CONTINUOUS EMISSIONS MONITORING ON STACKS - DATA ACQUISITION AND HANDLING SYSTEMS AND THE NEW EUROPEAN STANDARD EN 17255

The Quality Assurance (QA) requirements for Continuous Emissions Monitoring Systems (CEMS), also known as Automated Measuring Systems (AMS), are specified in the CEN standard EN 14181 which defines three Quality Assurance Levels - QAL1 (certification), QAL2 (calibration) and QAL3 (control). QAL1 requires type approval of the AMS which must have a suitable certification range when compared with the daily Emission Limit Value (ELV). QAL2 defines a straight-line calibration function, with a gradient and offset, that relates the AMS data to the test data obtained by an accredited test laboratory that uses a Standard Reference Method to independently measure each regulated pollutant, e.g., NO_x, SO_2, CO and dust. The standard deviation of the differences between the individual test points and the calibration line is a measure of the data scatter and this is known as the variability.

A functional test of the AMS is required prior to the QAL2 and prior to the Annual Surveillance Test (AST) in which the test laboratory annually checks the ongoing validity of the QAL2 calibration. A Valid Calibration Range is defined by the maximum emission concentration measured during the QAL2, extendable using AST data, but a repeat QAL2 is required if the reportable emissions regularly exceed the Valid Calibration Range based on a weekly check.

The linear QAL2 calibration must be applied to the averaged raw AMS data followed by correction to standard reference conditions. Prior to reporting to the authorities, for compliance assessment against Emission Limit Values (ELV), the deduction of the allowed measurement uncertainty may be performed, according to national emissions reporting requirements.

QAL3 requires that the operator performs regular zero and span checks on the AMS, to ensure that the AMS drift remains within pre-defined tolerances, using any control chart approach to plot the zero and span drift over time; only the CUSUM approach, defined in EN 14181, generates a drift correction that can be applied to the AMS data.

Introduction

All of the data transformation operations associated with EN 14181, and compliance reporting, are performed within the Data Acquisition and Handling System (DAHS) which is usually a commercial software package with the functionality shown in Figure 1. However, other options are allowed provided that they meet the requirements of the standard, particularly in relation to speed, accuracy, access, security and data validation.

Since the functionality of the DAHS is not covered by EN 14181, QA requirements for the DAHS are defined in EN 17255, as outlined in this article. EN 17255 is published in four parts, covering every aspect of DAHS operation as shown in Table 1, noting that Part 4 is awaiting final publication at time of writing. The QA requirements for DAHS, specified in EN 17255, follow the pattern established in EN 14181 for AMS. This article is based on presentations given by the authors at the Air Quality and Emissions (AQE) conference in 2022.

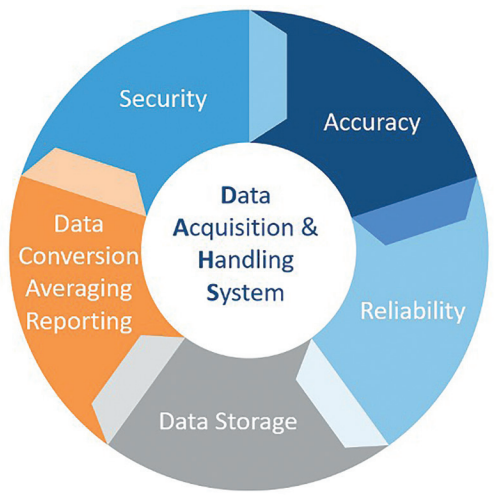


Figure 1: DAHS functionality

EN 17255 Part 1 – Requirements for the handling and reporting of data

Part 1 of the standard defines how raw emissions, peripheral and stack flow data are used to produce First Level Data (FLD) averages, typically a one-minute average calculated from data collected at no more than 10 second intervals. If applicable, a QAL3 drift correction (CUSUM) is applied prior to forming the FLD, and negative values are included in the FLD. However, the lower and upper limits of the measurement range are instead reported when the AMS is reading outside of its normal measuring range, i.e., when the AMS signal is overly negative or is overly high (saturated or over-range) unless regulations specify otherwise; these FLD, and any subsequently derived averages, are then flagged as being 'outside of range'. Additional FLD are determined for the AMS status of each emission, peripheral and stack flow measurement, and also for the plant status to determine when the plant is in normal operation.

Part 1 then defines how the Short-term Average (STA) is calculated from the FLD averages, typically over a half-hour period for Waste Incineration plant or a one-hour period for Large Combustion Plant, and taking into account the AMS status. The two-thirds rule applies, i.e., there must be at least 40 minutes of valid FLD and normal plant operation within an hour, or 20 minutes within a half-hour period, to produce a valid STA. If the plant is not operating for at least two-thirds of the STA, then the STA is flagged as 'plant not in reportable state'.

The STA is then 'calibrated', by applying the QAL2 gradient and offset, and then corrected to standard reference conditions at a fixed reference oxygen (O_2) concentration in the dry flue gas at 273.15 K and 101.3 kPa. Peripheral data are needed to perform this standardisation, including the oxygen content, water vapour content (if the AMS analyses a wet sample) and the temperature and pressure (for dust monitoring). If valid peripheral data are temporarily not available, substitute values can be used. Applying the QAL2 factors to the FLD produces the same result as for the STA. However, as shown in Figure 2, different results are obtained when standardising to reference conditions at the STA, rather than at the FLD which is common practice in some Member States. This is due to the non-linearity of the oxygen correction, noting that standardising at the STA, as now required by the standard, produces a lower result than standardising at the FLD, as also illustrated in Figure 2.

Validated short-term averages are calculated by subtracting the allowed measurement uncertainty from the STA prior to compliance assessment, e.g., by subtraction of the Confidence Intervals specified in the Industrial Emissions Directive. The way in which this is implemented varies between Member States.

Table 1: Structure of DAHS standard

EN 17255: Stationary source emissions - Data acquisition and handling systems			
Part 1	Part 2	Part 3	Part 4
Specification of requirements for the handling and reporting of data	Specification of requirements on data acquisition and handling systems	Specification of requirements for the performance test of data acquisition and handling systems	Specification of requirements for the installation and on-going quality assurance and quality control of data acquisition and handling systems

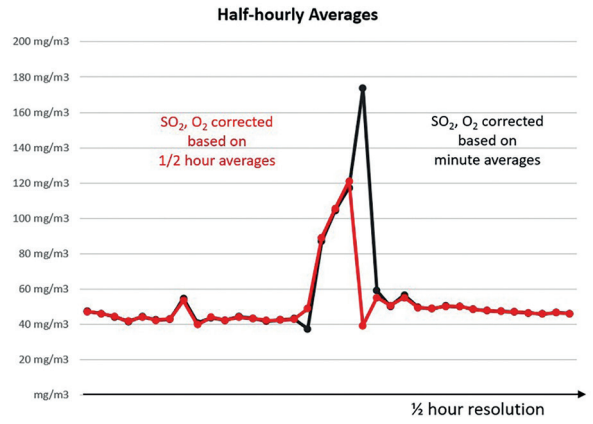


Figure 2: Importance of data averaging rules

Long-term averages (LTA), including daily averages, are calculated by averaging the validated STA data. The qualifying period for daily averages is 6 hours, i.e., the daily average is reported only when there are at least 6 h of valid STA data. Other long-term averages have a qualifying period of at least 10% of the LTA period, e.g., at least 72 hours or three days for a monthly average.

Mass emissions are calculated by multiplying the unvalidated concentration data by the stack flow data in the usual way, noting that these must be at the same reference conditions. However, the mass emission is set to zero if there are negative STA values of either concentration or flow.

Other topics covered by Part 1 of the standard include: i) definition of report contents; ii) monitoring and reporting the number of AMS invalid days, e.g., days with three or more missing STA for Large Combustion Plant; iii) flow weighted averaging for common stacks; iv) calculation of rolling averages; v) calculation of percentile concentrations; vi) monitoring and reporting exceedances of the Valid Calibration Range and vii) manual data entry.

EN 17255 Part 2 – DAHS requirements

Part 2 of the standard specifies requirements for data acquisition, data processing, data storage, data output, the generation of reports, system functions and data integrity.

A DAHS The various elements of the DAHS, including interfaces with the AMS, are shown in Figure 3 with the functionality described earlier mapped onto these elements in Figure 4.

B Interfaces Analog communication resolution shall be at least 12-bit (recommended 16-bit) with a relative accuracy better than 0.1% of range. Digital communication transfers the associated status information to the DAHS ensuring that there is unique addressing of input data sources, and synchronised transfer of values, and their corresponding status signals, with a resolution of 32-bit floating number according to IEEE 754. All communication interfaces must be well documented. The data sampling rate shall be at least every 10 seconds and manual data input is allowed for certain parameters.

C Input processing and production of FLD Loss of connection to the interfaces must be identified. Input data is valid if the connection is valid and the AMS is in measuring mode. FLD shall be stored along with status information and, if the raw concentration is scaled, any scaling factors that have been applied.

A	DAHS
B1	AMS data interface
B2	Peripheral data interface
B3	Plant data interface
C	Input processing and production of FLD
D1	Calculation of reported data
D2	Optional calculation of additional reported data,
E	Report generation
F	Data storage

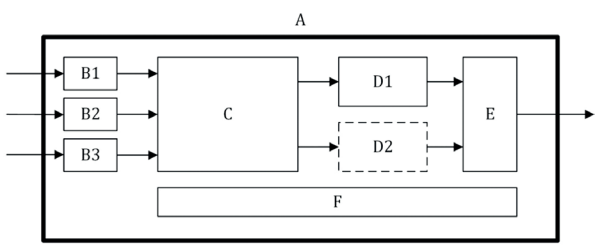


Figure 3: DAHS elements

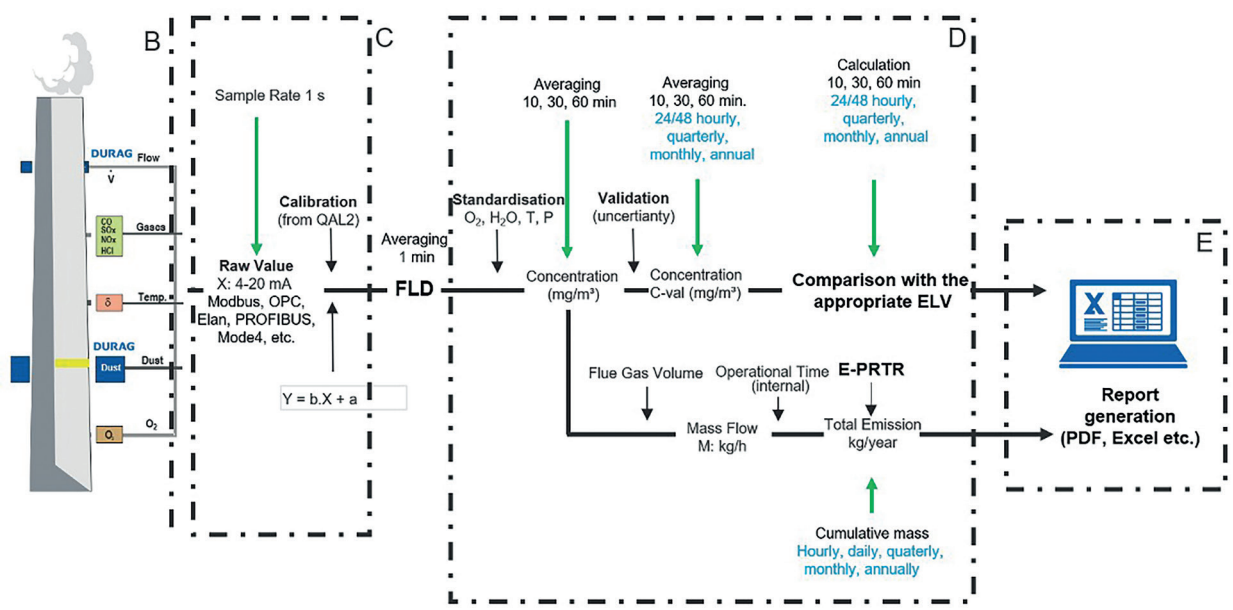


Figure 4: Data handling processes

D Calculation of reported data

Calculation of the calibrated, standardised and validated short-term averages follows the procedures specified in Part 1 of the standard as described above and as illustrated in Figure 4 which also shows the calculation of long-term averages and comparisons with the appropriate ELVs. Part 1 states that the QAL2 calibration is applied to the short-term average and notes that the QAL2 calibration can be applied to the first-level data without changing the results, as implemented in Figure 4.

Mass emissions calculation and reporting is also shown in Figure 4 with an example of submission of total annual mass emission to the European Pollutant Release and Transfer Register (E-PRTR).

Warnings, Alarms and Violations Monitoring of ELV exceedances (violations) and the AMS operational states, with the generation of corresponding alarms, is mandatory. An alarm shall be raised if the connection to an input source is broken. Alarms shall be stored with a start and an end timestamp, or with a start timestamp and an associated duration. Transmission of signals and alarms to external systems is required, e.g., the plant Distributed Control System (DCS).

E Report generation

System reports These reports shall contain: periods/hours of DAHS unavailability over the calendar year; FLD for selected inputs; QAL2/AST data, e.g., calibration functions and the Valid Calibration Rang along with the dates/times of the QAL2/AST testing and the associated parameter setting within the DAHS; QAL3 drift corrections (if applicable); event log entries; listing of warnings, alarms and violations with dates/times; DAHS configuration parameters with the date/time of the last revision; version numbers for software modules.

Emissions reporting for compliance purposes varies between Member States and sometimes within Member States. The DAHS must obviously be capable of producing these bespoke reports in the required formats and media, e.g., as a pdf or as an Excel workbook.

F Data storage The following requirements are specified for the data storage system: multiple concurrent user access; encrypted communication; tamper-proof data transfer and handling; permanent data retention for at least five calendar years; backup on an external device and prevention of data loss by transaction secure write operations.

System functions A watchdog is required to ensure that all elements of the DAHS are working as expected with an event log to record any unexpected or significant events, e.g., configuration changes. It must be possible to set the DAHS in a test mode to verify the configuration and check the reported data. The results shall be exportable in a simple, machine-readable format. With regards to system time management, a built-in motherboard PC clock is not sufficient and the use of a server with Network Time Protocol capability is allowed.

The event log shall include the: type of event (e.g. unsuccessful attempts to log in, communication faults to AMS, power cuts, watchdog restarts, changes to the system clock more than 5 seconds); event description; event category, e.g., an important event requiring immediate action or a less important event with an advisory notification; user name associated with the event and the time stamp of the log entry. Examples include: configuration changes; power loss; data communication issues and a change of the time clock greater than 5 seconds.

Part 2 of the standard covers only the basic structure of a DAHS, although the exact definition of where a DAHS starts and ends is useful guidance for the DAHS supplier. The requirements emphasise that secure data transmission is a must have in a modern IT environment. However, it should be noted that the detailed emissions reporting requirements are defined by local standards and guidance within each Member State.

EN 17255 Part 3 – DAHS Performance testing (certification)

Part 3 of the standard requires certification (type approval) of the DAHS and specifies how the requirements of Parts 1 and 2 of the standard are checked and verified during certification. This allows the plant operator to install a pre-qualified DAHS at the plant.

System tests are conducted by an independent test laboratory, on a single DAHS unit, with subsequent type approval granted by an independent certification body, e.g., TÜV. Every component of the DAHS is tested, i.e., all of the elements shown schematically in Figure 5.

Part 3 specifies and describes the DAHS test procedures and defines what is required of the independent test laboratory. Tests are defined as generic, specific (requiring additional test equipment and procedures) and documentation based, and the test results are assessed against the performance criteria defined in Parts 1 and 2 of the standard. Specific tests often require the injection of a test signal into the DAHS. Reporting checks take into account the intended application, e.g., Large Combustion Plant or Waste Incineration plant, and the system documentation is also reviewed.

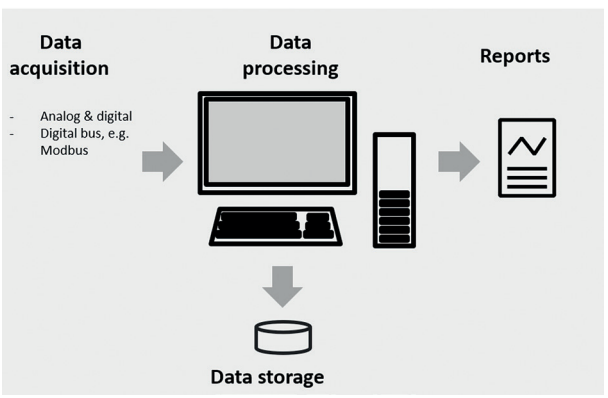
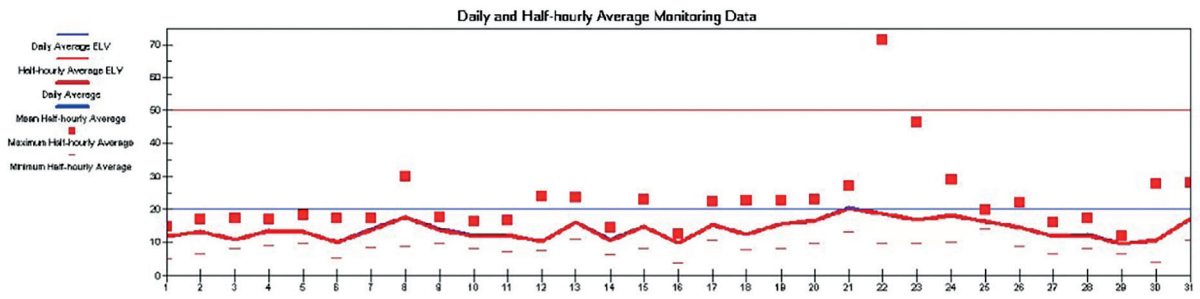


Figure 5: DAHS architecture

Procedures are defined for checking the following elements:

- Data acquisition: emissions, peripheral, flow, plant and manually entered data; sampling rate/resolution; Analogue Digital input ranges and accuracy; live zeros (a non-zero voltage or current is assigned to the start of the measuring range, enabling monitoring for broken wires) and the remote data logging unit.
- Input data processing: FLD formation, including the sampling interval; data flagging as valid/ invalid/out-of-range and QAL3 drift corrections (if applicable).
- Reported data: implementation of the calculation procedures for FLD, STA and LTA and checking warnings, alarms and violations.
- Reports: Generic and regulator specific emissions reports; system reports and the functioning of automatic and/or manual report generation.
- Data storage: date/time stamping; FLD, STA, warnings, alarms violations and events.
- System functions: check that every action shows up in the Event Log (DAHS initiated or manually entered); check that all configuration modifications are recorded in the Event Log; test



	Monthly summary		Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
			Half-hourly average ELV	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Half-hourly average	Monthly maximum	71	Maximum Half-hourly average	15	17	17	17	18	17	17	30	18	16	17	24	24	15	23	13	22	22	23	23	27	71	46	29	20	22	16	17	12	28	28
	Monthly mean	14	Mean Half-hourly average	12	13	11	13	13	10	14	18	14	12	12	10	16	11	15	10	15	13	15	16	20	19	17	18	16	15	12	12	10	11	17
	Monthly minimum	4	Minimum Half-hourly average	5	6	8	9	10	5	8	9	10	8	7	7	11	6	8	4	11	8	8	10	13	10	10	10	14	9	6	8	6	4	11
	Total Invalid results	0	No of Invalid results	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sum of exceedances	1	No of exceedances of ELV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
			Daily average ELV	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Daily average	Monthly maximum	20	Daily average	12	13	11	13	13	10	14	18	14	12	12	10	16	11	15	10	15	13	15	16	20	19	17	18	16	15	12	12	10	11	17
	No of invalid days	0	Value Valid?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Sum of exceedances	1	Value Exceeds ELV?	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N

Signed.....

Date.....

(Authorised to sign as a representative of the Operator)

Figure 6: DAHS reporting

the data export capability and check the test mode of the DAHS.

- Data integrity: DAHS availability; tamper-proof; prevention of data loss; data back-up; DAHS identification and time management.
- Documentation: check the completeness and accuracy of the DAHS documentation.

Table 1, in Part 3 of the standard, lists the characteristics that need to be tested, the type of test applicable (generic, specific or documentation) and the cross-references to the performance criteria in Parts 1 and 2 of the standard.

EN 17255 Part 4 – DAHS Installation and on-going QA/QC

Part 4 of the standard concerns the ongoing QA of the DAHS which is the responsibility of the plant operator and an independent test laboratory that is employed to verify the initial DAHS installation and then perform an annual functional test of the system.

The responsibilities of the plant operator and the test laboratory are listed below:

- Installation (operator/test laboratory)
- QAL2 aspects (test laboratory)
- Ongoing operation (operator)
- Annual functional test (test laboratory)
- Documentation (operator)

Installation The DAHS software installed by the operator must be certified according to Part 3 of the standard and installed according to the manufacturer's requirements, taking into account the conditions of the environmental permit. The DAHS location must be sufficiently stable and vibration free with appropriate weather protection and temperature control. Signal interface components not tested under Part 3 must meet the requirements of Part 2 of the standard. The installation documentation requirements are extensive and are detailed in Annex A of Part 4.

QAL2 factors must be applied in the DAHS, consistent with the raw data inputs and taking any applied scaling factors into account. The Valid Calibration Range is also entered along with the QAL2 variability if this is used for data validation.

The test laboratory is required to check that the above requirements are fulfilled and to record the baseline DAHS configuration and software version(s). The test laboratory also checks the assignments of Input/Output (I/O) signals in the tabulated installation record and the status of all I/O analogue & digital signals, i.e., that the signals are live and functioning properly.

The operator is recommended to establish a test plan for the annual function test of the plant specific installation and configuration of the DAHS and this plan is then updated following any system changes. The test laboratory then performs the annual functional test (see below) and produces a comprehensive installation report that describes the: plant; DAHS (including certification status); baseline configuration/parameter setting and results of the system and functional tests. Any observations or findings relating to the implementation of the QAL2/AST are also reported. The installation report also contains a summary of results.

QAL2 aspects The test laboratory is required to perform an annual function test of the DAHS in co-ordination with the QAL2/AST testing. This may be performed in parallel with either the AMS functional test or the QAL2/AST testing.

Ongoing operation The operator needs to implement QAL2 calibration functions and related parameters, including any Valid Calibration Range extensions from the AST, when these become available. Allowed numbers of exceedances of the Valid Calibration Range are based on an annual period so the time counter for monitoring exceedances needs to be reset by the operator in the DAHS. Prompt action is required in response to warnings, alarms and violations. There is also a requirement to perform a daily check of the completeness of reports and system messages. The operator needs to take corrective action as required, e.g., system repairs, and to document any interventions in the DAHS log book.

Annual Functional Test The test laboratory follows the test plan established during DAHS installation and checks the correct transmission of the: AMS measured signals, e.g., NOx; the AMS status signals, e.g., instrument malfunction, and the plant status signals, e.g., plant load and furnace temperature. The correct functioning of the redundant data recording system is also checked and, as above, the operator arranges correction of failures and errors and records interventions in the DAHS log book.

The annual functional test is very detailed and requires the checking of:

- parameter settings for each measurement channel including signal ranges, QAL2 parameters, reference values used for standardisation, averaging period, ELVs and data validation parameters, e.g., the Confidence Interval;
- plant status signals, plant operating states, counter resets associated with plant operation and the correct interpretation of the plant status when reporting emissions (Part 4 Annex B);
- changes in the DAHS configuration (with commentary);
- reporting against the plant permit requirements (Figure 6);
- any additional functionality associated with remote emission control modules and associated data transmission;
- the system time and the data back-up;
- the installation site for conformity with the manufacturer's specifications and safe working;
- data transmission using, for example, injected signals and fault simulations;
- protection against unauthorised parameter changes, e.g., restricted user access;
- any special features, e.g., calculation of energy weighted ELVs or restrictions on the fuel feed;
- flagging and evaluation of plant operating modes, e.g., start-up and shut-down or abatement malfunction;
- emissions report generation.

The functional test report must contain at least a statement of objectives, a description of plant and materials handled, a description of the DAHS, results of the functional tests and a summary of results. Any deviations and potential impacts must be documented and justified.

The functional test requires a combination of physical checks, e.g., signal injection, configuration checks and data/reporting checks. The Competent Authority in each Member State will need to approve the independent and competent test laboratories that are allowed to perform this test.

Part 4 of the standard addresses the regulatory gap between the output terminals of the AMS (covered by EN 14181) and the emissions compliance reporting. However, the DAHS documentation that must be maintained by the plant operator is extensive and includes: an installation report; a functional test plan and annual test reports; maintenance records and training records. Close cooperation between the Plant Operator and the test laboratory is required. However, it should be noted that Part 4 of the standard is in final draft and may be subject to change.

Summary

The EN 17255 standard, issued in four parts, addresses the QA/QC of data received by a Data Acquisition and Handling System (DAHS) from Automated Measuring Systems (AMS) or CEMS that are subject to EN 14181. The DAHS may receive analogue or digital inputs from both the AMS and the operational plant.

The DAHS receives 'raw' data from the emissions, peripherals and stack flow AMS, and then averages, calibrates, standardises and validates the data for regulatory compliance reporting. Part 1 of the standard specifies the rules for data handling and reporting. Part 2 specifies the basic system requirements for data acquisition, data processing, data storage, data output, the generation of reports, system functions and data integrity. Part 3 defines the DAHS certification or type approval process which requires testing of a single DAHS by an independent test laboratory followed by type approval by an independent certification body. Part 4 defines the ongoing QA/QC performed by the operator and an independent test laboratory that performs an annual functional test of the DAHS. The operator is required to keep detailed records and to fully document the DAHS performance.

This standard applies to DAHS installed after the date of implementation of the standard but this depends on regulatory interpretation and best practice.

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