Fluxus Natural Gas Engine

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Content

Flexim Company History

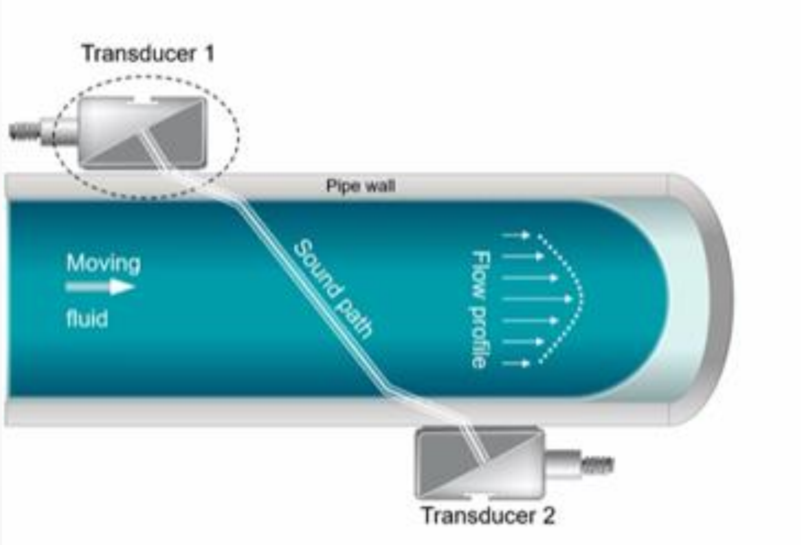
Headquarter in Berlin

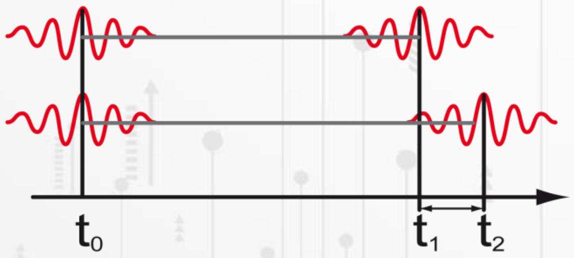
- 270 employees
- Manufacturing, calibration, research & development
- All shareholders are company founders
- Technology driven development

Global Company

- Branches worldwide
- Final production, service support points and calibration facilities in target markets
- Approximately 500 direct FLEXIM employees worldwide
- Extensive Representative and Distributor Network

Ultrasonic Meters Sound Speed Principle





Ultrasonic flow meters can measure sound speed and flow simultaneously:

Sonic velocity:

$$c_{Fluid} = \frac{l_{Fluid}}{\frac{t_{down} + t_{up}}{2} - t_0}$$

Volume flow:

$$Q = K_{\mathrm{Re}} \cdot A \cdot K_{\alpha} \frac{\Delta t}{2t_{fl}}$$

Introduction to Fluxus Natural Gas Engine

NORTH SEA FLOW MEASUREMENT WORKSHOP
measuring for the energy transition

- USM Gas Measurement is widely accepted in the Oil & Gas Industry, however, changes in gas composition can have an effect in meter accuracy and require additional field instrumentation to convert meter output from actual to standard conditions.
- Since natural gas is a multicomponent, not ideal gas, compressibility factor calculations are challenging and require knowledge of gas composition.
- Traditionally, the process of estimating the Z-factor involved empirical correlations, which often yielded weak results either due to their limited accuracy or due to calculation difficulties, therefore;

$$Z = \frac{PV}{nRT}$$

Not Applicable

Gas Chromatographer and a Flow Computers are used for:

1. **Unit conversion from actual to standard conditions**
2. **Calculate gas compressibility factor Z**
3. **Molecular weight**
4. **Density & Calorific Values**

Actual to Standard Conversion for Gases

- AGA-9 is the standard for ultrasonic gas flow measurement
- AGA-9 formula for Standard Volume:
- STD volume is compensated for pressure – temp - compressibility

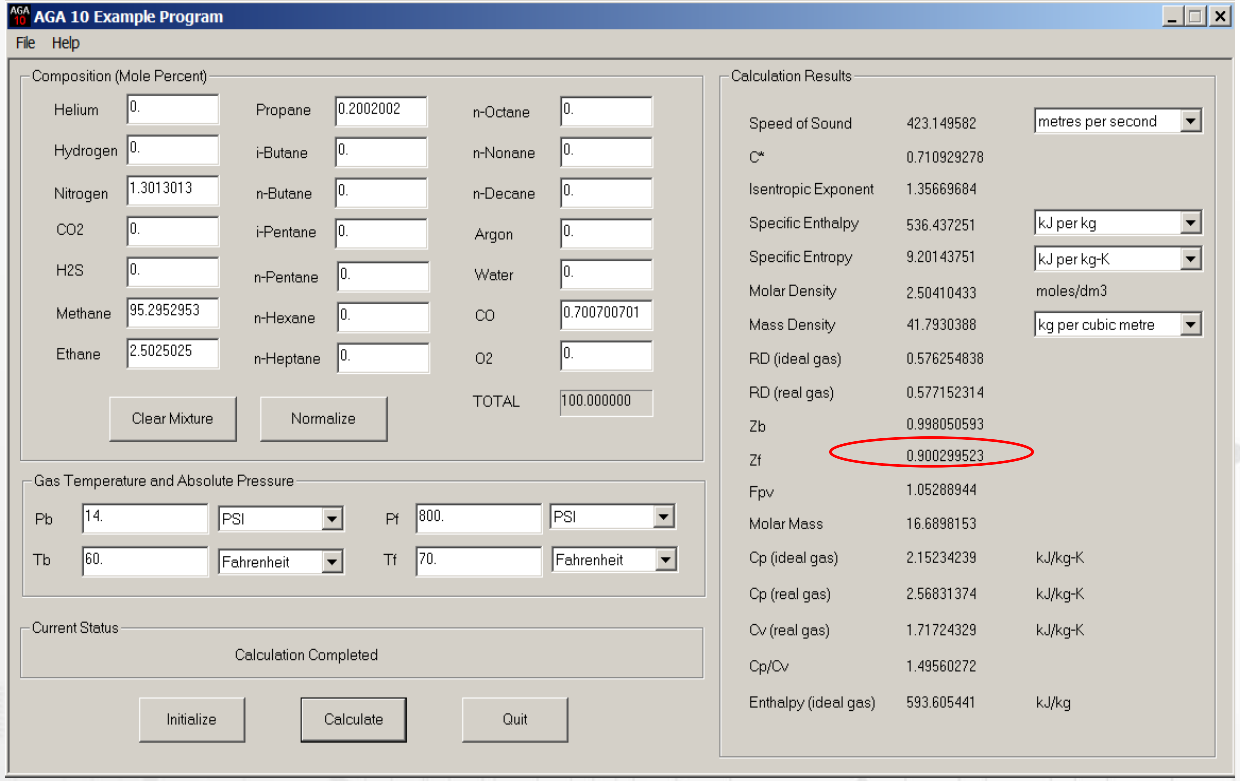
$$Q_b = Q_f \, (P_f/P_b)\,(T_b/T_f)\,(Z_b/Z_f)$$

Where:

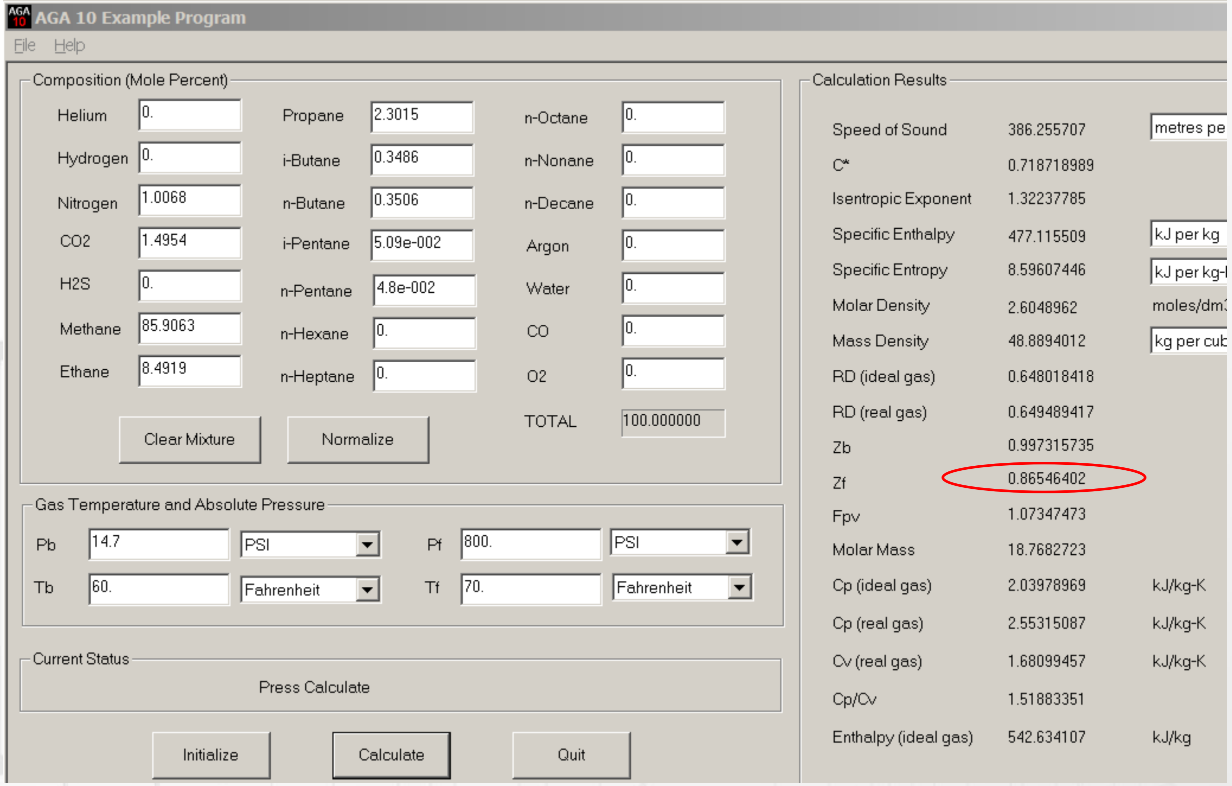
Q_b	=	Flow rate at base conditions
Q_f	=	Flow rate at flowing conditions
P_b	=	Base pressure, typically 14.73 psia (101.325 kPa)
P_f	=	Absolute static pressure of gas at flowing conditions from meter tap
T_b	=	Base temperature, typically 519.67 °R (288.15 °K)
T_f	=	Absolute temperature of gas at flowing conditions
Z_b	=	Compressibility factor of gas at base conditions, per A.G.A. Report No. 8
Z_f	=	Compressibility factor of gas at flowing conditions, per A.G.A. Report No. 8

Software – Calculates Z (compressibility)

Standard Natural Gas Example



Low Methane Content Example



Speed of Sound Changes Based On Gas Composition

- The speed of sound in natural gas is the velocity a sound wave travels in the gas.
- Properties of different gases such as composition, P&T affect the speed of sound
- Uncertainty in Compressibility factor = decreased accuracy

AGA 10 States:
"One of the USM meter diagnostics is comparing the speed of sound determined by the meter to the theoretical speed of sound in the gas as calculated by AGA Report No. 10."

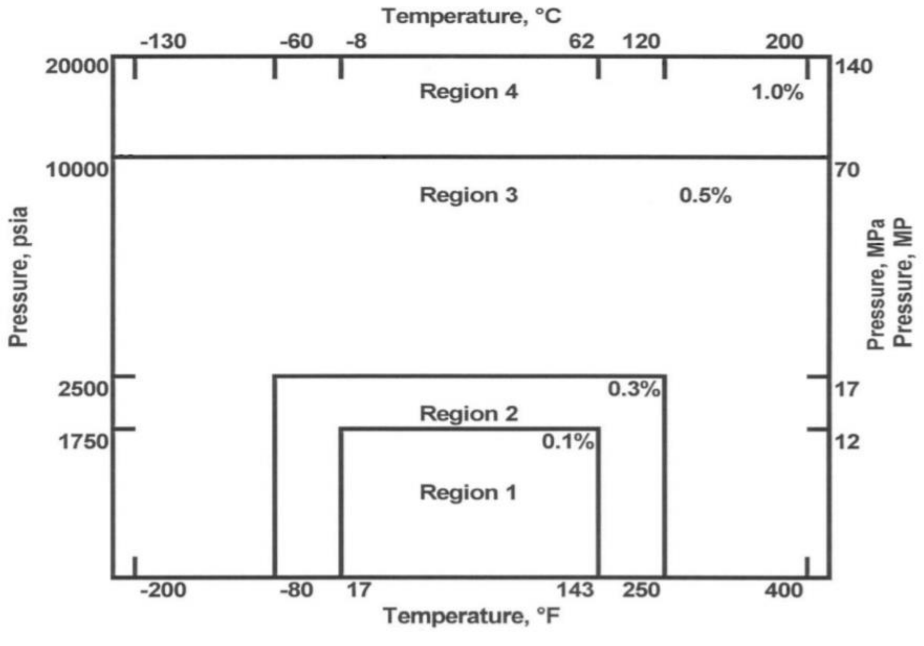


Figure 1: Targeted Uncertainty for Natural Gas Speed of Sound Using the AGA Report No. 10 Method

Typical Effect on SoS of P&T changes VS Composition Changes

TEMP → / PRESS ↓	30°F	31°F	35°F	40°F	60°F	70°F	90°F	100°F	120°F
200 PSIG	1351.1	1352.6	1358.5	1365.9	1394.4	1408.3	1435.1	1448.1	1473.4
201 PSIG	1351.0	1352.5	1358.4	1365.8	1394.3	1408.2	1435.0	1448.0	1473.4
202 PSIG	1350.9	1352.4	1358.3	1365.7	1394.3	1408.1	1434.9	1448.0	1473.3
205 PSIG	1350.5	1352.0	1358.0	1365.4	1394.0	1407.9	1434.8	1447.8	1473.2
210 PSIG	1350.0	1351.5	1357.5	1364.9	1393.6	1407.5	1434.4	1447.5	1472.9
500 PSIG	1321.6	1323.4	1330.4	1339.1	1372.4	1388.4	1418.9	1433.6	1461.9
501 PSIG	1321.5	1323.3	1330.3	1339.0	1372.4	1388.3	1418.9	1433.6	1461.9
502 PSIG	1321.4	1323.2	1330.3	1338.9	1372.3	1388.3	1418.8	1433.5	1461.9
505 PSIG	1320.7	1323.0	1330.0	1338.7	1372.1	1388.1	1418.7	1433.4	1461.8
510 PSIG	1320.7	1322.5	1329.6	1338.3	1371.8	1387.8	1418.5	1433.3	1461.7
1000 PSIG	1296.3	1298.4	1306.8	1317.1	1356.2	1374.6	1409.7	1426.4	1458.3
1001 PSIG	1296.3	1298.4	1306.8	1317.0	1356.2	1374.6	1409.7	1426.4	1458.3
1005 PSIG	1296.2	1298.4	1306.7	1317.0	1356.2	1374.7	1409.7	1426.4	1458.4
1010 PSIG	1296.2	1298.3	1306.7	1317.0	1356.2	1374.7	1409.7	1426.5	1458.5

Table 2 Speed of Sound in Ft/Sec

Components in Mole Percent	Gulf Coast Gas	Ekofisk Gas	Amarillo Gas	Air
Speed of Sound @14.73 & 60°F	1412.4	1365.6	1377.8	1118.05
G_r	0.581078	0.649521	0.608657	1.00
Heating Value	1036.05	1108.11	1034.85	
Methane	96.5222	85.9063	90.6724	
Nitrogen	0.2595	1.0068	3.1284	78.03
Carbon Dioxide	0.5956	1.4954	0.4676	0.03
Ethane	1.8186	8.4919	4.5279	
Propane	0.4596	2.3015	0.8280	
i-Butane	0.0977	0.3486	0.1037	
n-Butane	0.1007	0.3506	0.1563	
i-Pentane	0.0473	0.0509	0.0321	
n-Pentane	0.0324	0.0480	0.0443	
n- Hexane	0.0664	0.0000	0.0393	

Table 3 Reference Gas Compositions

Content

Fluxus - Natural Gas Engine Principle

- SoS and Thermodynamic variables applied to calculate Z, MW and HHV derived from pressure and temperature inputs under operating conditions.
- Standard unit conversion calculated dynamically withing the Fluxus meter
- Natural gases are divided into classes based on their HHV in MJ/Kg
- No need to know exact gas composition
- HHV calculation requires known % of N2 & CO2

Class 2. High HHV – NGE - H

name	min	mean	max
temperature [°C]	-1	30	81
pressure [bar]	0.4	63	98
HHV [MJ/kg]	43	51.9	54.7
mol. weight [g/mol]	16.7	18.9	30.8
methane [mol%]	42	87.1	97.1
ethane [mol%]	0.3	7.0	23.7
propane [mol%]	0.01	2.1	15.5
i-butane [mol%]	0	0.47	3.9
n-butane [mol%]	0	0.47	5.3
i-pentane [mol%]	0	0.16	1.44
n-pentane [mol%]	0	0.1	1.3
n-hexane [mol%]	0	0.13	1.02
n-heptane [mol%]	0	0.07	0.37
C8 & more [mol%]	0	0.02	0.21
O_2 [mol%]	0	0	0.22
N_2 [mol%]	0.08	0.44	6.97
CO_2 [mol%]	0	1.99	10.3

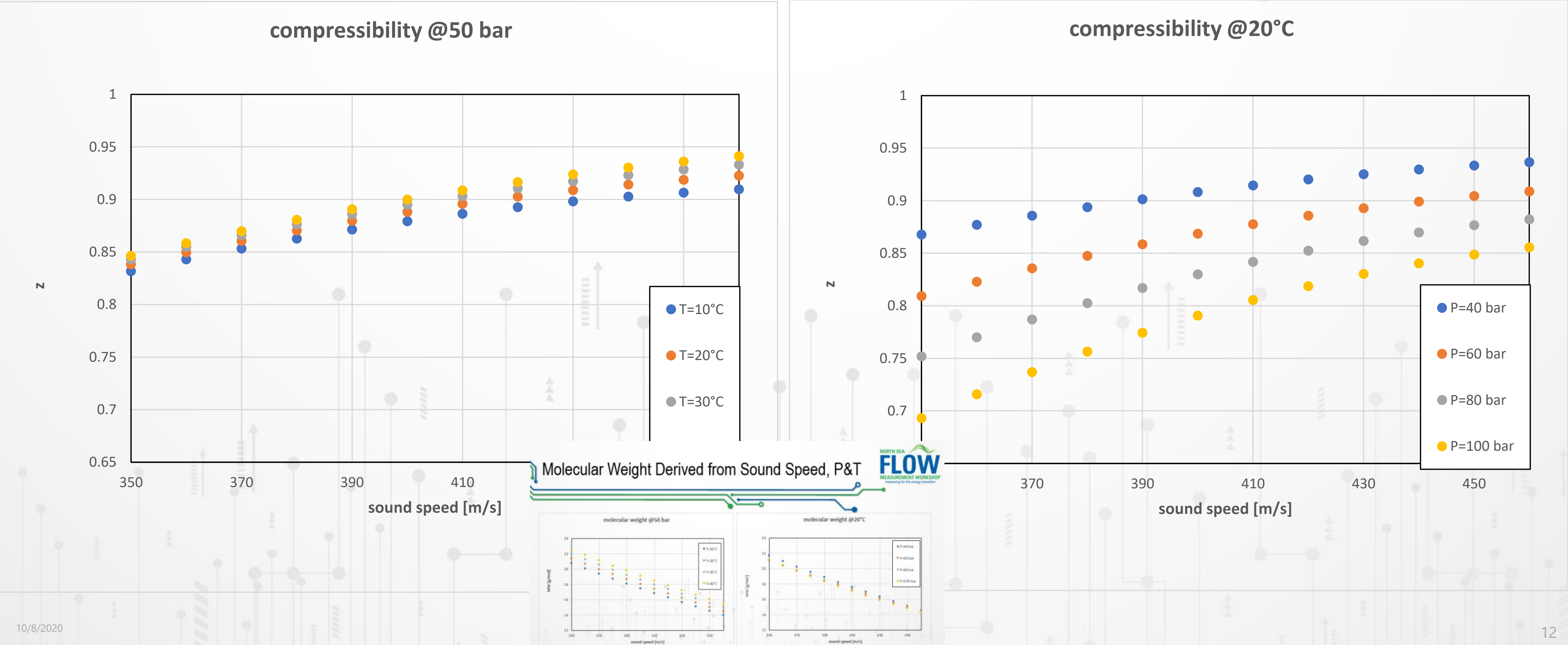
Class 3. High HHV – NGE - L

Name	min	mean	max
temperature [°C]	3	26	85
pressure [bar]	5	42	95
HHV [MJ/kg]	25	35.3	43.4
mol. weight [g/mol]	20.7	23.3	26.8
methane [mol%]	60.1	72.3	91.9
ethane [mol%]	2.34	5.02	9.74
propane [mol%]	0.69	1.87	3.81
i-butane [mol%]	0.15	0.42	0.93
n-butane [mol%]	0.14	0.51	1.09
i-pentane [mol%]	0.05	0.18	0.44
n-pentane [mol%]	0.03	0.14	0.32
n-hexane [mol%]	0.02	0.17	0.46
n-heptane [mol%]	0.01	0.09	0.22
C8 & more [mol%]	0	0.02	0.07
O_2 [mol%]	0	0	0.03
N_2 [mol%]	0.33	0.84	1.67
CO_2 [mol%]	10.3	18.4	32.8

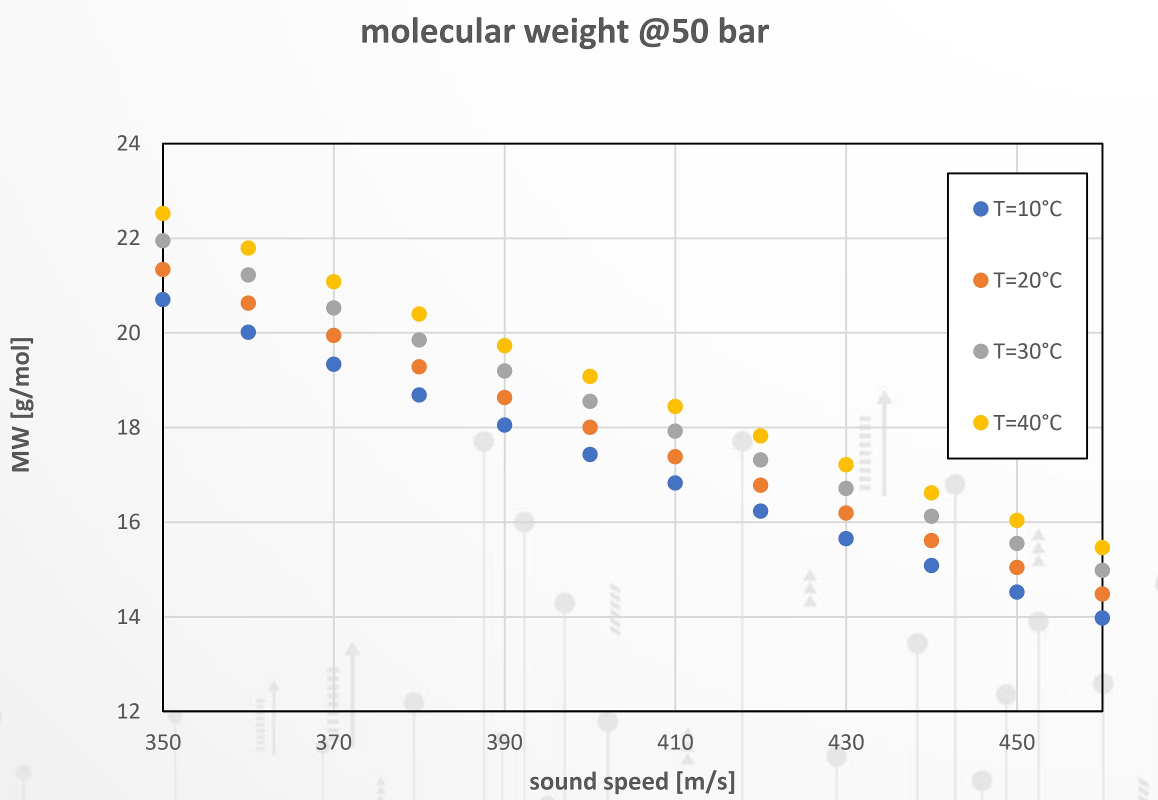
Class 4. High HHV – NGE - F

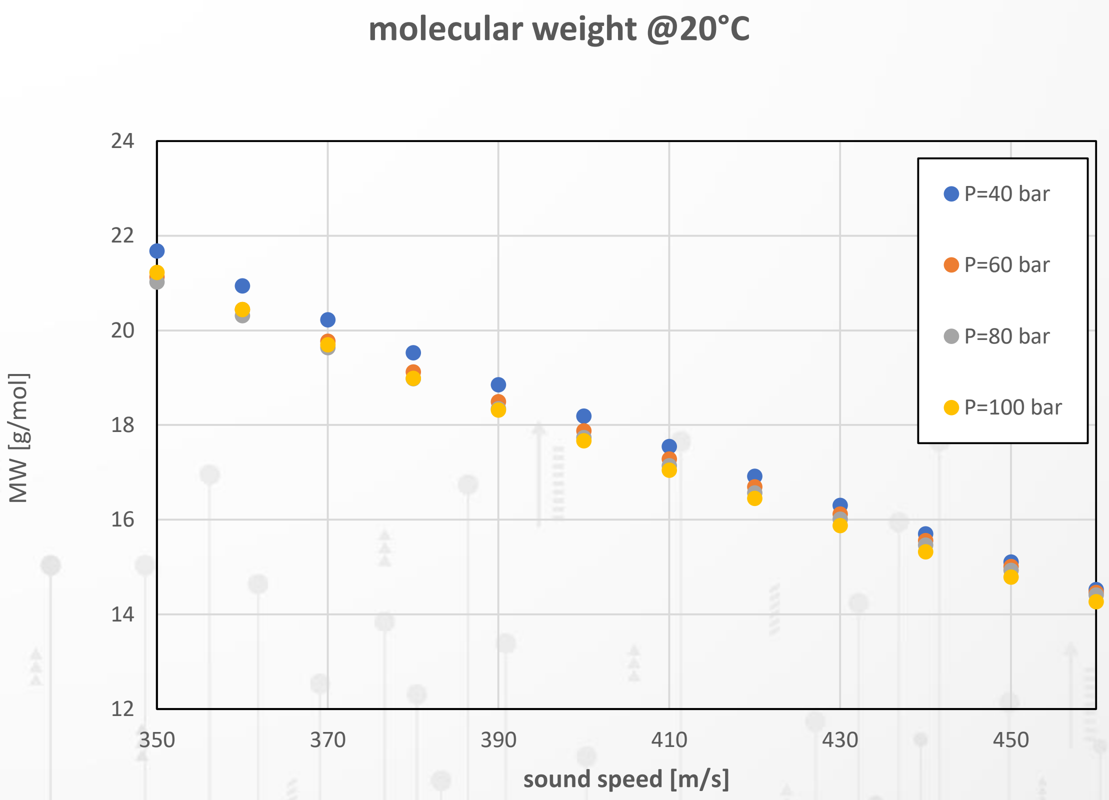
Name	min	mean	Max
temperature [°C]	10	28	52
pressure [bar]	0.05	6.3	53
HHV [MJ/kg]	1.9	16.2	53.2
mol. weight [g/mol]	17.3	31.8	41.6
methane [mol%]	8.1	42.9	95.0
ethane [mol%]	0.15	1.48	8.32
propane [mol%]	0.02	0.29	2.91
i-butane [mol%]	0	0.07	0.76
n-butane [mol%]	0	0.09	0.70
i-pentane [mol%]	0	0.03	0.39
n-pentane [mol%]	0	0.03	0.72
n-hexane [mol%]	0	0.06	3.05
n-heptane [mol%]	0	0.06	1.92
C8 & more [mol%]	0	0.02	0.32
O_2 [mol%]	0	0.01	0.64
N_2 [mol%]	0.18	0.75	3.29
CO_2 [mol%]	0	54.3	90.6

Compressibility (***Z Factor***) Derived from Sound Speed, P&T



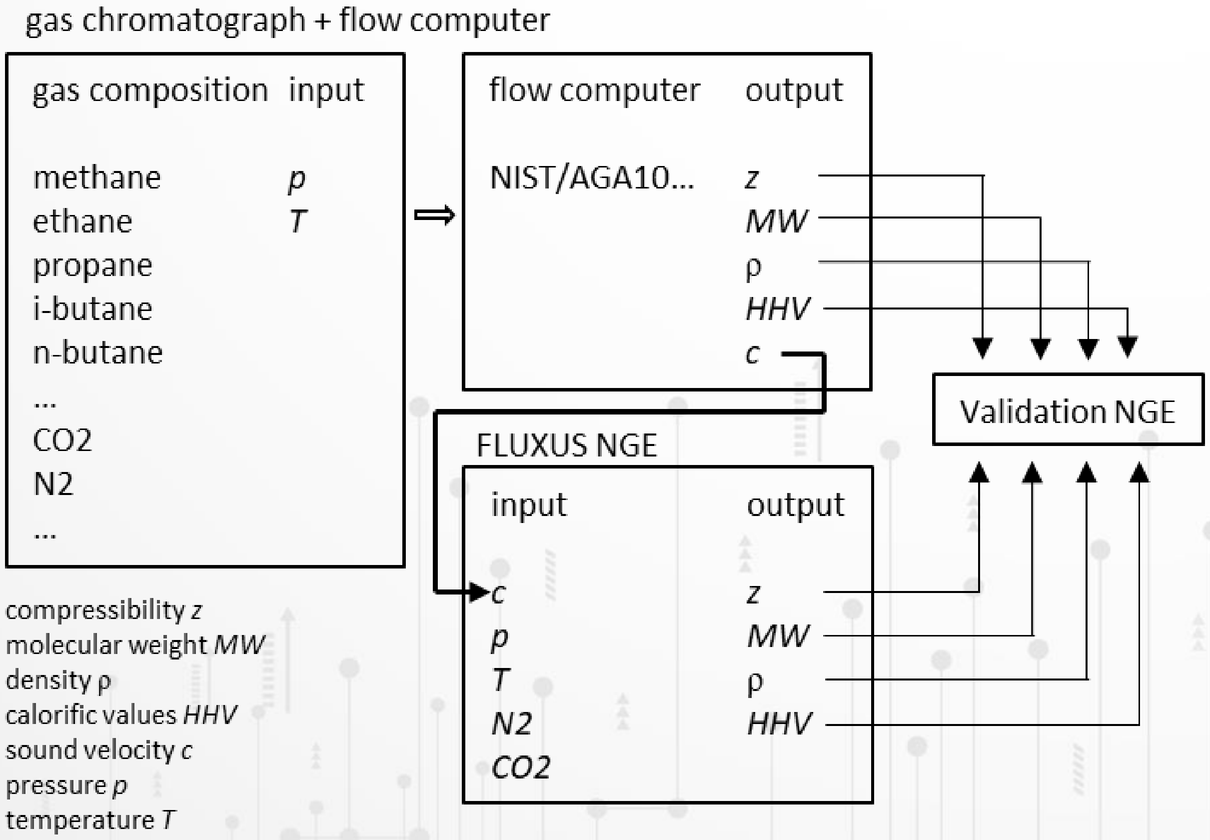
Molecular Weight Derived from Sound Speed, P&T





Fluxus - Natural Gas Engine Principle

Industry-standard method vs. NGE



Internal Calculations derived from SoS

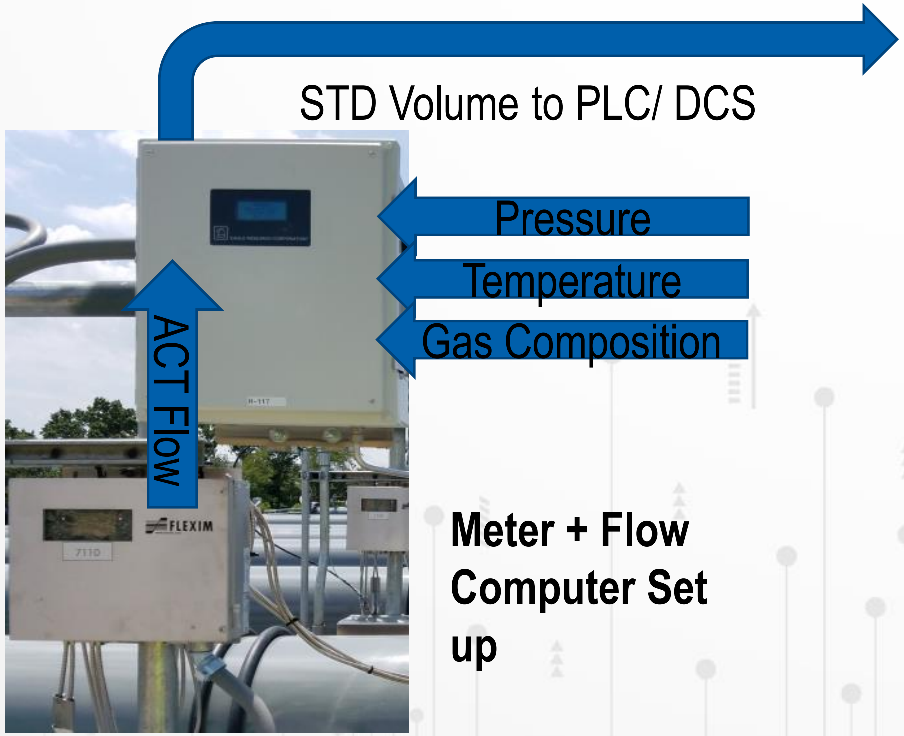
- *zNGE = z(c, T, p)*
- *MWNGE = MW(c, T, p)*
- *HHVNGE = HHV(c, MW, N2, CO2)*

Measurement uncertainties

- Technical specs of P&T Sensors
- Sound velocity uncertainty of Fluxus Clamp on meter
- Meter installation & Sensitivity coefficients

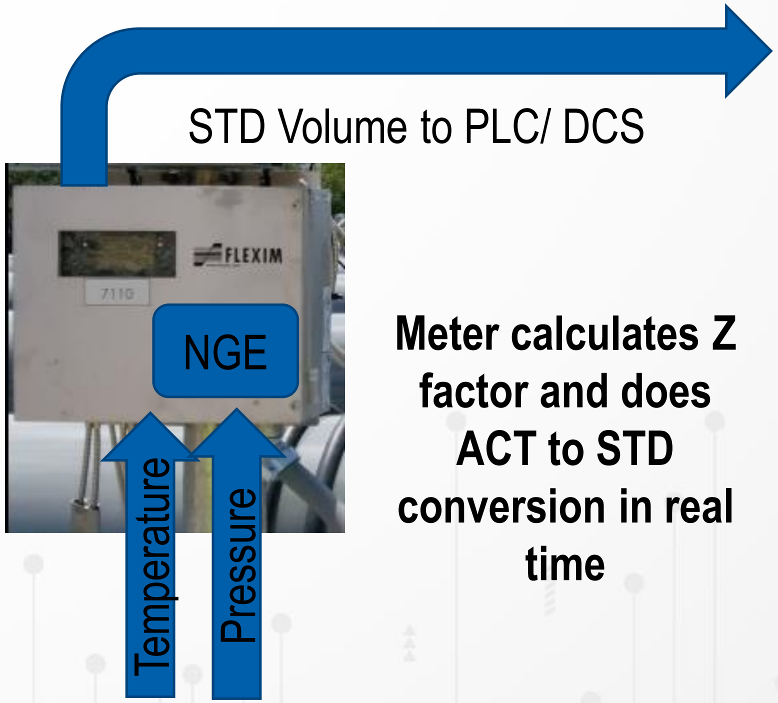
Natural Gas Engine Replaces Flow Computer

Standard methodology



Meter + Flow Computer Set up

VS



Meter calculates Z factor and does ACT to STD conversion in real time

New Simplified Approach

NGE Accuracy Results Comparison Vs Flow Comp.

Compressibility z and MW for NGE vs. flow computer

	class 2	class 3	class 4
sample std. dev. z_{NGE}	0.7%	0.9%	0.4%
data points within 1%	84.3%	80.3%	96.2%
data points within 2%	97.6%	91.0%	99.5%
data points >3% off	0.1%	0.7%	0%
sample std. dev. MW_{NGE}	1.1%	1.3%	1.1%
data points within 1%	59.0%	65.3%	85.8%
data points within 2%	90.4%	85.3%	92.9%
data points >3% off	3.5%	4.7%	4.4%

HHV for NGE vs. flow computer

	class 2	class 3	class 4
sample std. dev. HHV in MJ/kg	0.7%	1.2%	3.4%
data points within 1%	85.1%	52.3%	19.7%
data points within 2%	98.8%	85.7%	29.0%
data points >3% off	0.0%	1.7%	19.1%
sample std. dev. HHV in MJ/m^3	1.4%	2.3%	4.6%
data points within 1%	59.1%	33.3%	20.8%
data points within 2%	88.2%	61.7%	31.2%
data points >3% off	5.0%	26.7%	19.1%

Over 2000 measuring points were evaluated and compared to Flow Computer outputs to determine deviation.

How Does Class Selection Affect NGE Calculations?

P [bar]	60
T [°C]	20

		nitrogen	CO2	methane	ethane	propane	isobutane	butane	isopentane	pentane	hexane	heptane	octane
Ref. Gas H	Nordsee H	0.009	0.019	0.863	0.086	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ref. Gas L	Ingreso a Planta ADLA	1.287	18.537	74.442	3.303	1.209	0.251	0.400	0.158	0.131	0.167	0.095	0.021

Z & MW Results

FLUXUS measure	NIST		NGE correct gas class		NGE wrong gas class	
c	Z	MW	Z	MW	Z	MW
[m/s]		[g/mol]		[g/mol]		[g/mol]
390.78	0.860	18.43	0.860	18.64	0.890	18.70
346.90	0.842	22.84	0.840	22.48	0.805	22.01

NGE vs NIST Z Factor calculation with +/- 0.6% deviation

HHV Results

NIST	NGE correct gas class	NGE wrong gas class
HHV	HHV	HHV
[MJ/kg]	[MJ/kg]	[MJ/kg]
51.56	51.6	54
34.30	34.2	32.1

NGE vs NIST HHV Factor calculation with +/- 0.3% deviation

Content

Conclusion

1. Fluxus NGE embedded feature in Clamp On Ultrasonic Meter
2. Enables real time dynamic gas compressibility calculation without a known composition input
3. Performs actual to standard conversion without flow computer.
4. Live line pressure and temperature inputs required
5. 3 main gas classes for end user to select based on HHV
6. MW and HHV calculations possible with known N2 and CO2 content

Content

References

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