



Global Leaders in Gas Measurement



Instrument Performance Evaluation, comparing ISO 10723 and NORSO^K I-106

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North Sea Flow Measurement Workshop 2017

Overview of presentation

- Importance of the GC and its performance
- Importance of a good quality calibration gas
- Introduce Norsok I-106 test & ISO 10723 and highlight different evaluation approaches
- Highlight some of the additional benefits from the ISO approach
- Results of using an ISO 10723 to generate a Norsok test report
- Summary

Fit for purpose?

Sometimes it's obvious if equipment is fit for purpose.....





Fit for purpose?

Sometimes it is not obvious.....

Gas Quality instrumentation (which to choose?)



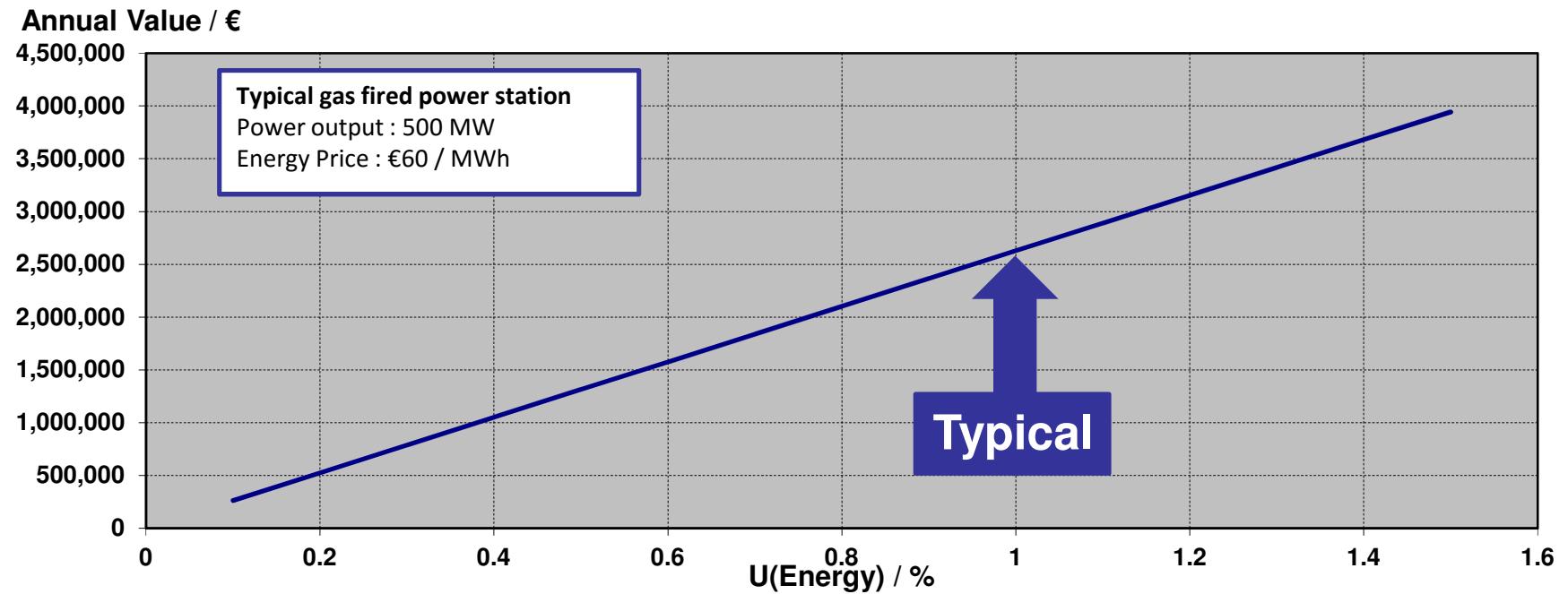
Answer....Best performing instrument



Natural Gas Quality Measurement

- Composition (content) of natural gas
 - Inert gases
 - Nitrogen, carbon dioxide, helium, argon
 - Hydrocarbons
 - Methane, ethane, propane, iso-butane, n-butane, pentanes, hexanes +
- Properties (characteristics) of natural gas
 - Calorific value, Wobbe number, standard density (ISO 6976)
 - Compression factor, line density (ISO 12213, AGA 8)
 - Hydrocarbon dew point (ISO 23874)
 - Emission factors (BS 8609)

Financial risks in energy metering



NORSOK I-106

NORSOK STANDARD

I-106

Edition 1, November 2014

**Fiscal metering systems for hydrocarbon liquid
and gas**

BS EN ISO 10723

BS EN ISO 10723:2012



BSI Standards Publication

**Natural gas — Performance
evaluation for analytical
systems**

Norsok I-106

- Published 2014
- Norwegian Standard
- Defines pass / fail criteria of 0.3% for GCV based on:
 - Linearity
 - Repeatability
 - Uncertainty

ISO 10723

- Published 2012
- International Standard
- Defines a method, OIML & GUM compliant
- No pass / fail criteria
- Establishes
 - Bias
 - Uncertainty
- Bias and uncertainty compared to established limits

Calibration gas

- The gas chromatograph is a comparator
 - [wrist watch analogy](#)
- calibration gas
 - principal driver for accuracy of measurements
 - inaccuracies in the calibration gas will produce errors in stream gas results
- NORSOK specifies uncertainty limits for calibration and test gases (Table2)
- ISO 10723 does not specify but requires uncertainties which are used in the calculations



Issues: Low temperature



Using a non-homogeneous calibration gas

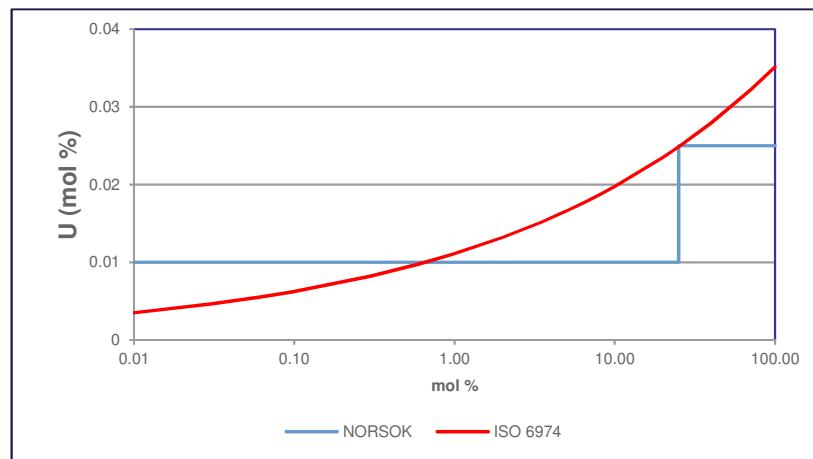
- Cup of tea analogy



Repeatability Comparison

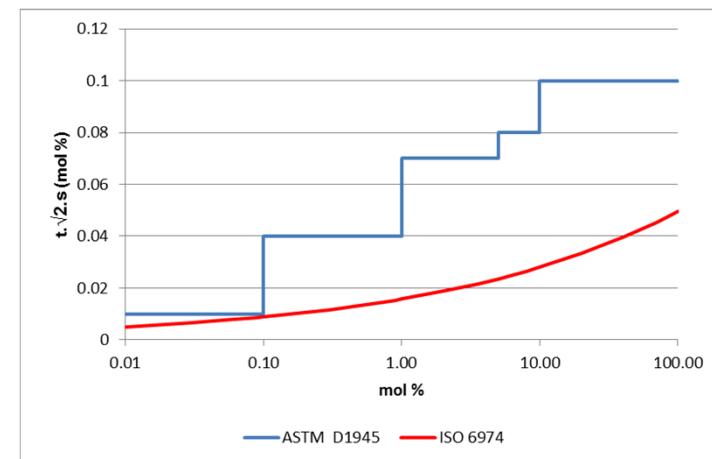
Norsok

Component range (mole %)	SD (mole %) $U_{RXi/2}$
0 to 25	0.01
25 to 100	0.025



ISO 10723

Component Range (mol%)	SD (mole %)
Not set	



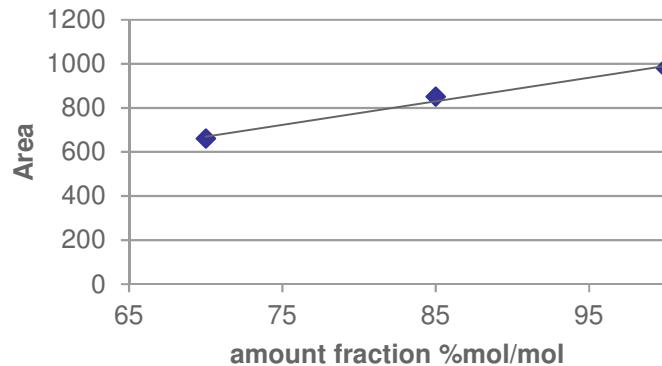
Why does ISO 10723 not set a repeatability criteria?

- Now common practice to accept errors in the measurement of component amount fractions provided their effect does not give rise to unacceptable errors in physical properties.
- Question: If the repeatability of 50 ppm nitrogen in natural gas was greater than the defined limit, what would the effect be on the calculated calorific value?
- Answer:A very small effect....**should this instrument fail?**
- The ISO 10723 provides data which can be compared to Maximum Permissible Bias (MPB) & Maximum Permissible Error (MPE) limits.

Linearity Comparison

Norsok

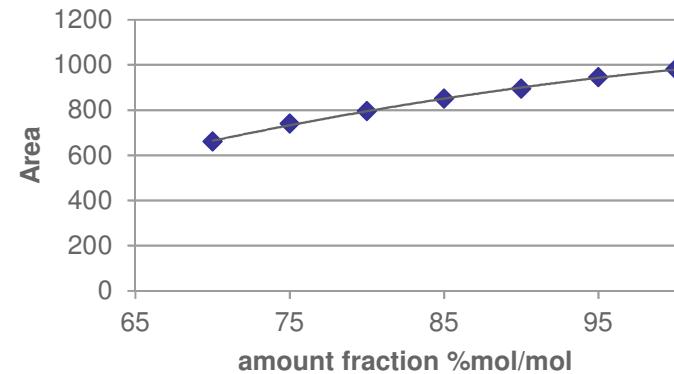
- 3 point check



Can only describe a linear response

ISO 10723

- 7 point check

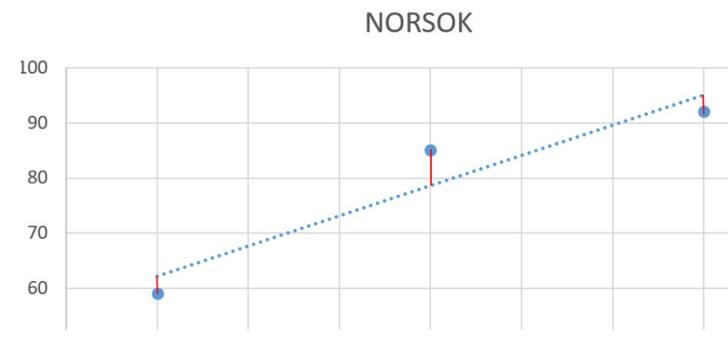


Can describe a response up to 3rd order polynomial

Dealing with non-linearity

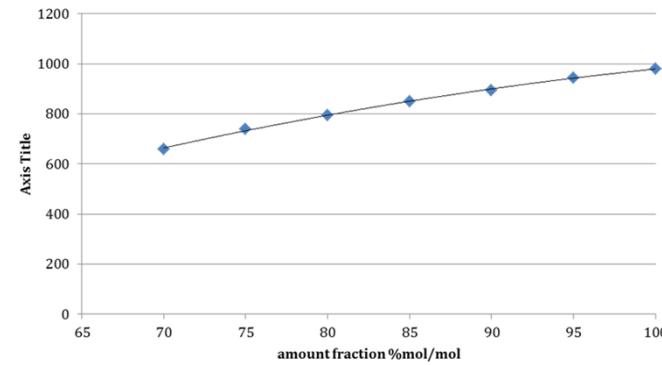
NORSOK

- Determines the maximum difference between the measured and reference values



ISO 10723

- GLS regression analysis to determine best fit polynomial

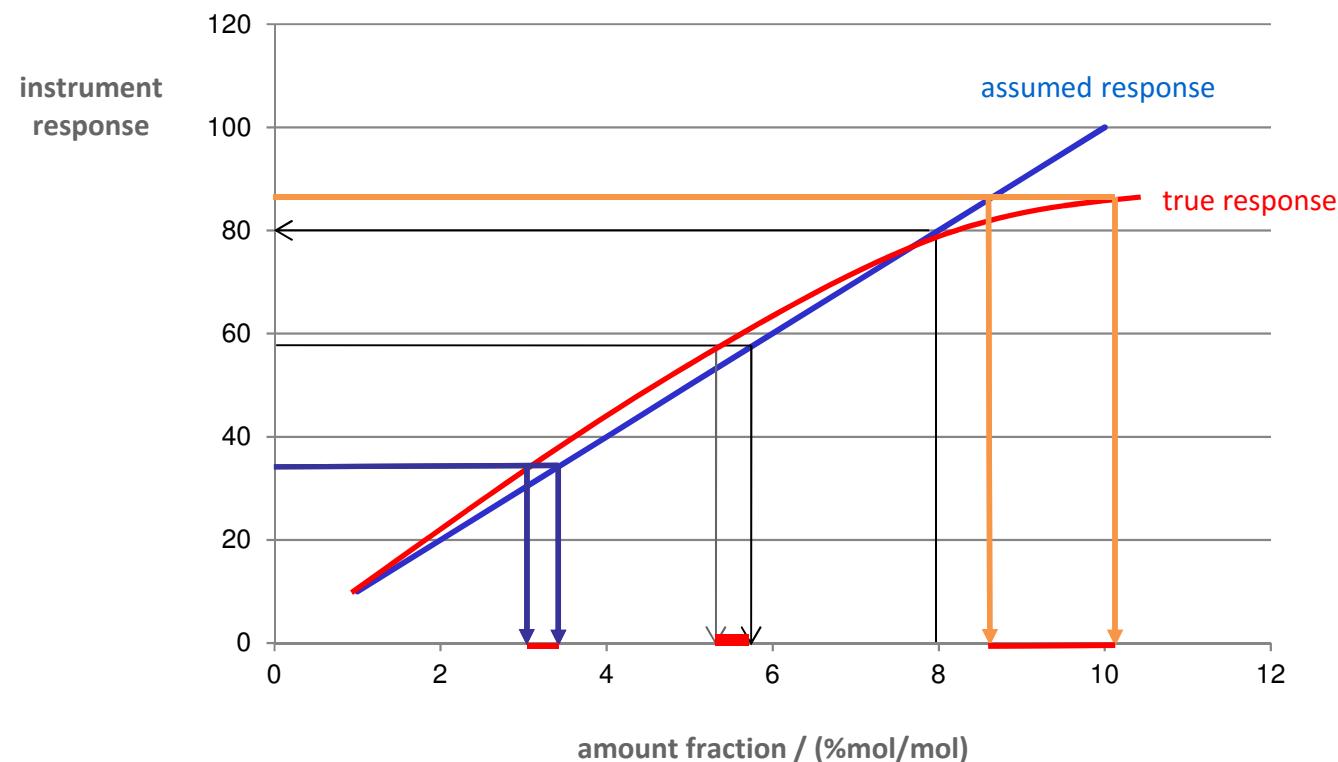


ISO 10723 linearity results

<i>analysis functions</i>	b0	b1	b2	b3
nitrogen	-0.017179	3.5065E-08		
carbon dioxide	-0.004192	2.8518E-08		
methane	-35.387687	9.2935E-08	-2.5389E-17	4.5636E-27
ethane	-0.000212	2.5554E-08	9.2811E-19	
propane	0.001788	2.0175E-08	5.5523E-19	
iso-butane	-0.001934	1.8142E-08	-2.6520E-17	2.9626E-25
n-butane	0.001298	1.6822E-08		
neo-pentane	-0.000626	4.3305E-06		
iso-pentane	-0.000115	4.9747E-06		
n-pentane	0.000730	5.4949E-06		
n-hexane	-0.002471	1.2986E-08		

<i>calibration functions</i>	a0	a1	a2	a3
nitrogen	4.9003E+05	2.8519E+07		
carbon dioxide	1.4527E+05	3.5066E+07		
methane	6.0415E+08	4.0349E+06	2.2557E+05	-9.5467E+02
ethane	1.0604E+04	3.9125E+07	-5.3093E+04	
propane	-8.8783E+04	4.9567E+07	-6.6639E+04	
iso-butane	1.0708E+05	5.5094E+07	4.7783E+06	-3.0139E+06
n-butane	-7.7112E+04	5.9448E+07		
neo-pentane	1.4337E+02	2.3115E+05		
iso-pentane	2.3400E+01	2.0101E+05		
n-pentane	-1.3289E+02	1.8199E+05		
n-hexane	1.9137E+05	7.6958E+07		

Non-linear response errors



Combining uncertainties - NORSOK

12.2.6.2.4 Total expanded uncertainty

Total expanded uncertainty ($k=2$) of X_i is calculated as follows:

$$U_{Xi} = (U_{RxI}^2 + U_{CxI}^2 + U_{LxI}^2)^{0.5}$$

U_{Xi} shall be expressed in mole %.

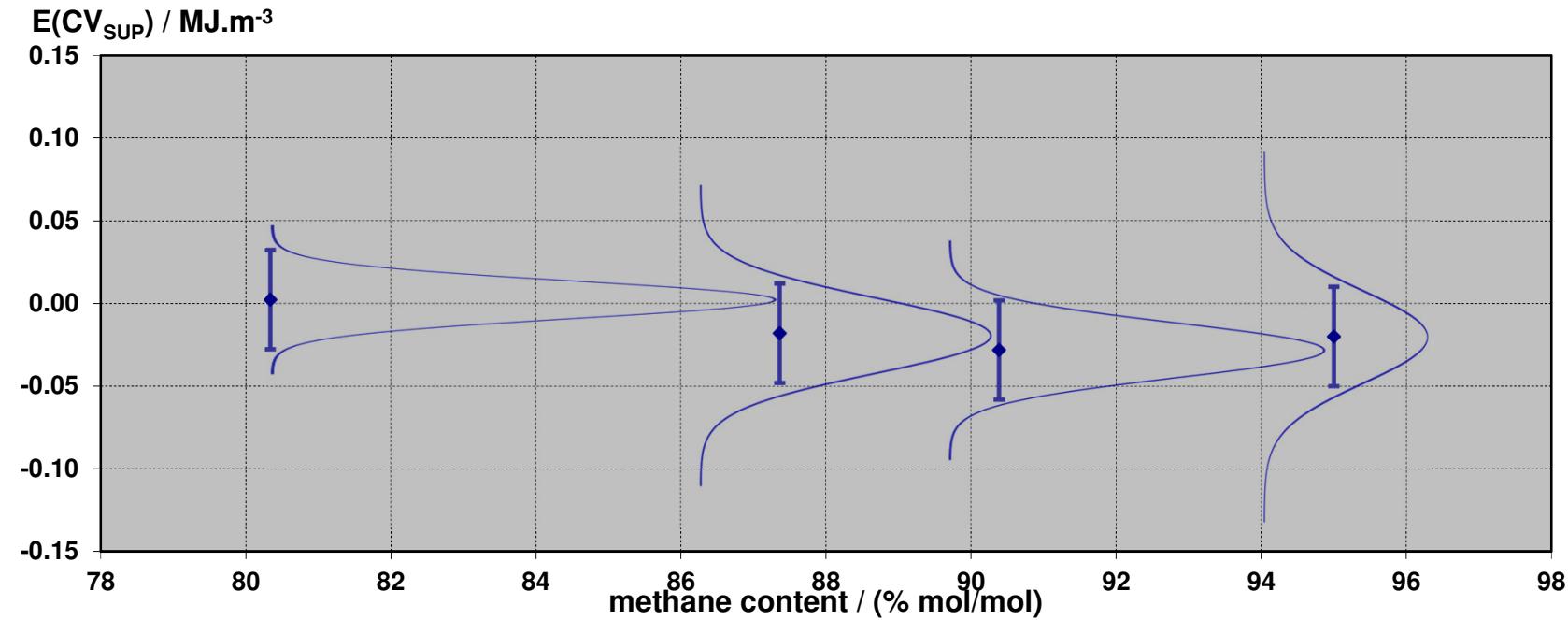
12.2.6.2.5 Gross calorific value

The resulting uncertainty in gross calorific value, U_{Hs} , shall be less than 0,30 % of the gross calorific value,

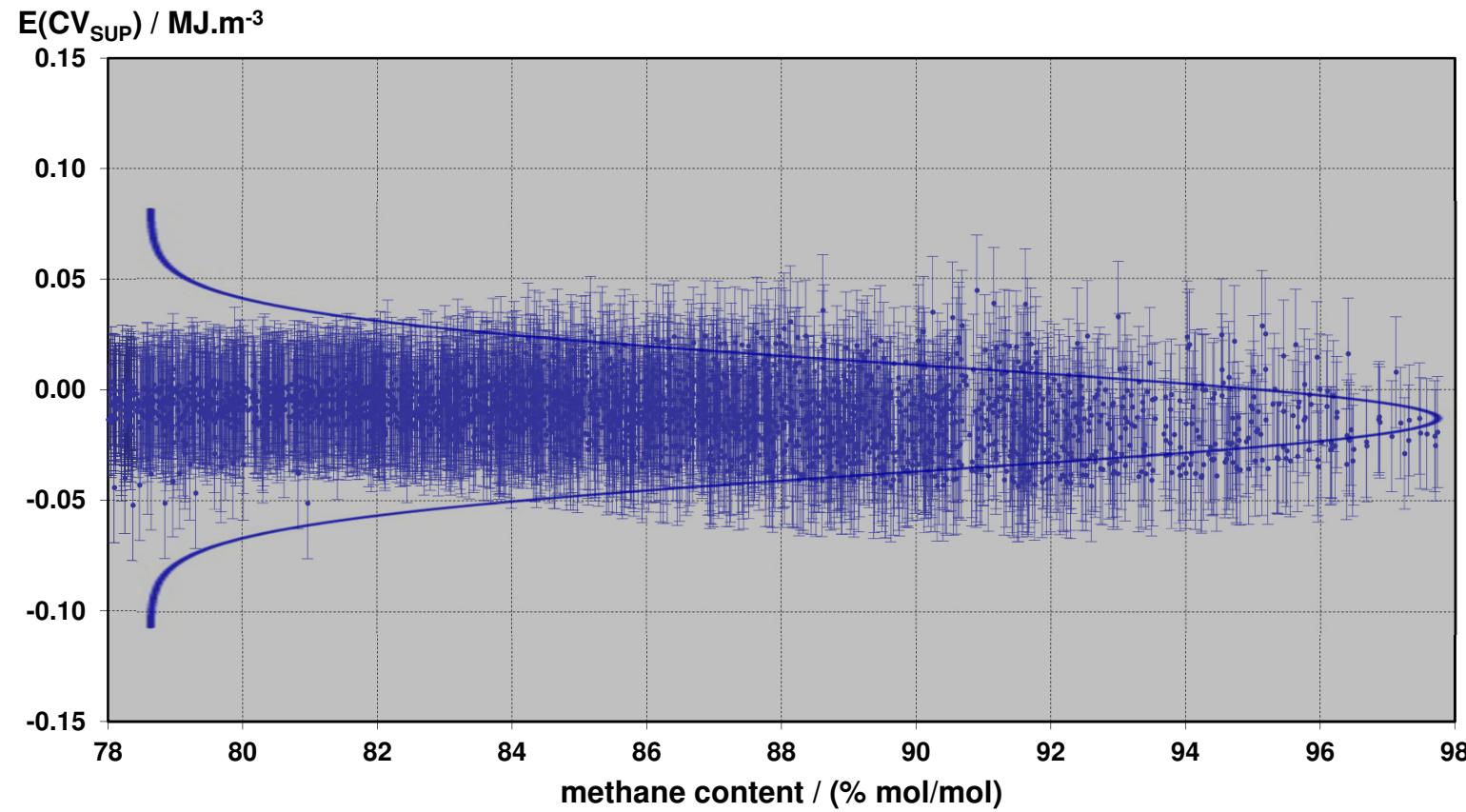
Modelling performance using ISO 10723

- The ISO 10723 models the GC performance
 - Linearity
 - Repeatability
 - Calibration gas composition & uncertainty
- Monte Carlo is run on 10,000 simulated gas compositions to establish
 - Mean error – Bias
 - Uncertainty on the error

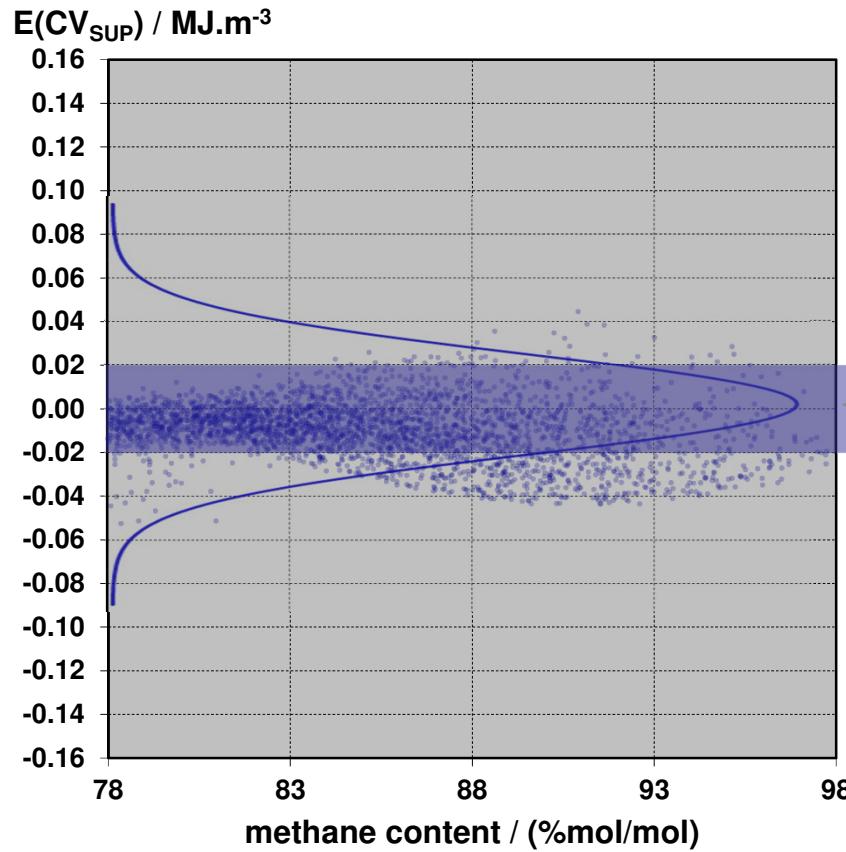
Errors and uncertainties on errors



Error Distribution



Mean Error (Bias)

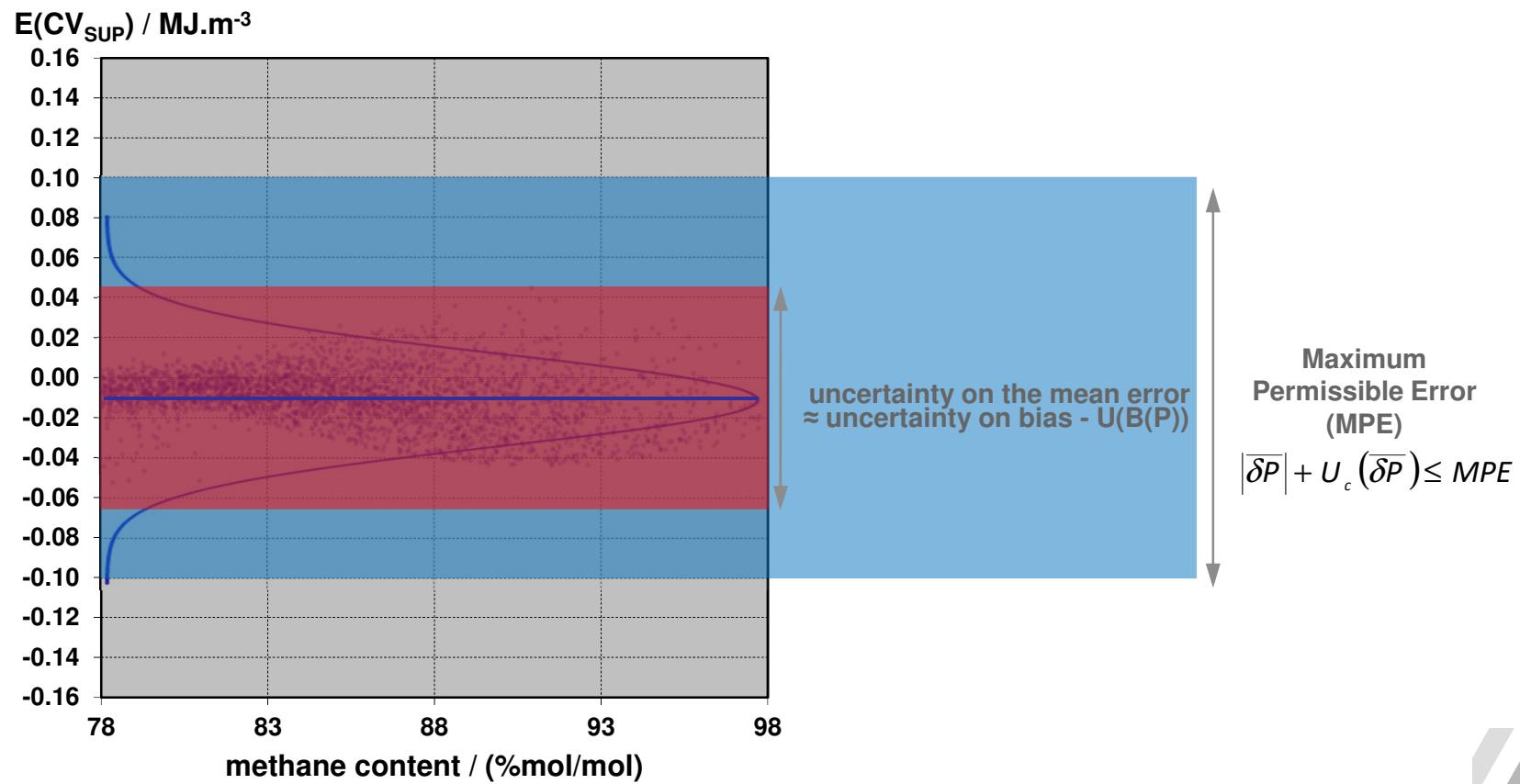


mean error = **bias** - B(P)

Maximum
Permissible Bias
(MPB)

$$|\bar{\delta P}| \leq MPB$$

Uncertainty on Mean Error



Errors and Uncertainties - Summary

component	calibration gas	range (% mol/mol)		errors			uncertainties			bias
		x,min	x,max	E(x),min	E(x),mean	E(x),max	U(x),min	U(x),mean	U(x),max	B(x) (%mol/mol)
nitrogen	4.566	0.001	9.983	-0.033	0.014	0.055	0.005	0.027	0.055	0.0142 ± 0.0440
				-0.35%	4.39%	2973.06%	0.55%	0.83%	29.51%	
carbon dioxide	3.31	0.007	6.999	-0.016	0.012	0.062	0.000	0.016	0.033	0.0117 ± 0.0321
				-0.23%	0.87%	56.64%	0.47%	0.50%	2.60%	
methane	80.311	78.027	97.950	-0.117	-0.045	0.093	0.008	0.041	0.059	-0.0447 ± 0.1000
				-0.13%	-0.05%	0.12%	0.01%	0.05%	0.07%	
ethane	7.03	0.013	11.944	-0.087	0.013	0.063	0.000	0.019	0.049	0.0130 ± 0.0503
				-0.73%	0.80%	3.65%	0.41%	0.46%	0.96%	
propane	3.304	0.004	6.851	-0.029	0.003	0.025	0.001	0.008	0.036	0.0029 ± 0.0167
				-49.52%	0.04%	1.46%	0.52%	0.69%	29.81%	
iso-butane	0.5245	0.001	0.999	-0.002	0.001	0.011	0.000	0.002	0.007	0.0007 ± 0.0050
				-1.03%	1.59%	232.12%	0.67%	0.82%	10.07%	
n-butane	0.4983	0.001	0.964	-0.001	0.000	0.009	0.000	0.002	0.007	0.0004 ± 0.0042
				-61.81%	-0.92%	1.21%	0.00%	0.81%	16.01%	
neo-pentane	0.1122	0.000	0.034	0.000	0.001	0.001	0.000	0.000	0.001	0.0006 ± 0.0002
				1.22%	78.28%	7277.83%	1.65%	5.28%	21.21%	
iso-pentane	0.1123	0.000	0.348	-0.001	0.000	0.003	0.000	0.001	0.004	0.0003 ± 0.0018
				-0.23%	0.88%	125.38%	1.07%	1.47%	72.29%	
n-pentane	0.1098	0.000	0.350	-0.001	0.000	0.005	0.000	0.001	0.005	0.0002 ± 0.0023
				-95.25%	-1.57%	1.45%	0.00%	2.04%	382.06%	
n-hexane	0.1159	0.000	0.350	-0.005	0.001	0.002	0.000	0.002	0.007	0.0008 ± 0.0043
				-1.52%	28.44%	6398.26%	2.05%	2.18%	4.65%	

property	range			errors			uncertainties			bias
	P,min	P,mean	P,max	E(P),min	E(P),mean	E(P),max	U(P),min	U(P),mean	U(P),max	B(P)
calorific value (superior)	31.7	37.9	46.0	-0.039	-0.0011	0.032	0.004	0.017	0.029	-0.001 ± 0.029
real superior calorific value (MJ.m ⁻³)				-0.088%	-0.003%	0.079%	0.010%	0.045%	0.075%	

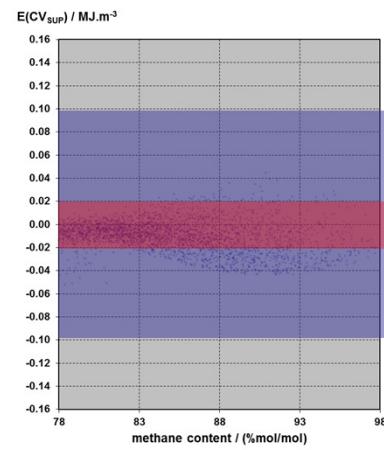
Uncertainty Comparison

- Norsok

Property	Uncertainty
Gross CV	< 0.3%

- ISO 10723 (UK specification)

Property	Uncertainty
Gross CV	MPB < 0.09 MJ.m ³
Gross CV	MPE < 0.18 MJ.m ³
	MJ.m ³ (0.45%)



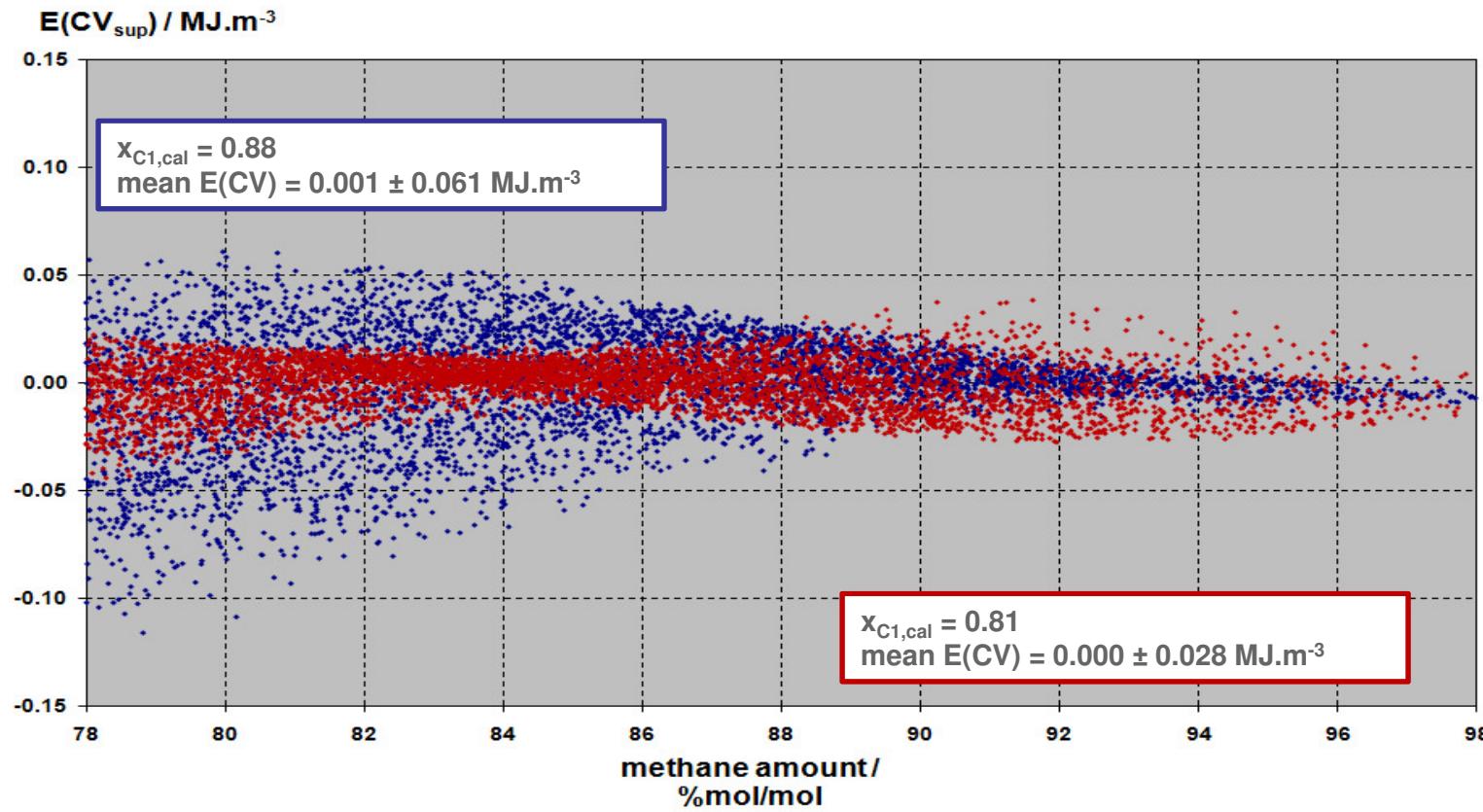


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Additional advantages of ISO 10723

Optimising Calibration Gas Design



Operating the GC in a type 1 mode (ISO6974)

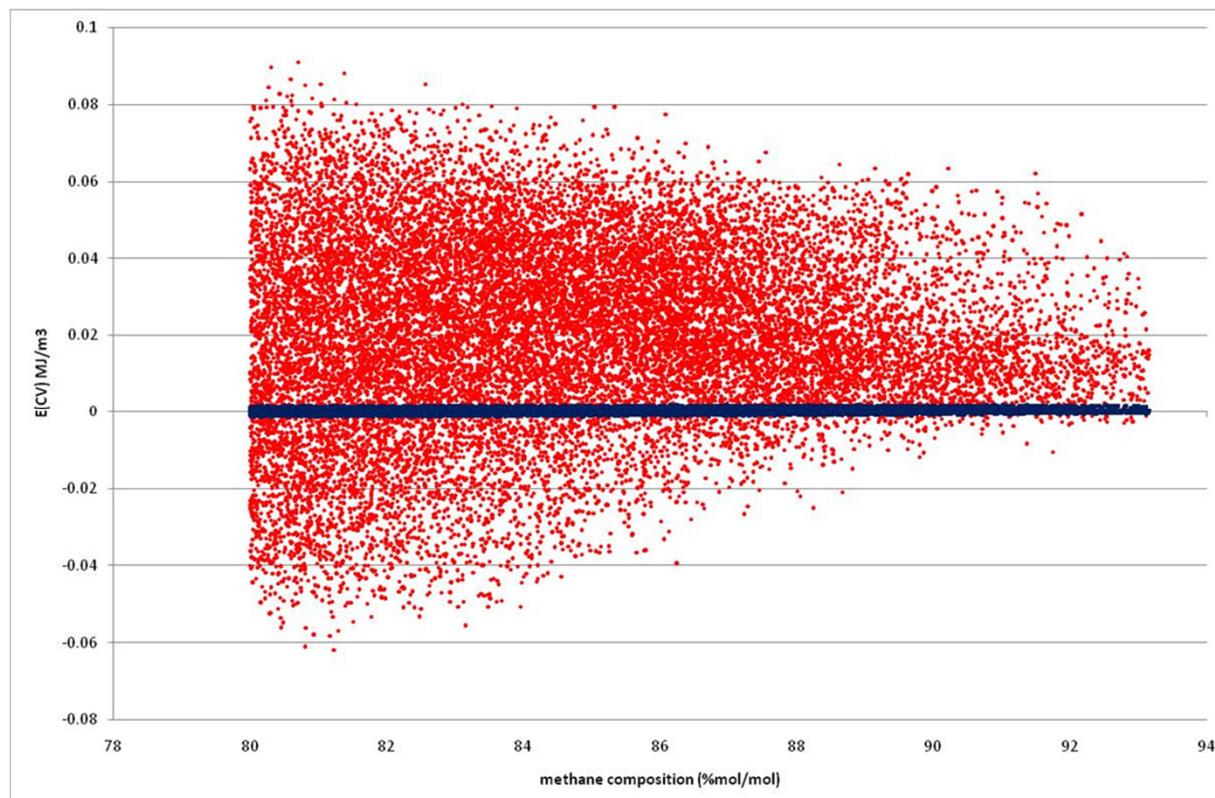
Component Data Table 1 (Total Concentration = 99.99931%)

#	Component	Multi-level Calib 'a'	Multi-level Calib 'b'	Multi-level Calib 'c'	Multi-level Calib 'd'	Ref Component	Rel Resp Factor
1	C6+47/35/17	0	0	7.0135e-008	-0.002305	None	0
2	PROPANE	0	0	1.0838e-007	0.00093282	None	0
3	i-BUTANE	0	0	9.4729e-008	-0.0015043	None	0
4	n-BUTANE	0	0	9.1269e-008	0.0024629	None	0
5	NEOPENTANE	0	0	0	0	None	0
6	i-PENTANE	0	0	1.5178e-005	-0.00075068	None	0
7	n-PENTANE	0	0	1.6396e-005	0.00096001	None	0
8	NITROGEN	0	0	1.8562e-007	-0.0099587	None	0
9	METHANE	0	0	2.4456e-007	-6.6871	None	0
10	CARBON DIOXIDE	0	0	1.5324e-007	-0.0039513	None	0
11	ETHANE	0	2.4536e-017	1.3646e-007	-0.00044109	None	0

Std Comps (F2)... Std Values (F3)... Raw Data (F4)... Update STD (F5) Sort RT (F6) OK Cancel

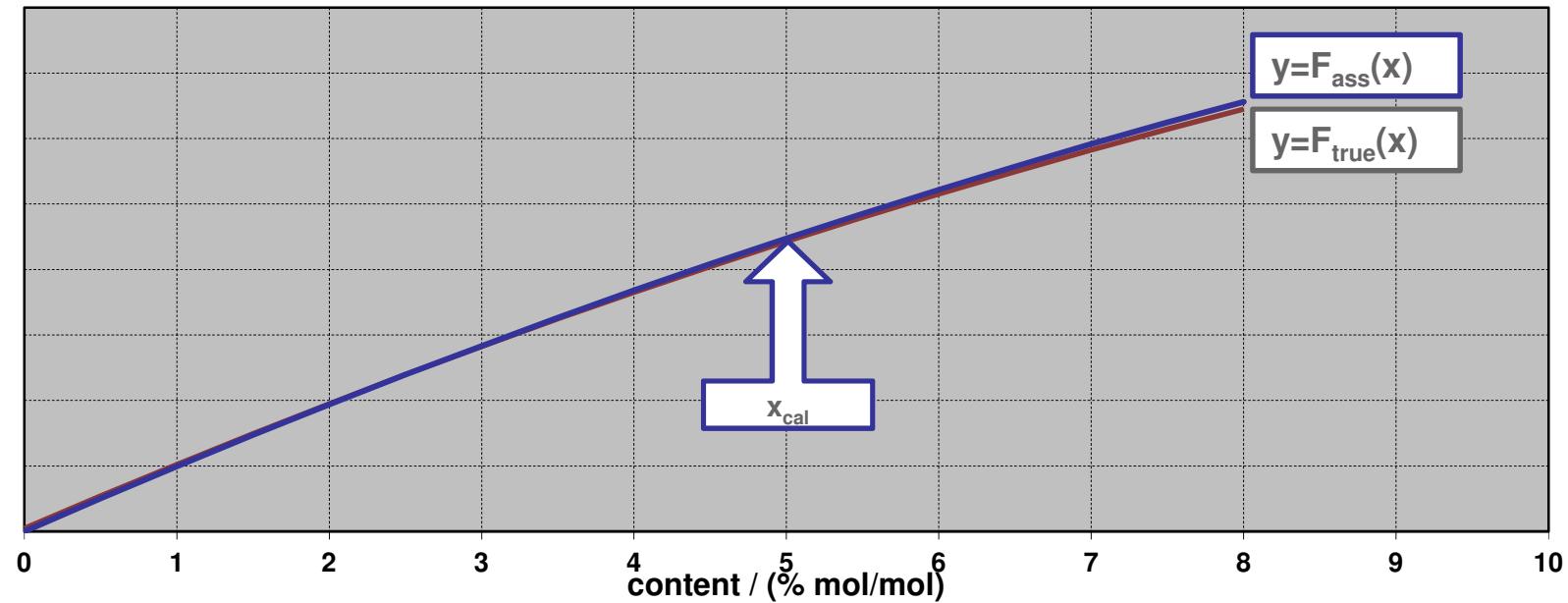
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Type 1 mode vs Type 2 mode



Calibration gas – reduce dewpoint = increase fill pressure

response / (peak area)





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Simulating a NORSOK Test using ISO 10723 data

Simulating a NORSOK Test using ISO 10723 data

Component	Danalyser	
	Simulated	Real
	Linearity Uncertainty Uncertainty $K = 2$ U_{LXi}	Linearity Uncertainty Uncertainty $K = 2$ U_{LXi}
C1	0.111	0.118
C2	0.028	0.031
C3	0.010	0.016
iC4	0.001	0.001
nC4	0.006	0.002
neoC5	0.000	0.000
iC5	0.001	0.000
nC5	0.000	0.001
C6	0.054	0.060
N2	0.003	0.002
CO2	0.008	0.008
O2	0.000	0.000
$U_{HS} (\%_{rel})$	0.18%	0.20%
$U_{ms} (\%_{rel})$	0.18%	0.20%
$U_{EF} (\%_{rel})$	0.22%	0.24%

Simulating a NORSOK Test using ISO 10723 data

Component	Encal	
	Simulated	Real
	Linearity Uncertainty Uncertainty K =2 U_{LX_i}	Linearity Uncertainty Uncertainty K =2 U_{LX_i}
C1	0.001	0.192
C2	0.001	0.019
C3	0.0004	0.007
iC4	0.0001	0.001
nC4	0.002	0.002
neoC5	0.000	0.000
iC5	0.000	0.000
nC5	0.000	0.000
C6	0.0002	0.001
N2	0.0002	0.002
CO2	0.000	0.007
O2	0.000	0.000
$U_{HS} (\%_{rel})$	0.03%	0.04%
$U_{ms} (\%_{rel})$	0.04%	0.06%
$U_{EF} (\%_{rel})$	0.04%	0.06%

Simulating a NORSOK Test using ISO 10723 data

Component	Maxum II	
	Simulated Linearity Uncertainty Uncertainty K =2 U_{LXi}	Real Linearity Uncertainty Uncertainty K =2 U_{LXi}
C1	0.065	0.092
C2	0.043	0.049
C3	0.012	0.023
iC4	0.001	0.003
nC4	0.001	0.002
neoC5	0.000	0.000
iC5	0.001	0.001
nC5	0.000	0.001
C6	0.003	0.003
N2	0.002	0.008
CO2	0.001	0.003
O2	0.000	0.000
$U_{HS} (\%_{rel})$	0.04%	0.05%
$U_{ms} (\%_{rel})$	0.04%	0.05%
$U_{EF} (\%_{rel})$	0.05%	0.06%

Summary

- Norsok test & ISO 10723 both determine instrument performance ✓
- ISO 10723 has some additional advantages:
 - Accurately model instrument response characteristics (up to 3rd order polynomial)
 - Determine uncertainties over range or determine the instrument range within a given uncertainty
 - Provides data for GC to be operated in Type 1 mode according to ISO 6974 (minimising errors)
 - Determine optimum calibration gas composition
 - Decide if a new stream can be added to an existing GC
 - Identify which component is at fault if issues are identified with GC
 - Determine Limits of Detection (LOD)
 - ISO 17025 calibration certificate can be issued for Emissions Trading Requirements (EU/ETS)
 - Can be used to simulate NORSOOK test results



Global Leaders in Gas Measurement

Contact details



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ISO 9001:2008 FS 554539



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