Technology Transfer Seminar

Practical Solutions for Applying BS EN 14181: 2004

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The Importance of QAL3

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The importance of QAL3

- QAL3 - General
- Statistical Process Control (SPC)
- Calculation of S_{AMS}
- Example control charts
- Reporting requirements
- Summary
- Sources of information

QAL3 – general

- QAL3 is a procedure to maintain and demonstrate the quality of the AMS during ongoing operation.
- The purpose of QAL3 is to detect drift and changes in precision in the AMS by performing regular checks of the zero and span readings.
- These checks may be made using reference materials or by using surrogate methods.

QAL3 – general (cont.)

- In order to determine whether any changes in the zero and span values are due to actual drift, or whether they are caused by random deviations, zero and span values are plotted on control charts and compared to allowable variations expressed as standard deviations, or S_{AMS} in EN 14181.

QAL3 – general (cont.)

Do not undertake QAL2 tests until QAL3 procedures are in operation (strongly recommended) or are ready to operate immediately after QAL2 tests are completed.

Who carries out QAL3?

- The implementation and performance of QAL3 procedures are the responsibility of the plant operator.
- It is also the responsibility of the plant operator to ensure that the AMS is operating within the valid calibration range.

Statistical process control (SPC)

- Statistical process control (SPC) is a method for achieving quality control in manufacturing processes.
- Control charts or process behaviour charts are widely used to assess the nature of variation in a process and to facilitate forecasting and management.
- EN 14181 suggests the use of two types of control chart to detect drift and changes in precision in the AMS: Shewhart charts and CUSUM control charts. Other types may be used.

Statistical process control (SPC) (cont.)

- Shewhart charts are good at detecting large changes in the process mean or variance.
- CUSUM charts, while not as intuitive and simple to operate as Shewhart charts, are more efficient in detecting small drifts in the mean of a process.

Why do we need control charts?

- Frequent adjustments to AMS are often not needed.
- Frequent adjustments can degrade accuracy.
- Key objective is to determine drift.

What is S_{AMS}?

- S_{AMS} is the estimated uncertainty of the AMS, expressed as a standard deviation.
- Both Shewhart and CUSUM control charts use multiples of S_{AMS} to determine if changes in zero and span values are due to actual drift, or to random deviations due to variations in voltage, ambient temperature etc.
- Shewhart and CUSUM charts use different multiples of S_{AMS} as warning levels and alarm levels.

Calculation of S_{AMS}

The standard deviation S_{AMS} is calculated by:

$$S_{AMS} = \sqrt{(u_{temp})^2 + (u_{volt})^2 + (u_{pres})^2 + (u_{others})^2}$$

Where

u_{temp}	is the uncertainty from variations in ambient temperature
u_{volt}	is the uncertainty from variations in voltage
u_{pres}	is the uncertainty from variations in stack gas pressure for in situ AMS
u_{others}	is the uncertainty from other sources, e.g. cross-sensitivity to other determinands, detection limit etc.

Target values for control charts

- Shewhart and CUSUM approaches require target values to be chosen for span and zero.
- The target values (C) could be the concentration of the span or zero gas used for calibration checks, or a surrogate calibration method.

What span gas concentration to use?

- It is not necessary to use calibration gases supplied by a manufacturer accredited to the EN ISO/IEC 17025 standard, but the gases must be stable.
- As a “rule of thumb”, the span gas concentration should be about 75% of 1.5 times the half-hourly ELV set for the process.
- If half-hourly ELV is not set, choose a concentration approximately equal to the normal, average stack gas concentration.

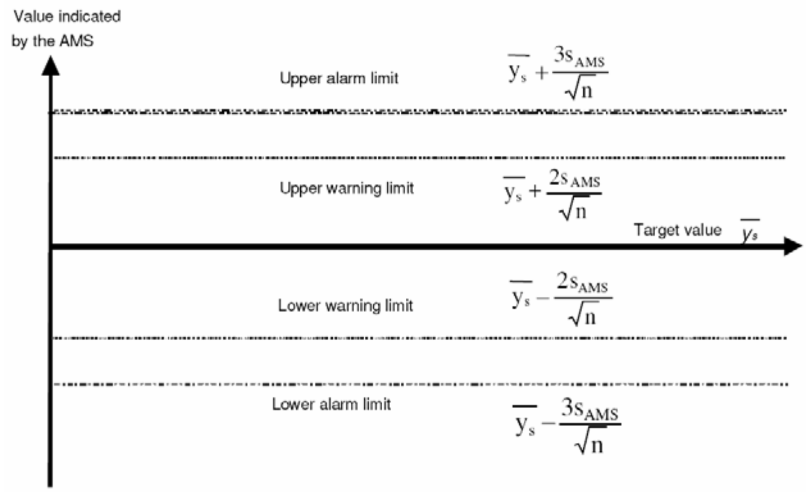
Shewhart control charts

- There are many types of Shewhart control charts including average, range, standard deviation, individuals, moving range etc.
- The simplest chart which may be plotted is one for individual measurements, known as an individuals chart.

Shewhart control charts (cont.)

- The limits are set using multiples of the uncertainty of the AMS or S_{AMS} for the applicable certified range.
- For Shewhart individuals charts, with a sample number of one, i.e. one calibration, it is usual to use warning and alarm limits of 2 x S_{AMS} (approximately 95% CI) and 3 x S_{AMS} (approximately 99% CI) respectively.

Example template for Shewhart individuals charts – span chart



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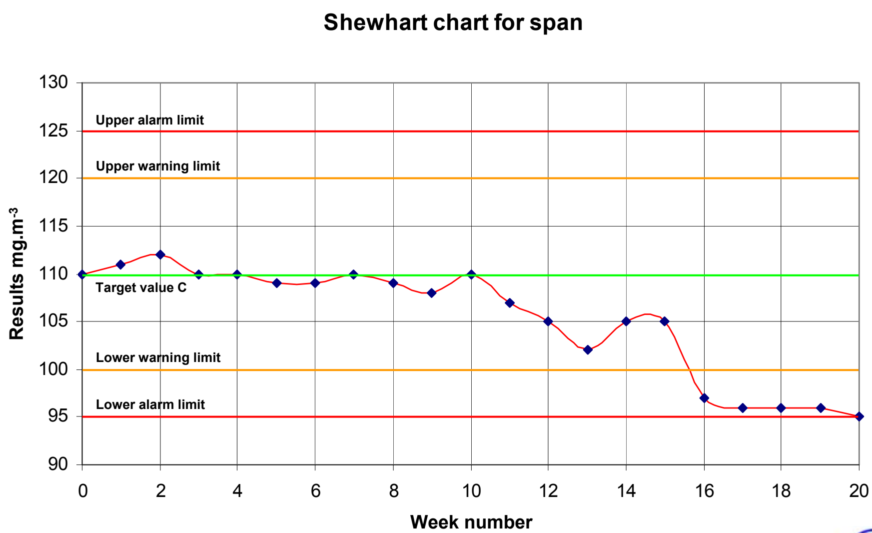
Example Shewhart individuals chart



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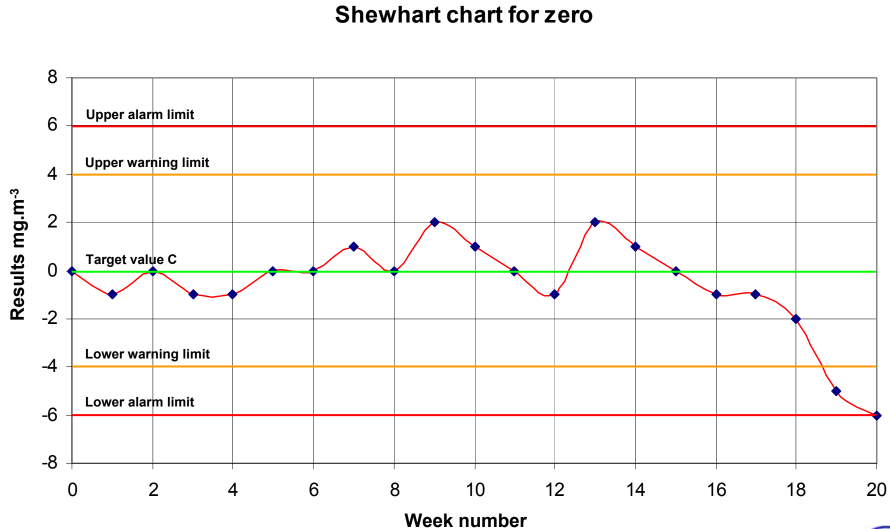
Example Shewhart individuals chart



Shewhart control charts (cont.)

- EN 14181 requires the operator to intervene when:
  - One or more data points are beyond one of the alarm limits
  - Three consecutive data points are beyond one of the warning limits
  - Four points among five consecutive ones are beyond half the alarm limits for span
  - Eight consecutive points are on the same side of the mean
  - Six consecutive points are either increasing or decreasing

CUSUM charts

- The CUSUM or cumulative sum chart uses all of the data and is therefore a more sensitive way to detect slight changes in the mean.
- If a target C is being considered, then the operating principle of the chart is to calculate the difference between each new value and value C, and to add this to a cumulative sum.

CUSUM charts (cont.)

- A CUSUM chart is essentially a running total of deviations from some pre-selected reference value.
- It is sensitive in detecting changes in the mean.
- Any change in the mean, and the extent of the change, is indicated visually by a change in the slope of the graph:
  - the CUSUM slope is upwards, observations are above target
  - the CUSUM slope is downwards, observations are below target
  - the CUSUM slope is horizontal, observations are on target
  - the CUSUM slope changes, the observations are changing level
  - the absolute value of the CUSUM score has little meaning

CUSUM charts (cont.)

- If μ_0 is the target value for the process mean, $\overline{x}_j$ is the average of the j[th] sample, then the CUSUM chart is formed by plotting the quantity:

$$C_i = \sum_{j=1}^{i} \left(\overline{x}_j - \mu_0 \right)$$

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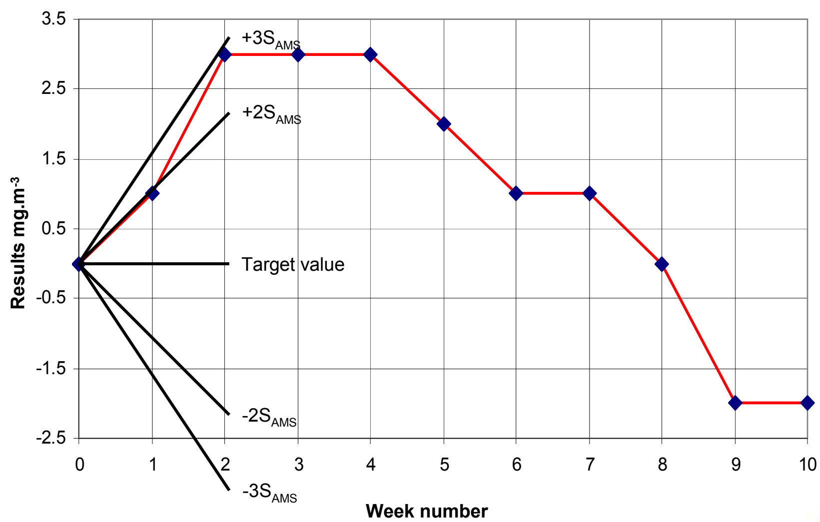
Example CUSUM chart for span drift



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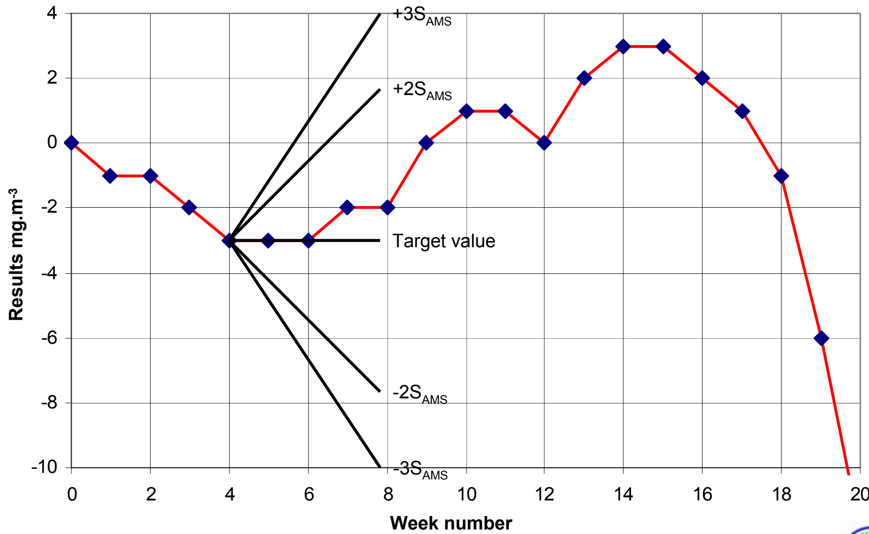
Example CUSUM chart for zero drift



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Design and use of control charts according to Annex C of EN 14181

- Annex C of EN 14181 contains specifications for the design and use of control charts for AMS drift and precision.
- In this approach the amount of AMS drift and decrease in precision is compared to the uncertainty of the measured value.

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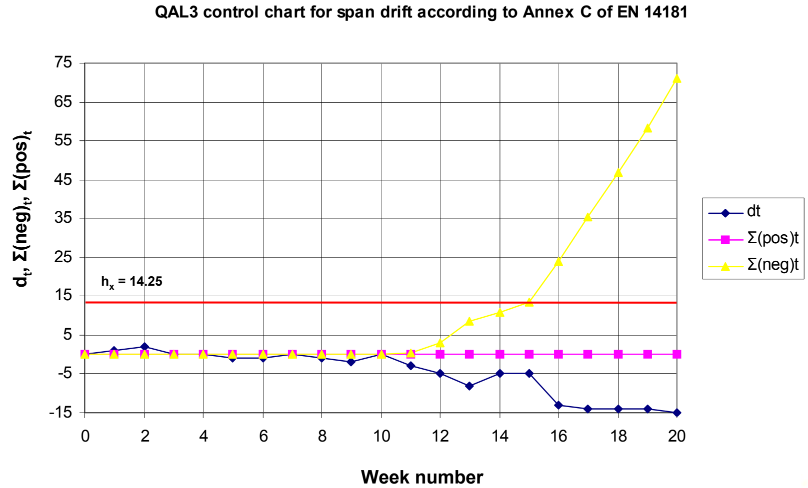
Design and use of control charts according to Annex C of EN 14181 (cont.)

- If either $\Sigma(pos)_t$ or $\Sigma(neg)_t$ exceed the alarm limits then adjustment of the AMS is required.
- If s_t exceeds the alarm limits the instrument manufacturer shall be contacted.

Design and use of control charts according to Annex C of EN 14181 (cont.)

- Annex C of BS EN 14181 specifies 0.501 and 2.85 x S_{AMS} for drift and 1.85 and 6.9 x S_{AMS}^2 for precision.
- In practice limits will differ depending on the performance of the analyser.

Example EN 14181 control charts – span drift



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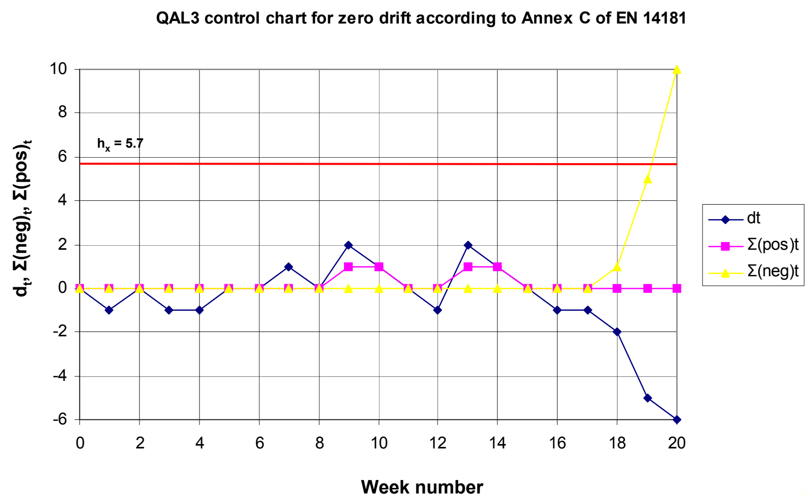
Example EN 14181 control charts – zero drift



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QAL3 reporting requirements

- AMS details – monitoring approach and technique, operating range, make & model.
- AMS changes – details of changes in make, model & serial numbers.
- Service visit records – routine maintenance.

QAL3 reporting requirements (cont.)

- Manufacturer’s call out records.
- Operator’s routine maintenance and corrective actions.
- QAL3 baseline re-sets – summary.
- Zero & span drift plots.
- Zero & span drift tabulation.

Summary

- Do not carry out QAL2 tests until QAL3 procedures are in operation.
- Shewhart and CUSUM control charts are recommended – other types may be used.
- Shewhart charts are good at detecting large changes in the process mean or variance.
- CUSUM charts are not as simple or intuitive as Shewhart charts, but are better at detecting small drifts.
- The procedure specified in Annex C of EN 14181 is not a simple CUSUM. It can be used to determine if, and by how much, the AMS needs to be externally adjusted.

Sources of information

- BS EN 14181: 2004.
- Technical Guidance Note M20.
- Method Implementation Document MID 14181.
- Method Implementation Document MID 13284-2.
- BS 7785: 1994 – Shewhart Control Charts.
- BS 5703-1: 2003 – CUSUM Control Charts.


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