how to perform ongoing verification (AST in Section 8) [2].

QAL2

It is not recommended to implement QAL2 for equipment used to monitor the captured CO_2, as it should not be necessary to continuously create a new calibration function for well-functioning equipment which is maintained regularly.

AST

The procedure for conducting an AST, on the other hand, can be used as a model for third-party verification of monitoring equipment measuring the purity of the captured CO_2. Since QAL2 is not recommended, no individual calibration function will be calculated for the equipment. Instead, it is recommended to use the calibration function $y = x$ (assuming the monitoring equipment is completely linear and shows the correct concentration) when performing an AST. If the equipment fails the AST and it is not immediately possible to identify the issue that caused the failure, the monitoring equipment should be serviced as soon as possible. After service or repair, a new AST should be performed to confirm that the monitoring equipment now functions as intended.

The frequency of an AST should, as the name suggests, be at least once per year. The exact frequency should be agreed upon with the recipient of the captured CO_2. It may be considered to perform them more frequently initially if the AMS type is unfamiliar or uncertified. EN 14181 requires at least 5 parallel measurements during an AST [2]. For plants with very stable operation, fewer measurements may be considered, but there should always be at least 3 valid measurements. If the CO_2 capture plant is installed at a facility with more variable operation, leading to fluctuating CO_2 capture performance, at least 5 measurements should always be performed, of which at least 3 must be valid.

Parallel measurements during an AST require an SRM, but currently, one is lacking for the components included in the CO_2 specifications in a CO_2 matrix. Measurements in a CO_2 matrix differ from flue gas measurements, and the SRM used for flue gas measurements might therefore not be applicable. In many cases, alternative measurement methods may be needed for parallel measurements. The most important factor is that the methods used have sufficient accuracy and detection limits and are performed by a company accredited for such measurements, or at least experienced with the methods. Further information on possible measurement methods for quality assurance can be found in the following white paper: Methods for measuring impurities in CO_2 [12].

As part of data processing for AST, both SRM results and AMS values are converted to reference conditions (see item (1) and (4) in Figure 6 of Section 8.4 in EN 14181) [2]. Conversion to reference conditions is performed to test variability, where the quality requirement, also stated at reference conditions, is used as part of the control. For captured CO_2, it is not considered relevant to convert to reference conditions due to the low levels of O_2 or H_2O, but normalisation of the results (e.g. 0°C, 1013 mbar) is still relevant. Additionally, the quality requirements established above will rarely be stated at reference conditions. Instead, it should be ensured that both SRM results and AMS values are converted to the same units and conditions as the quality requirement prior to performing a variability test. Alternatively, the quality requirement can be converted to the unit and condition at which the AMS operates. The key is to ensure that all values compared are in the same unit and condition, and that this is clearly stated in the report.

Functional test

EN 14181 requires a functional test of monitoring equipment prior to a QAL2 or AST [2], and it is recommended that this test is conducted less than one month before parallel measurements.

It is not recommended to retain this requirement for monitoring equipment for the captured CO_2 stream if the equipment is maintained regularly.

Valid interval for calibration

When QAL2 is not recommended, no valid interval for calibration is established. It is therefore not relevant to consider whether the valid calibration interval for the AST should be extended.

Internal quality control – QAL3

QAL3 is the internal quality control of the AMS conducted by the plant itself. The procedures and requirements specified in EN 14181 should also be applicable to AMS for captured CO_2 to the extent where a monitor can be verified by either a calibration gas or a different type of reference material [2]. Since most monitoring equipment to be used as AMS for captured CO_2 is likely to be extractive monitors, the rules and requirements relevant for these will be recommended.

When setting control chart limits, it is recommended to always use a percentage of the quality requirement. This may require converting the quality requirement to the same unit as the AMS results. In cases where a monitor cannot be continuously checked by the plant itself, consideration should be given to increasing the frequency of AST to ensure continuous control of the monitoring equipment. Alternatively, another method of monitoring the equipment between independent quality assurance checks should be established.

ISO 27928:2025 describes, in relation to the CCUS industry, verification of permanent plant instrumentation, including calibration and inspection to ensure that the specified requirements are met [3].

Reporting

Section 8.7 of EN 14181 describes a list of requirements for the content of an AST report. It is generally recommended that these requirements apply to an AST report for an AMS for CO_2 gas, except for items g) and h), as these items are not relevant and therefore not included in the recommended AST for captured CO_2 [2].

Requirements from recipients

Currently, the following recipients of the captured CO_2 have been identified in Denmark and the surrounding European region:

- Northern Lights (Norway)
- INEOS Greensand (Denmark)
- Porthos (the Netherlands)
- Aramis (the Netherlands)

The recipients differ in the method applied upon receiving the captured CO_2, as the CO_2 can be delivered either by ships or directly by pipeline via customer-built facilities connected to the transport system of the given recipient.

This section outlines the requirements set by the different recipients and will be presented according to the type of delivery of the captured CO_2.

Pipeline

The recipients expecting to receive the captured CO_2 in pipelines are (from the list above) Aramis and Porthos, which expect customer-built facilities to be attached to and deliver captured CO_2 directly into the onshore transport system prior to storage.

The requirements set by Porthos are collected in a standard published by Porthos, and the main point is presented in the following [13].

→ *"The customer is responsible for constructing a facility able to connect and deliver a flow of CO_2 into the Porthos Transport System. The operation of the custom-built facility is strongly related to the Safeguarding System along with the maintenance and testing of the Safeguarding System ensuring constant operation, as the ability to deliver CO_2 from a customer facility into the Porthos Transport System is dependent upon the Safeguarding System. The maintenance and test of the Safeguarding System shall follow IEC-61511.*

The Safeguarding System must continuously measure the CO_2 flow to ensure that the CO_2 specifications are met along with ensuring that the flow can be automatically and immediately discontinued if the CO_2 specifications no longer are met. Both H_2O and O_2 shall be measured *continuously and safeguarded in any case, while other components can be excluded after correspondence with Porthos."*

Porthos presents the use of a GC for determination of the captured CO_2 and all components along with a list of references and alternative methods to consider.

Cargo

Northern Lights expects the captured CO_2 to be delivered as batches provided/transported by ships prior to storage. Further information on the requirements set by Northern Lights has not been available.

Conclusion

The CCUS industry is experiencing rapid development, and reliable determination of the CO_2 purity is becoming increasingly important to ensure safe transport and storage of the captured CO_2. Currently, standards, methods and procedures for quality control of monitoring systems for CO_2 purity are lacking. The requirements for CO_2 purity are set by the recipients, but with limited requirements to the system for quality control. Standards are being developed for the CCUS industry, including focus on the system for quality control of monitoring equipment controlling the CO_2 purity.

This technical report has presented a proposed how a system for quality control can be constructed, inspired by the system already known for emissions to air, as many of these principles can be applied to the developing industry.

This report proposes:

- The use of independent third-party verification
- Requirements for monitoring location as well as equipment to ensure representative sampling and reliable measurements
- Evaluation of monitoring equipment suitability, including uncertainty assessment
- Requirements for both annual control and internal control of the monitoring equipment
- Establishment of quality requirements linked to the CO_2 specifications imposed by recipients.

The proposed framework is intended as a practical starting point that can be implemented before dedicated CCUS-specific quality assurance standards become available. By introducing a structured approach to quality control, plant operators, technology providers, infrastructure operators and storage recipients can increase confidence in measurement results, reduce operational risks and support transparency throughout the CCUS value chain.

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Appendix

Appendix A

CO_2 specifications

Table 1: CO_2 specifications listing the maximum allowable concentration of each impurity provided by different companies and projects available in December 2025.

Component			Aramis				
		Northern Lights (ppm-mol) [14]	**Ships (ppm-mol) [18]**	**Pipelines (ppm-mol)**	**Porthos (ppm-mol)** [15]	**ISBT (v/v)** [16]	**EIGA (v/v)** [17]
Carbon dioxide	CO_2	Balance (minimum 99.81%)	Balance	≥ 95 %	≥ 95 %	≥ 99.90 %	≥ 99.90 %
Water	H_2O	≤ 30 ppm	≤ 30 ppm	≤ 70 ppm	≤ 70 ppm	≤ 20 ppm	≤ 20 ppm
Oxygen	O_2	≤ 10 ppm	≤ 10 ppm	≤ 40 ppm	≤ 40 ppm	≤ 30 ppm	≤ 30 ppm
Sulphur oxides	SO_x	≤ 10 ppm	≤ 10 ppm	-	-	-	-
Sulphur dioxide	SO_2	-	-	-	-	≤ 1 ppm	-
Total sulphur	-	-	-	-	≤ 20 ppm	≤ 0.1 ppm[i]	≤ 0.1 ppm[i]
$H_2S+COS+SO_x+$ DMS[ii]	-	-	-	≤ 20 ppm	-	-	-
Nitrous oxides	NO_x	≤ 1.5 ppm	≤ 1.5 ppm	≤ 2.5 ppm	≤ 5 ppm	≤ 5 ppm	-
Nitrogen monoxide	NO	-	-	-	-	≤ 2.5 ppm	≤ 2.5 ppm
Nitrogen dioxide	NO_2	-	-	-	-	≤ 2.5 ppm	≤ 2.5 ppm
$O_2+N_2+H_2+Ar+$ CH_4+CO	-	-	≤ 2,000 ppm	≤ 4 %	≤ 4 %	-	-
Hydrogen sulphide	H_2S	≤ 1 ppm	≤ 5 ppm	≤ 5 ppm	≤ 5 ppm	-	-
Amines	-	≤ 10 ppm	≤ 10 ppm	≤ 1 ppm	≤ 1 ppm	-	-
Ammonia	NH_3	≤ 10 ppm	≤ 10 ppm	≤ 3 ppm	≤ 3 ppm	≤ 2.5 ppm	≤ 2.5 ppm
Formaldehyde	CH_2O	≤ 20 ppm	≤ 20 ppm	-	-	-	-
Acetaldehyde	CH_3CHO	≤ 20 ppm	≤ 20 ppm	-	-	≤ 0.2 ppm	≤ 0.2 ppm
Aldehydes	-	-	-	≤ 10 ppm	≤ 10 ppm	-	-
Mercury	Hg	≤ 0.0003 ppm	≤ 0.03 ppm	-	-	-	-
Carbon monoxide	CO	≤ 100 ppm	≤ 1,200 ppm	≤ 750 ppm	≤ 750 ppm	≤ 10 ppm	≤ 10 ppm
Hydrogen	H_2	≤ 50 ppm	≤ 500 ppm	≤ 7,500 ppm	≤ 7,500 ppm	-	-
Cadmium, Thallium	Cd + Tl	-	≤ 30 ppb	-	-	-	-

Methane	CH_4	≤ 100 ppm	-	≤ 1 %	≤ 1 %	-	-
Nitrogen	N_2	≤ 50 ppm	-	≤ 2.4 %	≤ 2.4 %	-	-
Argon	Ar	≤ 100 ppm	-	≤ 0.4 %	≤ 0.4 %	-	-
Methanol	CH_3OH	≤ 30 ppm	≤ 40 ppm	≤ 620 ppm	≤ 620 ppm	≤ 10 ppm	≤ 10 ppm
Ethanol	C_2H_5OH	≤ 1 ppm	≤ 20 ppm	≤ 20 ppm	≤ 20 ppm	-	-
Total volatile organic compounds	TVOC	≤ 10 ppm[iii]	≤ 10 ppm	≤ 10 ppm	≤ 10 ppm[iv]	≤ 50 ppm[v]	-
Total volatile hydrocarbons	-	-	-	-	-	-	≤ 50 ppm[vi]
Mono-ethylene glycol	MEG	≤ 0.2 ppm	-	Follow dew-point specification	Follow dew-point specification	-	-
Tri-ethylene glycol	TEG	≤ 0.2 ppm	-	Follow dew-point specification	Follow dew-point specification	-	-
BTEX[vii]	BTEX	≤ 0.5 ppm[vii]	-	-	-	-	-
Ethylene	C_2H_4	≤ 50 ppm	-	-	-	-	-
Hydrogen cyanide	HCN	≤ 100 ppm	-	≤ 2 ppm	≤ 2 ppm	ND[viii]	≤ 0.5 ppm
Vinyl chloride	C_2H_3Cl	-	-	-	-	ND[viii]	-
Aliphatic hydrocarbons	C_2+/C_3+	C_3+ ≤ 1,100 ppm[ix]	-	C_2+ ≤ 1,200 ppm	C_2+ ≤ 1,200 ppm[x]	-	-
Aromatic hydrocarbons	-	-	-	-	≤ 0.1 ppm[xi]	≤ 0.02 ppm [xii]	≤ 0.02 ppm
Ethane	C_2H_6	≤ 75 ppm	-	-	-	-	-
Solids, particles, dust	-	≤ 1 µm	≤ 1 µm	≤ 1 µm	-	-	-
Carboxylic acids and amides	-	-	-	≤ 1 ppm	≤ 1 ppm	-	-
P-containing compounds	-	-	-	≤ 1 ppm	≤ 1 ppm	-	-
Non-volatile residue	NVR	-	-	-	-	≤ 10 ppm w/w	≤ 10 ppm w/w
Non-volatile organic residue	NVOR	-	-	-	-	≤ 5 ppm w/w	≤ 5 ppm w/w
Phosphine						≤ 0.3 ppm	
Ethylene oxide						≤ 0.2 ppm	
Dew point	-	-	-	-10°c at 20 bars	-10°c at 20 bars	-	-
Toxic compounds		-	-	-	[xiii]	-	-

i Excluding SO_2
ii DMS: Dimethyl Sulphide, $(CH_3)_2S$
iii Total Volatile Organic Compounds (VOC) are VOC in addition to the ones listed separately in this specification, i.e., Ethanol, Methanol, Formaldehyde, Acetaldehyde and BTEX, and includes the following components: 1-propanol < 1 ppm-mol, 2-butanol < 1 ppm-mol, 1,2,4-trimethylbenzene < 5 ppm-mol.

iv Excl. methane, total aliphatic hydrocarbons (C_2 to C_{10}), methanol, ethanol and aldehydes.
v Calculated as methane, of which ≤ 20 ppm v/v is non-methane hydrocarbons.
vi THC might be considered as TVOC in some cases, but chemically, TVOC and THC differ.
vii BTEX refers to the following chemical compounds: Benzene, Toluene, Ethylbenzene and Xylene
viii Not detectable by the method
ix Total amount of hydrocarbons not to exceed 1,100 ppm-mol. Individual limits for groups of HCs: C_3 < 1,100 ppm-mol, C_4-C_5 < 815 ppm-mol, C_6-C_7 < 75 ppm-mol, C_8-C_9 < 8 ppm-mol.
x C_2 to C_{10}
xi C_6 to C_{10}, incl. BTEX
xii C_6H_6
xiii Toxic compounds: although CO_2 and other gases like H_2 and N_2 can pose a risk of asphyxiation, Porthos would like to know other components in the stream which impose risk on personal safety to be considered in Porthos´ HSE policy.

Appendix B

Steps of Quality Assurance

Table 2: Overview of the different steps included in Quality Assurance related to air emissions.

Quality level	Standard(s)	Description	Typically performed by	Frequency
QAL1	EN 15267 Part 3 EN ISO 14956	Certification and documentation that the AMS can meet the maximum permissible uncertainty	Manufacturer/supplier of the AMS	Performed once before procurement or replacement of the AMS
AMS and SRM monitoring location	ISO 15259 EN 16911 Part 2 (flow) EN 13284 Part 1 (dust)	Requirements for the AMS and SRM measurement location. Includes, among other things, testing the suitability of the measurement location for traverse measurements, a homogeneity test for gases, and a preliminary study for flow	Accredited measurement company	Once (repeated in the event of significant changes)
QAL2	EN 14181 (gases) EN 13284 Part 2 (dust) EN 16911 Part 2 (flow) EN 14884 (Hg)	Calibration of the ams: functional test Establishment of the calibration function, valid calibration range, and verification of measurement performance	Functional test: Ams supplier or measurement company Parallel measurements: Accredited measurement company	At least every 5 years
QAL3		Ongoing quality control of the AMS. Check of zero and span points	Plant owner	Once per maintenance interval or at least once per month
AST		Verification of the calibration function and measurement performance	Functional test: ams supplier or measurement company Parallel measurements: accredited measurement company	Annually in the years when QAL2 is not performed

Appendix C

Overview of standards

Table 3: Overview of relevant standards along with a brief description of content.

Standard number	Standard title	Brief description of content
EN 1328-2:2017	Stationary source emissions - determination of low range mass concentration of dust - Part 2: quality assurance of automated measuring systems	Specifies quality assurance procedures for automated measuring systems (ams) used for continuous dust monitoring in stationary source emissions. The standard covers calibration, validation, ongoing quality assurance, performance checks, and the application of EN 14181 to dust ams.
DS/EN 14884:2022	Stationary source emissions - determination of total gaseous mercury in waste gases from stationary sources - automated measuring systems	Specifies performance requirements, test procedures, installation criteria, calibration, and quality assurance requirements for automated measuring systems measuring total gaseous mercury (hg) emissions from stationary sources.
DS/EN ISO 14956:2002	Air quality - evaluation of the suitability of a measurement procedure by comparison with a required measurement uncertainty	Provides a framework for assessing the fitness-for-purpose of measurement procedures by estimating measurement uncertainty, evaluating performance characteristics, and verifying compliance with required measurement quality.
DS/EN ISO 6974-1:2012	Natural gas - determination of composition and associated uncertainty by gas chromatography - part 1: general guidelines and calculation of composition	Provides general guidance on gas chromatographic analysis of natural gas, including calibration, data processing, and calculation of gas composition.
DS/ISO 15259:2023	Air quality - measurement of stationary source emissions — requirements for measurement sections and sites and for the measurement objective, plan and report	Specifies requirements for emission measurement locations, sampling strategies, measurement planning, and reporting to ensure representative and comparable measurements from stationary sources.
DS/EN 15267:2023	Air quality – assessment of air quality monitoring equipment Part 1: general principles of certification Part 2: initial assessment of the manufacturer's quality management system and post-certification surveillance Part 3: performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources	Specifies the general principles and framework for the certification of air quality and automated monitoring systems. Defines requirements for assessing and monitoring the manufacturer's quality management system as part of the certification process. Specifies performance requirements and test procedures for ams used for continuous monitoring of emissions from stationary sources.
EN ISO 16911-2:2013	Stationary source emissions -manual and automatic determination of velocity and volume flow rate in ducts - Part 2: automated measuring systems	Specifies requirements for quality assurance, calibration, validation, installation, operation, and performance evaluation of automated measuring systems used for continuous measurement of flue gas velocity and volume flow rate in ducts and stacks.
EN 17255	Stationary source emissions – data acquisition and handling systems Part 1: specification of requirements Part 4: specification of performance tests	Specifies requirements for data acquisition and handling systems (DAHS) used with automated measuring systems (AMS) for emissions monitoring. It defines requirements for data collection, processing, storage, validation, reporting, traceability, security, and calculation of emission values for regulatory compliance.

		Defines performance testing procedures for dahs. It specifies verification and validation methods to demonstrate correct implementation of calculations, data handling, storage, reporting functions, alarms, and compliance-related data processing.
DS/ISO 27928:2025	Carbon dioxide capture, transportation and geological storage - carbon dioxide capture - performance evaluation methods for CO_2 capture connected to a CO_2-intensive plant	Specifies performance indicators, measurement methods, and verification procedures for evaluating CO_2 capture systems at large industrial emission sources.
DS/ISO/TR 27921:2020	Carbon dioxide capture, transportation and geological storage - cross-cutting issues - CO_2 stream composition	Provides guidance on CO_2 stream composition, impurities, safety aspects, corrosion risks, transport, storage, and monitoring requirements within CCS value chains.
DS/ISO/TR 27929:2025	Carbon dioxide capture, transportation and geological storage - transportation of carbon dioxide by ship	Technical report addressing the design, operation, safety, and integration of ship-based CO_2 transport within ccs infrastructure.
EN 14181:2014	Stationary source emissions - quality assurance of automated measuring systems	Defines quality assurance procedures for automated measuring systems (ams), including QAL1, QAL2, QAL3 and annual surveillance tests (AST).
MEL-16:2025	Monitoring emissions to air - quality assurance of automated measuring systems (AMS)	Danish technical guidance document covering installation, calibration, validation, operation, maintenance, and quality assurance of ams and associated data handling systems.
MEL-22:2025	Monitoring emissions to air - quality in emission measurements	Danish technical guidance document describing quality assurance requirements for manual emission measurements, including sampling, uncertainty assessment, quality control, and reporting.