MEASUREMENT UNCERTAINTY REPORT

1. Main data

Name	**A.1 - Preparation of a Calibration Standard**
File	A1 - Preparation of a calibration standard.gmf
Created	03.06.2017 14:55 :
Modified	26.05.2015 09:16 :
File version	4.10 (15.05.21) / QMSys GUM Enterprise

MCM	Adaptive procedure	Tolerance	Number of trials
Yes	No	1.0δ	$100x10^3$

1.1. Description

A calibration standard is prepared from a high purity metal (cadmium) with a concentration of ca.1000 mg/l.

1.2. Model

$$C_{Cd} = 1000 * m * P / V$$
$$V = V_{Nom} + \delta V_{Cal} + \delta V_{Rep} + \delta V_{Temp}$$

1.3. List of Quantities

Quantity	Name
C_{Cd}	concentration of the calibration standard
m	mass of the high purity metal
P	purity of the metal given as mass fraction
V	volume of the liquid of the calibration standard
V_{Nom}	Nominal volume of the flask
δV_{Cal}	Uncertainty contribution to the volume due to uncertainty in calibration of the flask
δV_{Rep}	Variation in filling the flask to the mark
δV_{Temp}	Uncertainty contribution to the volume due to temperature variation

1.4. Quantities description

Quantity	Description	Comment
C_{Cd}	Type: Result Unit: $mg.l^{-1}$ Uncert. unit: $mg.l^{-1}$ Factor: 1 Format: Absolute Distribution: Normal distribution Coverage probability (%): 95.45 Proof of capability: Yes Tolerance or distribution interval: 20 $mg.l^{-1}$ Capability index-Limit value: Cm = 4 Compliance assessment: Two-sided Lower specification limit: 990 $mg.l^{-1}$ Upper specification limit: 1010 $mg.l^{-1}$ Decision rule: Stringent Acceptance - Stringent Rejection	Maximum Permissible Error (MPE) is ± 1lang1033 %.
m	Type: Type B Unit: mg Uncert. unit: mg Factor: 1 Uncertainty estimate: Stand. uncertainty Distribution: Normal Value: 100,28mg Stand. uncertainty: 0.05mg Degrees of freedom: ∞	The relevant mass of cadmium is determined by a tared weighing, giving *m*= 0.10028 g. The uncertainty associated with the mass of the cadmium is estimated, using the data from the calibration certificate and the manufacturer's recommendations on uncertainty estimation, as 0.05 mg.
P	Type: Type B Unit:	The purity of the cadmium is given on the certificate as 0.9999 ±0.0001. Because there

	Uncert. unit: Factor: 1 Uncertainty estimate: Relative limit of error Distribution: Rectangular Value: 0,9999 Half-width of limits: 0,0001 Rel. error of uncertainty: 0	is no additional information about the uncertainty value, a rectangular distribution is assumed.
V	Type: Interim result Unit: ml Uncert. unit: ml Factor: 1	The volume of the solution contained in the volumetric flask is subject to three major sources of uncertainty: - The uncertainty in the certified internal volume of the flask. - Variation in filling the flask to the mark. - The flask and solution temperatures differing from the temperature at which the volume of the flask was calibrated.
V_{Nom}	Type: Constant Unit: ml Uncert. unit: ml Factor: 1 Value: 100ml	
δV_{Cal}	Type: Type B Unit: ml Uncert. unit: ml Factor: 1 Uncertainty estimate: Relative limit of error Distribution: Triangular Value: 0ml Half-width of limits: 0,1ml Rel. error of uncertainty: 0	The manufacturer quotes a volume for the flask of 100 ml ±0.1 ml measured at a temperature of 20 °C. The value of the uncertainty is given without a confidence level or distribution information, so an assumption is necessary. Here, the standard uncertainty is calculated assuming a triangular distribution.
δV_{Rep}	Type: Type B Unit: Uncert. unit: Factor: 1 Uncertainty estimate: Stand. uncertainty Distribution: Normal Value: 0 Stand. uncertainty: 0.02 Degrees of freedom: ∞	The uncertainty due to variations in filling can be estimated from a repeatability experiment on a typical example of the flask used. A series of ten fill and weigh experiments on a typical 100 ml flask gave a standard deviation of 0.02 ml. This can be used directly as a standard uncertainty.
δV_{Temp}	Type: Type B Unit: ml Uncert. unit: ml Factor: 1 Uncertainty estimate: Relative limit of error Distribution: Rectangular Value: 0ml Half-width of limits: 0,084ml Rel. error of uncertainty: 0	According to the manufacturer the flask has been calibrated at a temperature of 20 °C, whereas the laboratory temperature varies between the limits of ±4 °C. The uncertainty from this effect can be calculated from the estimate of the temperature range and the coefficient of the volume expansion. The volume expansion of the liquid is considerably larger than that of the flask, so only the former needs to be considered. The coefficient of volume expansion for water is $2.1 \cdot 10^{-4}$ °C^{-1}, which leads to a volume variation of $\pm (100 \cdot 4 \cdot 2.1 \cdot 10^{-4}) = \pm 0.084$ ml The standard uncertainty is calculated using the assumption of a rectangular distribution for the temperature variation.

1.5. Correlation matrix (Input quantities)

Quantity 1	Quantity 2	Correlation coefficient
		0

2. Observations

Quantity	Unit	Number of observations	Observations	Mean value	Stand. uncertainty	Bayesian stand. uncertainty
		0				

3. GUF - Uncertainty budget

3.1. Budget

Quantity	Value	Stand. uncertainty	Distribution	DoF	Sensitivity coefficient	Quantities with zero contribution
m	100,2800 mg	0,0500 mg	Normal	∞	10,0 l^{-1}	
P	0,9999000	0,0000577	Rectangular	∞	1000 mg.l^{-1}	
V	100,0000 ml	0,0665 ml		0		
V_{Nom}	100 ml					
δV_{Cal}	0,0 ml	0,0408 ml	Triangular	∞	10,0 mg.ml^{-1}.l^{-1}	
δV_{Rep}	0,0	0,0200	Normal	∞	10,0 mg.l^{-1}	
δV_{Temp}	0,0 ml	0,0485 ml	Rectangular	∞	10,0 mg.ml^{-1}.l^{-1}	

3.2. Combined Standard Uncertainty

Quantity	Comb. stand. uncertainty	Comb. relat. uncertainty	Effective degrees of freedom
C_{Cd}	0,835 mg.l^{-1}	0,000833	∞

3.3. Result

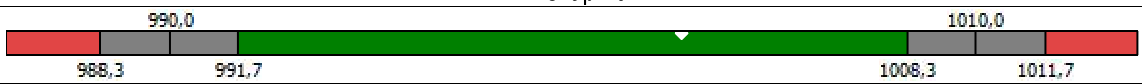
Quantity	Value	Expanded uncertainty	Expanded rel. uncertainty	Coverage factor	Coverage probability	Distribution
C_{Cd}	1002,7 mg.l^{-1}	± 1,7 mg.l^{-1}	± 0,17 %	2.00	95.45 %	Normal

3.4. GUF - Validation

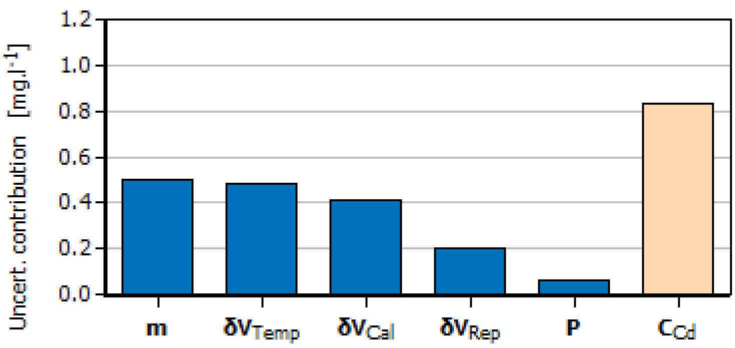
Quantity	Validation	Tolerance δ	Δ Coverage interval	Δ Result	Δ Comb. stand. uncert.
C_{Cd}	Yes	0,05	[-0,01:0,01]	0,0	0,0

3.5. Proof of capability and compliance assessment

Quantity	Capability	Index	Limit value	Compliance	P-inside	P-outside
C_{Cd}	Yes	Cm = 6.0	4	Yes	100.000%	0.000%

Quantity	Graphic
C_{Cd}	

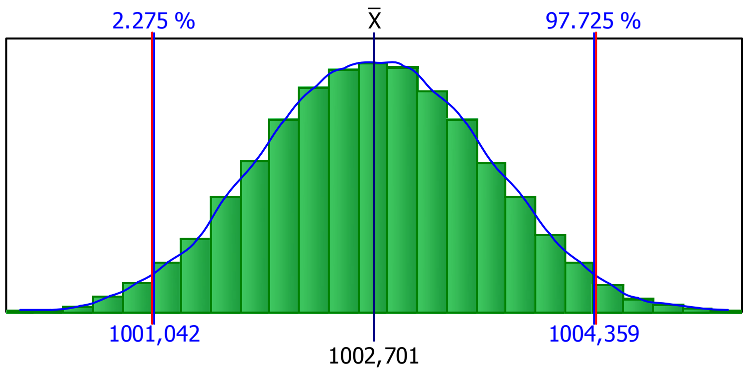
3.6. Charts

Quantity	Uncert. contribution	Rel. contribution	Graphic
m	0,500 mg.l^{-1}	35.82 %	
δV_{Temp}	0,486 mg.l^{-1}	33.91 %	
δV_{Cal}	0,409 mg.l^{-1}	24.03 %	
δV_{Rep}	0,200 mg.l^{-1}	5.76 %	
P	0,0579 mg.l^{-1}	0.48 %	
C_{Cd}	0,835 mg.l^{-1}		

4. MCM - Uncertainty budget

4.1. Statistical parameters

Quantity	Maximum	Minimum	Mean value	Stand. deviation	Quantile	Quantile
C_{Cd}	1005,838 mg.l^{-1}	999,432 mg.l^{-1}	1002,701 mg.l^{-1}	0,837 mg.l^{-1}	1001,042 mg.l^{-1} (2.275%)	1004,359 mg.l^{-1} (97.725%)

Quantity	Skewness	Kurtosis	Histogram
C_{Cd}	0.003	-0.173	

4.2. MCM validation

Validation	Tolerance	2S(y)	2S(u)	2S(y-low)	2S(y-high)
Yes	0,05	0,00496	0,00244	0,0102	0,00979

4.3. Combined Standard Uncertainty

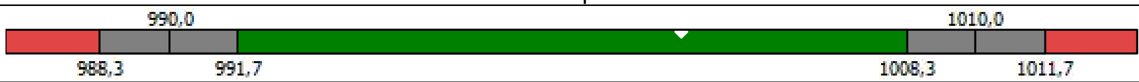
Quantity	Comb. stand. uncertainty	Comb. relat. uncertainty	Distribution
C_{Cd}	0,837 mg.l^{-1}	0,000835	Normal

4.4. Result

Quantity	Result	Expanded uncertainty	Expanded rel. uncertainty	Coverage factor	Probability
C_{Cd}	1002,70 mg.l^{-1}	± 1,7 mg.l^{-1}	± 0,17 %	1.98	95.45 %

4.5. Proof of capability and compliance assessment

Quantity	Capability	Index	Limit value	Compliance	P-inside	P-outside
C_{Cd}	Yes	Cm = 6.0	4	Yes	100.000%	0.000%

Quantity	Graphic
C_{Cd}	

5. Comment

Quantity	Comment
C_{Cd}	