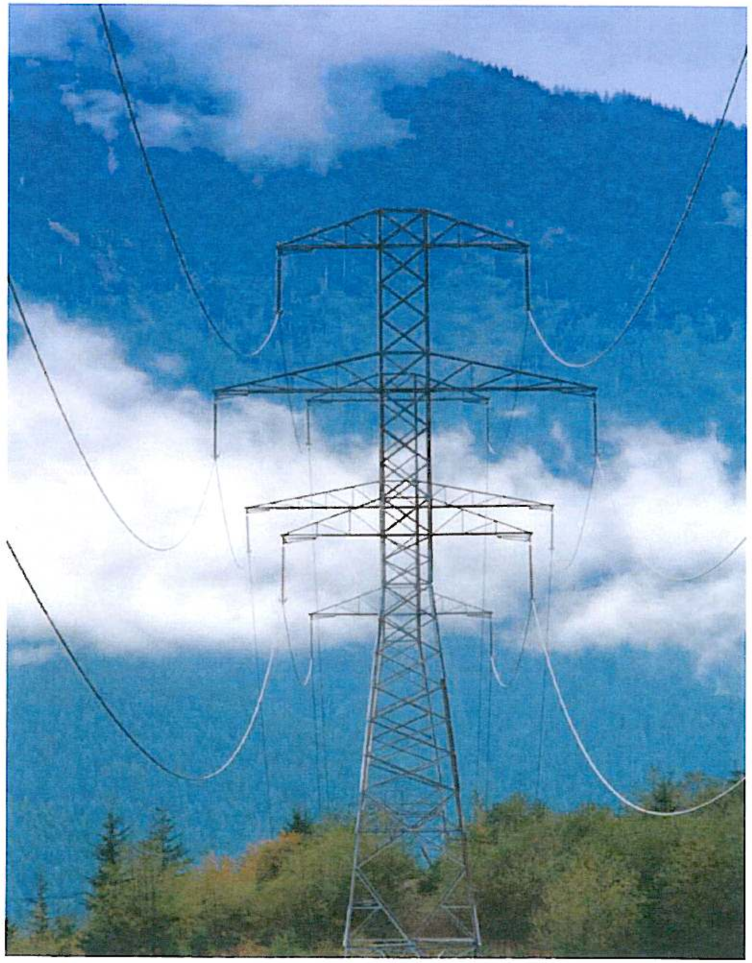


Gas Density Monitoring Equipment

EPA-Conference on SF_6 & the Environment, 2006, San Antonio

Thomas Heckler, WIKA Germany

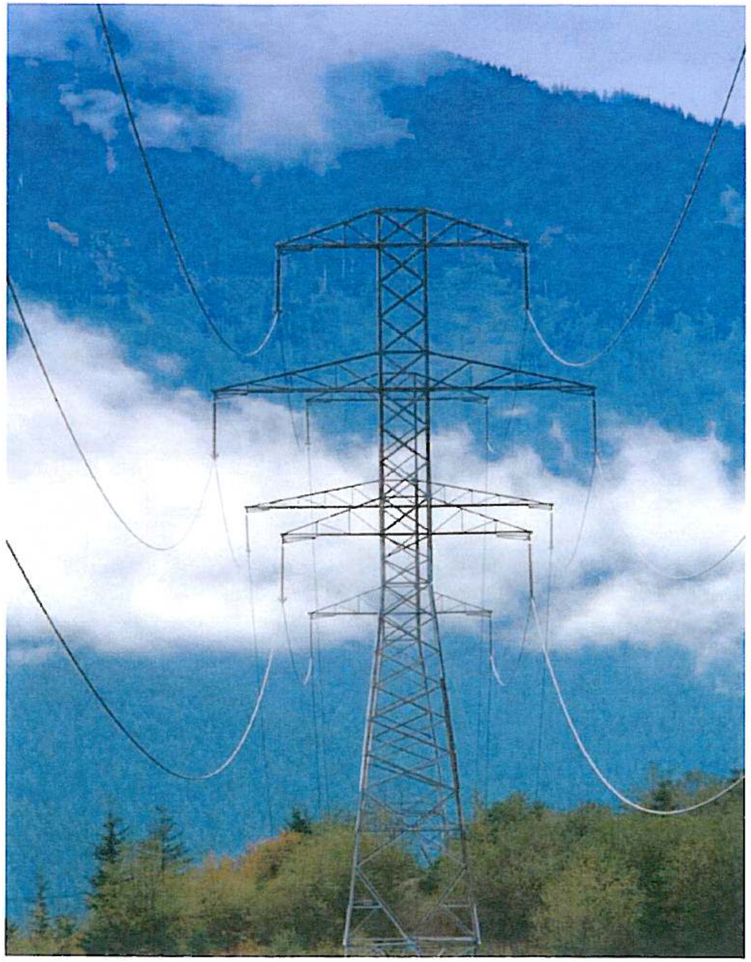
Table of Contents:

WIKA

Gas Density Monitoring Equipment

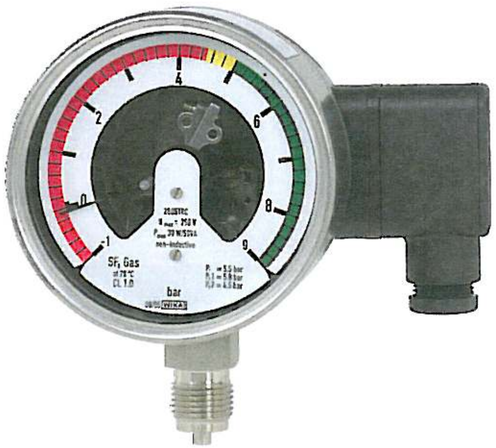
EPA-Conference on SF_6 & the Environment, 2006, San Antonio

Thomas Heckler, WIKA Germany



WIKA in the T&D world

Purpose of Gas Density Monitoring

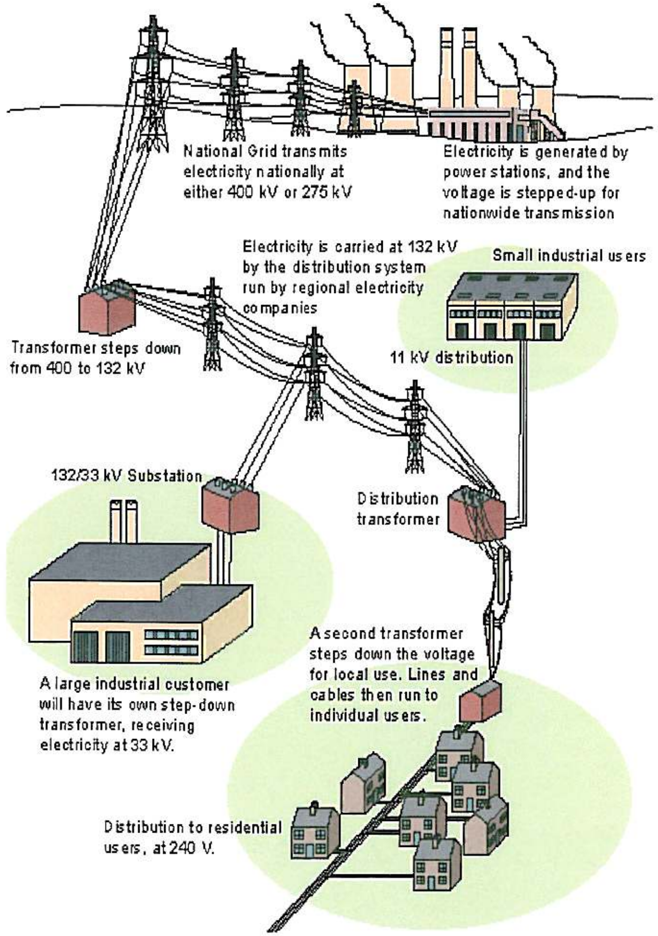


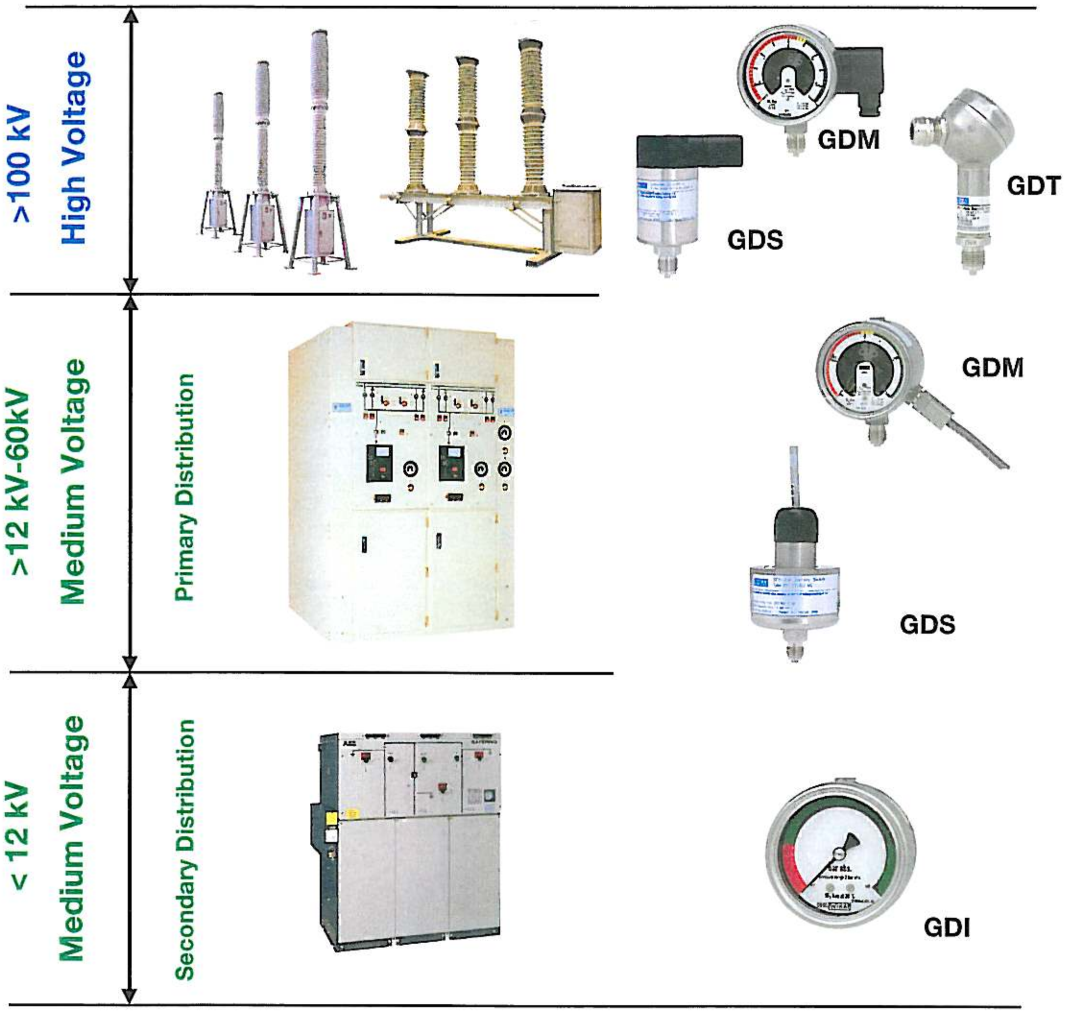
Gas Density Monitors

furnish proof of ...

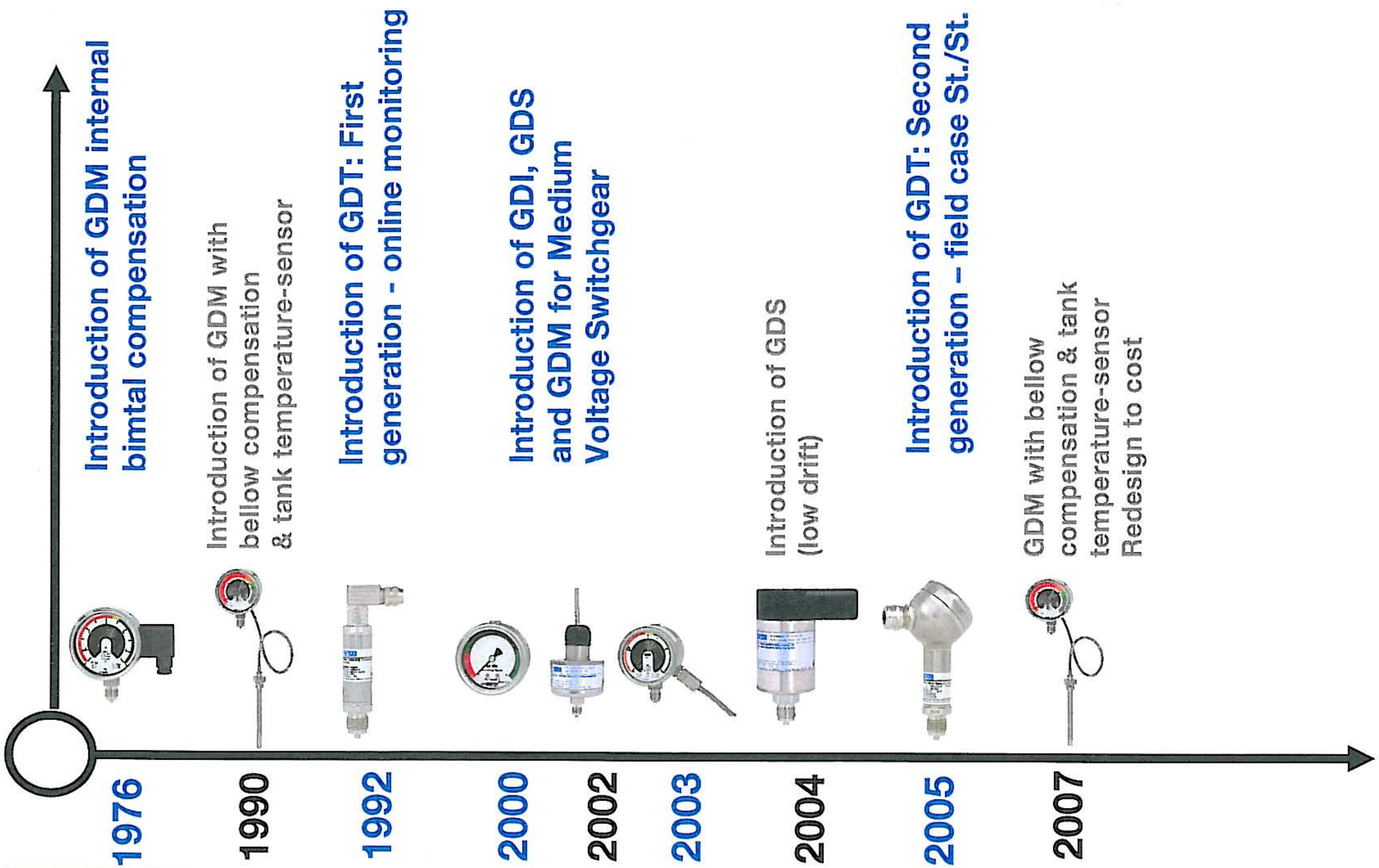
- the **safe operatiing condition** of a breaker
- the **filling process** of a breaker
- the **situation of the actual density** in a tank

Application | Portfolio of Products





Milestones in Leak Detection



Milestones in Leak Detection

Installed Fleet of Gas Monitoring Equipment

Product line:

GDM bi-metal compensated____________more than **450.000**

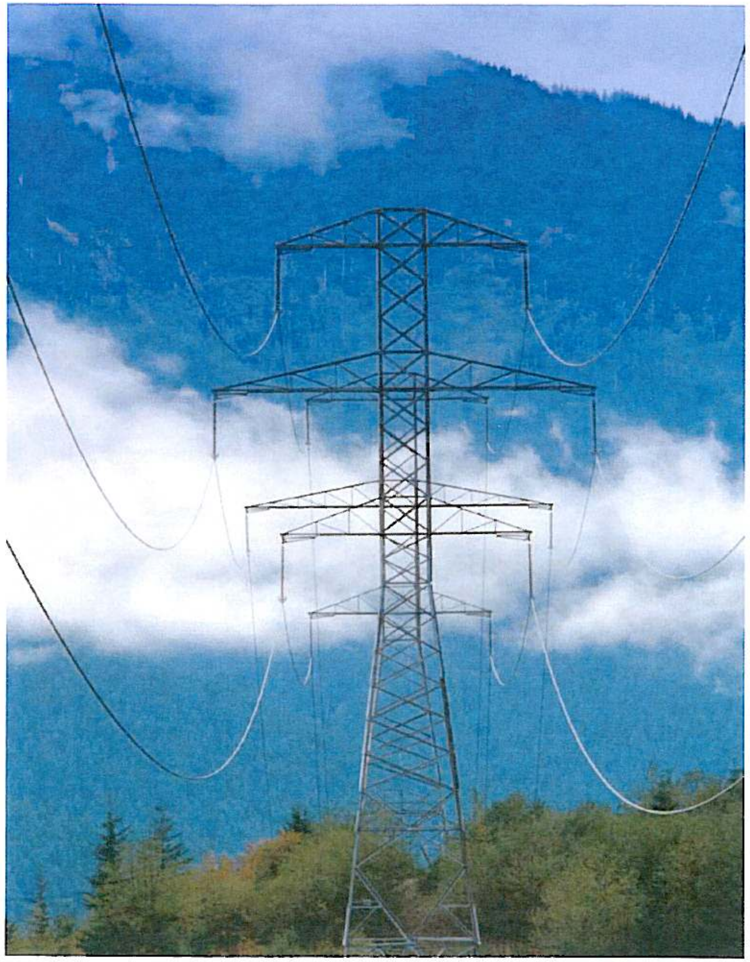
GDI bi-metal compensated____________more than **100.000**

GDM bellow compensation
& **tank temperature** sensor_____________more than **35.000**

GDS reference chamber compensation__more than **17.000**

GDT electronically compensated________more than **16.000**

In the last 15 years **618.000 instruments installed**



SF_6 Real Gas Law

Accuracy

Quest for higher Accuracy

Spherical View of SF_6 (Reference = True Values)

● $\delta = 47{,}91$ [g/l] = $p_{20\,°C} = 6{,}200$ bar

$\delta = 47{,}91$ [g/l] = $p_{60\,°C} = 7{,}454$ bar

$\delta = 47{,}91$ [g/l] = $p_{-20\,°C} = 4{,}867$ bar

real gas law (virial equation) :

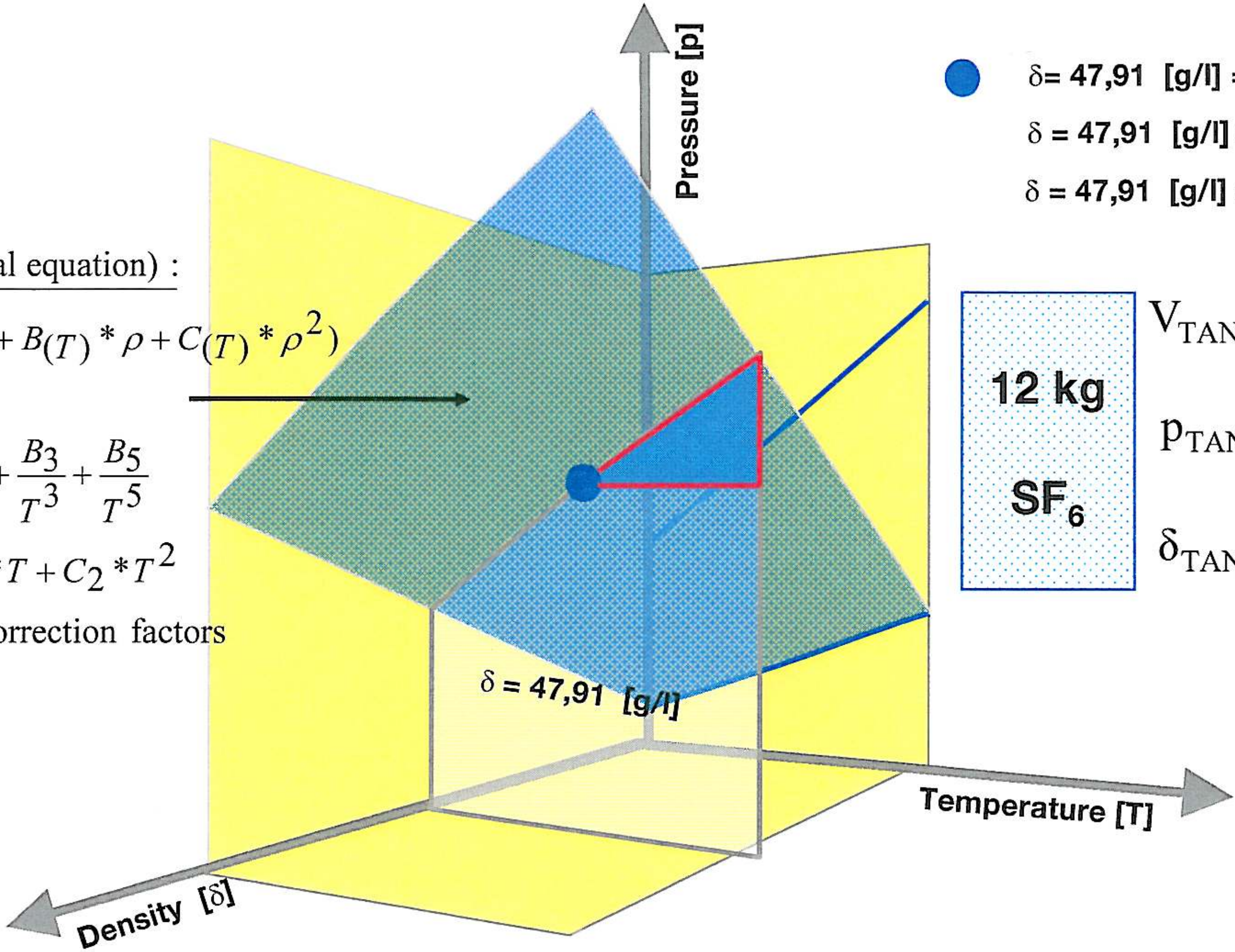
$$p = \rho * R * T * (1 + B_{(T)} * \rho + C_{(T)} * \rho^2)$$

with

$$B_{(T)} = B_0 + \frac{B_1}{T} + \frac{B_3}{T^3} + \frac{B_5}{T^5}$$

$$C_{(T)} = C_0 + C_1 * T + C_2 * T^2$$

$B_{(T)}, C_{(T)}$ are correction factors



12 kg

SF_6

$$V_{TANK} = 250\,l$$

$$p_{TANK} = 6{,}20\ bar_{rel}$$

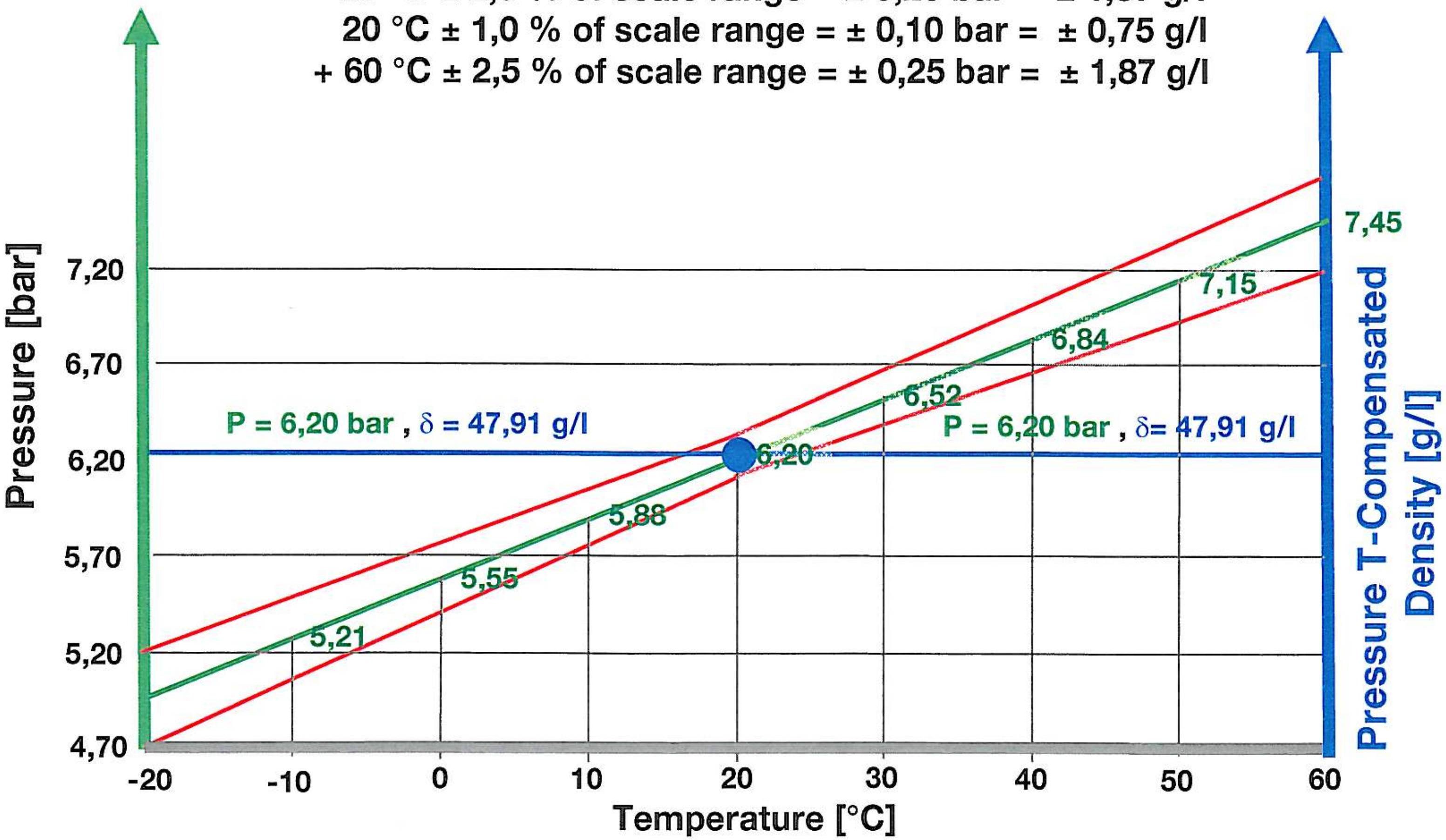
$$\delta_{TANK} = 47{,}91 \frac{g}{l}$$

Please Note: Example only not in scale

Pressure-Temperature Chart of SF_6 Standard GDM

Example: Errorband of Instrument with Range of 10 bar and calibrated for 6,20 bar (47,91g/l)

– 20 °C ± 2,5 % of scale range = ± 0,25 bar = ± 1,87 g/l
20 °C ± 1,0 % of scale range = ± 0,10 bar = ± 0,75 g/l
+ 60 °C ± 2,5 % of scale range = ± 0,25 bar = ± 1,87 g/l



Please Note: Example only not in scale

Quest for High Precision Instrumentation

Equation: Loss of SF_6 **High Voltage:**

$$V_{TANK} = 250\,l$$

$$p_{TANK} = 6{,}20\ bar_{rel}$$

$$\delta_{TANK} = 47{,}91 \frac{g}{l}$$

1,0 % p.a.
(relative to the quantity in the product)

Voluntary Commitment:

< 0.5 % p.a.
(relative to the quantity in the product)

$$m_{SF6} = \delta_{TANK} * V_{TANK}$$

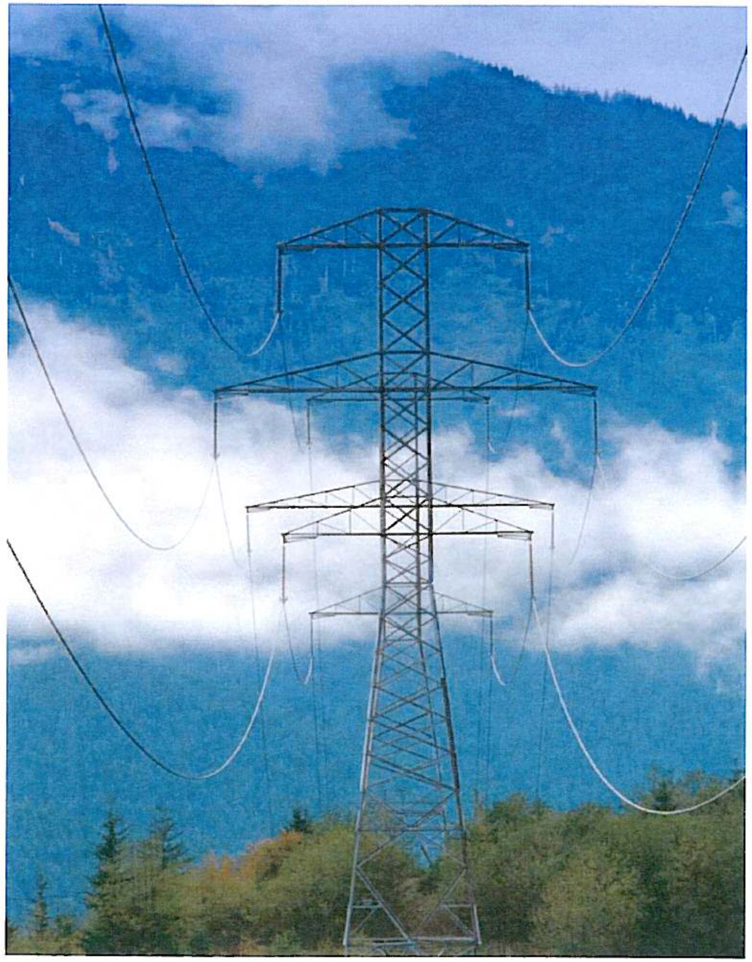
$$m_{SF6} = 11977\ g$$

1,0 %/year :

Δm/year = 119,8 g/year ⇨ **Δδ/year = 0,48 g/l** ⇨ **Δp = 0,065 bar/year**

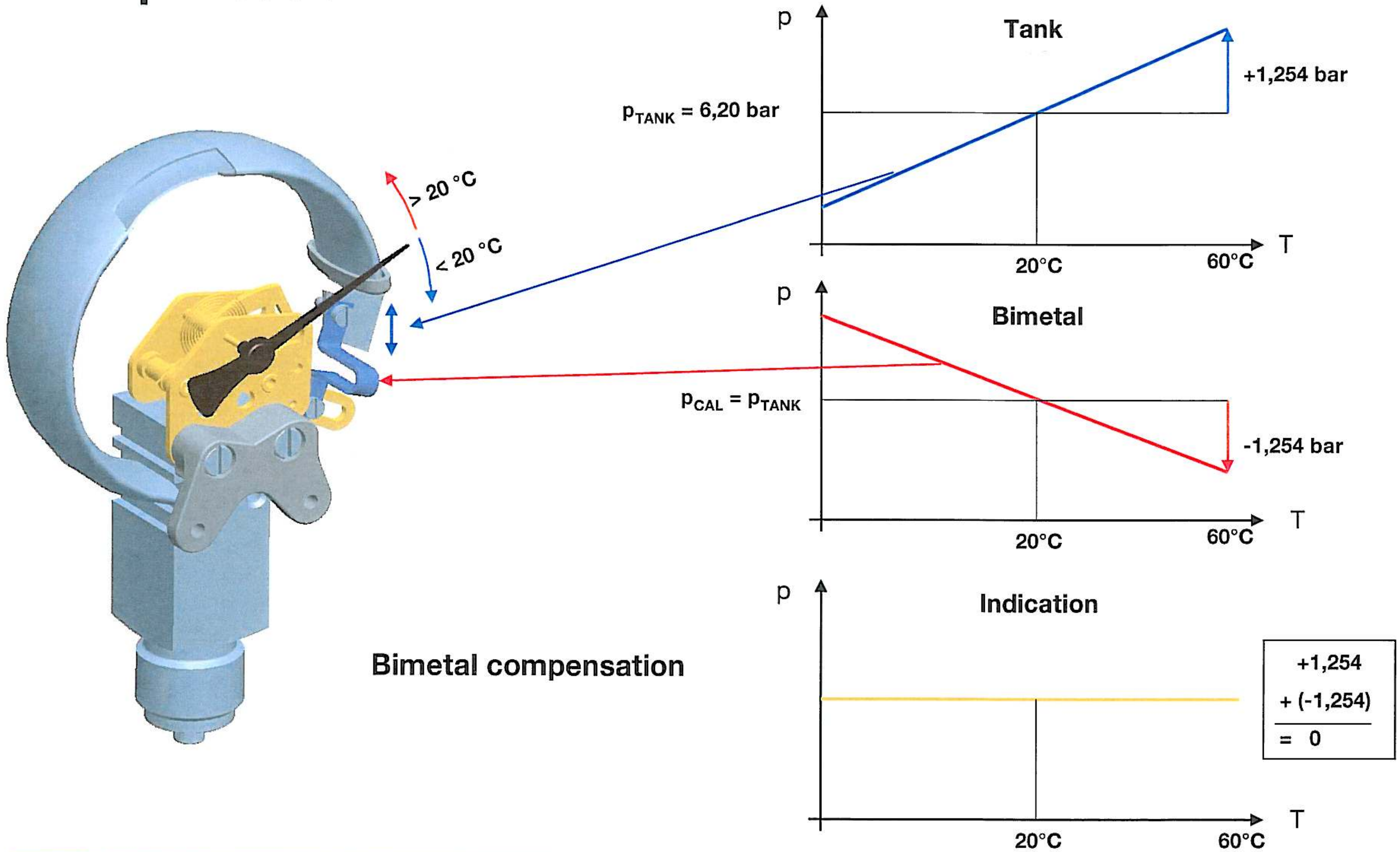
0,5 %/year :

Δm/year = 59,9 g/year ⇨ **Δδ/year = 0,24 g/l** ⇨ **Δp = 0,032 bar/year**



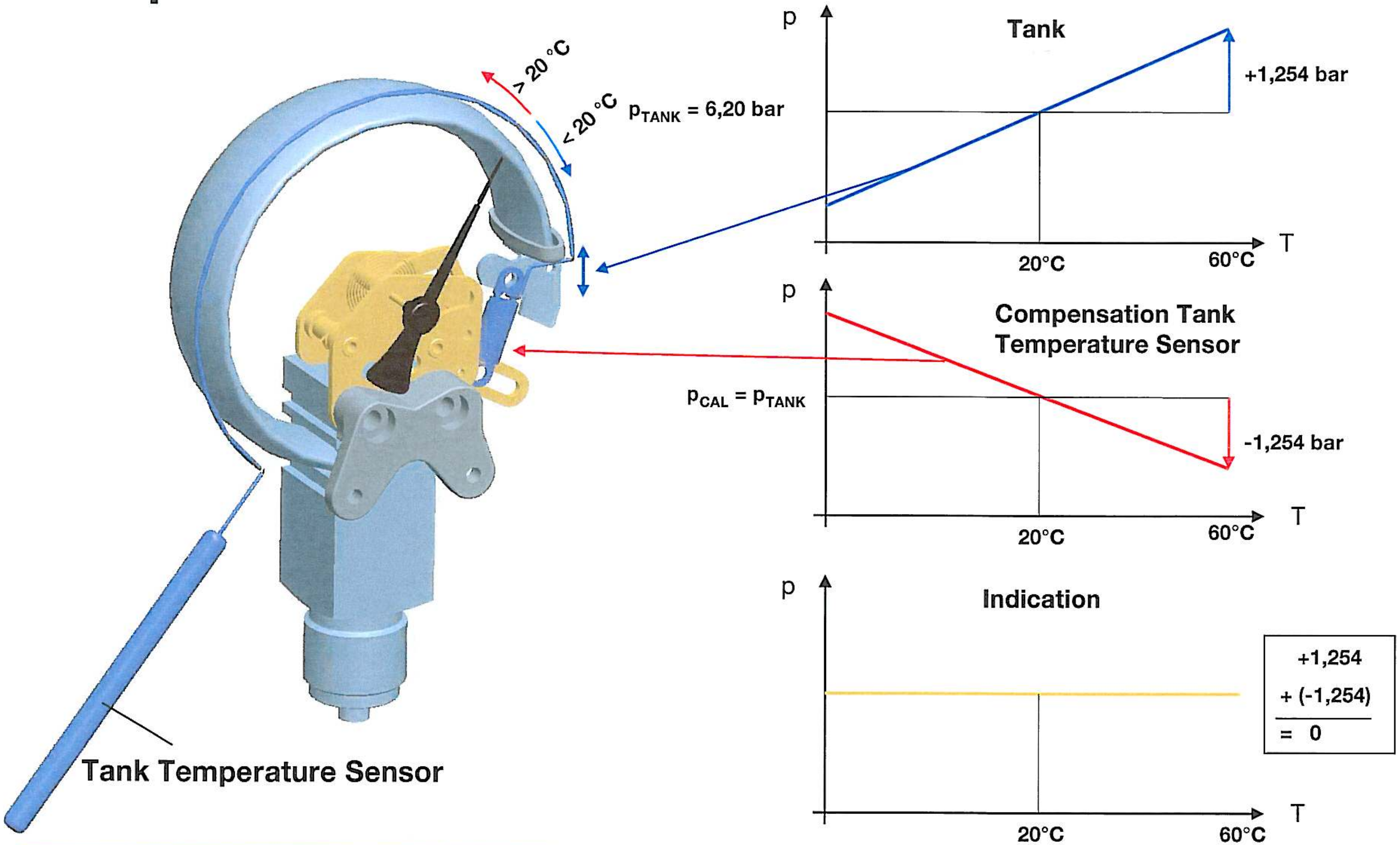
Compensation

Compensation

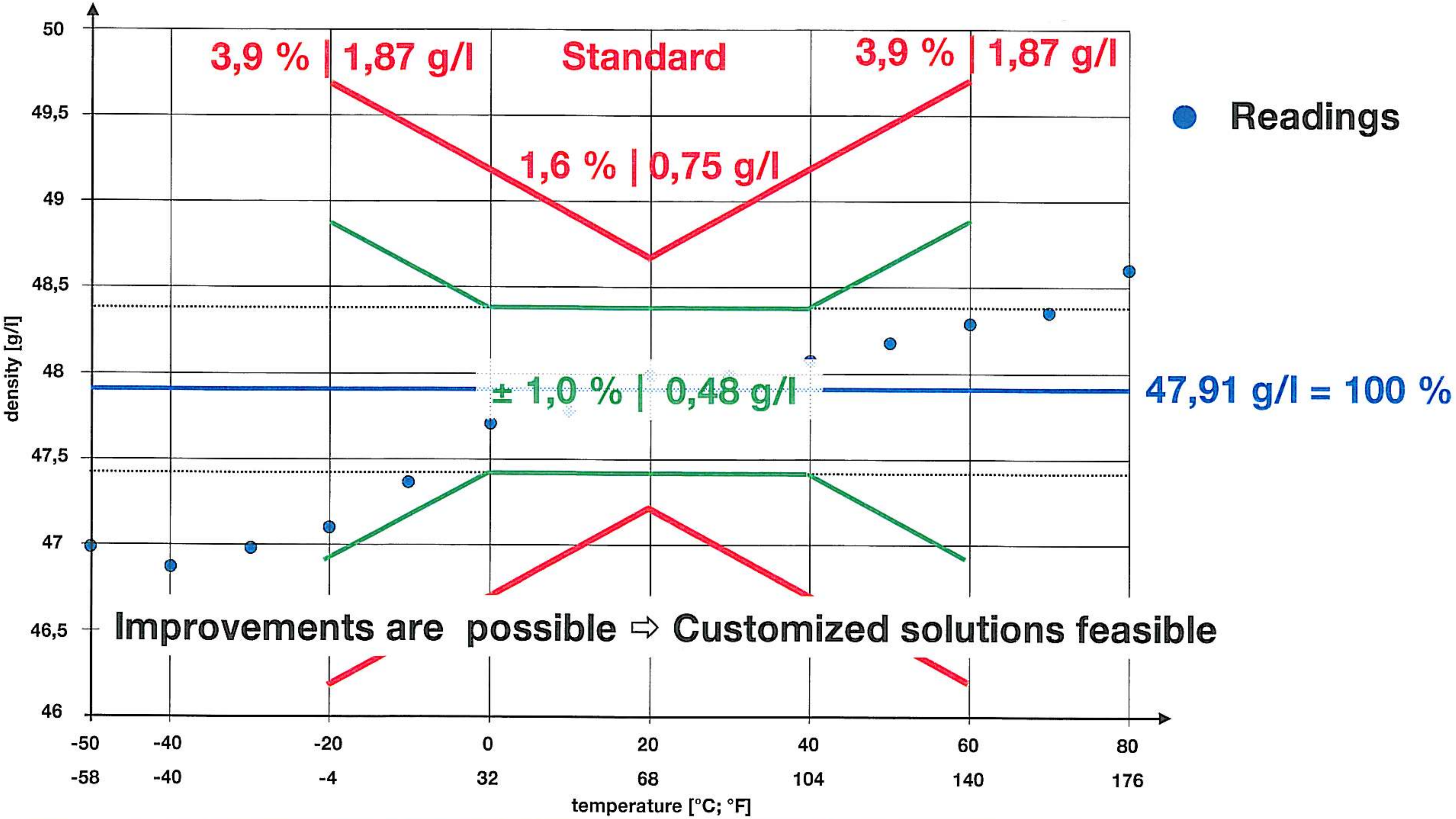


Bimetal compensation

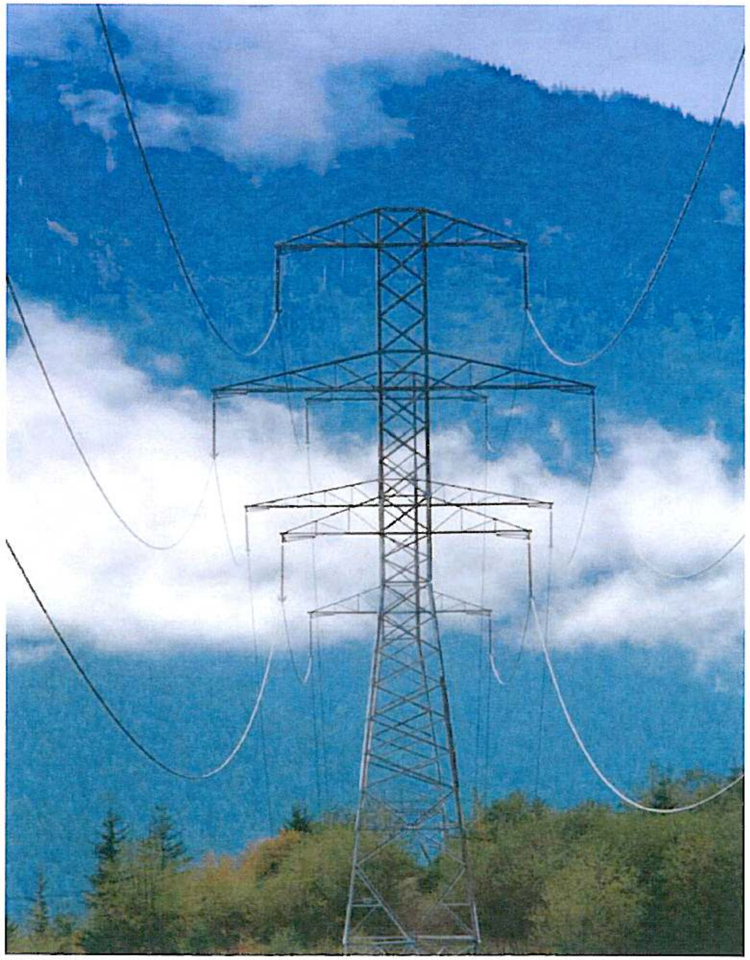
Compensation



What can WIKA do to improve the Errorband @ p_{cal}



Improvements are possible ⇨ Customized solutions feasible



Density Measurement Methods

Pressure Gauges | Temperature Gauges | P-T – Charts or Tables

Reading influenced by:

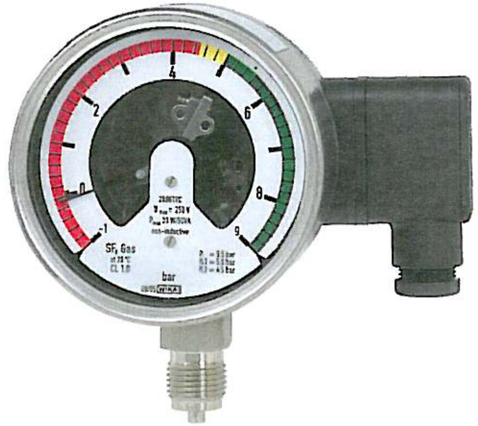
- Altitude (systematic)
- Weather System (High – Low –Pressure) erratic
- Temperature difference between gas and ambient
- Erratic reading errors of the operator due to small scales (graduations)
- Inaccurate SF_6 pressure temperature charts
- Misinterpretation of color codes and dial information

Do not use this method to monitor SF_6 ⇨ **It is a potential Safety Risk due to misunderstandings**

WIKA
Part of your business

Gas Density Monitors

GDM NS 4 in.



Bimetal compensated Gas Density Monitors combine 2 functions (Switching / Indication) NS: 2 ½ in. & 4 in.

- Hermetically sealed (no erratic influences)
- Integral tank test feasible
- Excellent long-term stability (St./St)
- Full Vacuum test
- Laser welded contacts

GDM NS 2 ½ in.

<< 0,001 mbar / breaker operation 40 g & 60 g, 10 ms

Errorband	: -20/60 °C 2,5 % f.s.d.
(calibration pressure)	: 20 °C 1,0 % f.s.d

Temperature Range: -50 ... 80 °C upon request

Higher precision upon request

Gas Density Indicators

Bimetal compensated Gas Density Indicators- indicate only

GDI NS 2 ½ in.

NS: 2 ½ in. & 4 in.

- Hermetically sealed (no erratic influences)
- Integral tank test feasible
- Excellent long-term stability (St./St)
- Full Vacuum test
- Laser welded contacts
- Submersible

Errorband	: -20/60 °C 2,5 % f.s.d.
(calibration pressure)	: 20 °C 1,0 % f.s.d

Temperature Range: -50 ... 80 °C upon request

Higher precision upon request

Gas Density Monitors c/w ext. Tank T-Sensor

- Hermetically sealed (no erratic influences)
- Integral tank test feasible
- Excellent long-term stability (St./St)
- Full Vacuum test
- Laser welded contacts

Fast response time of compensation

Ideal for tanks equipped with tank heaters

Errorband	: -20/60 °C 2,5 % f.s.d.
(calibration pressure)	: 20 °C 1,0 % f.s.d

Higher precision upon request

Uncertainties due to disbalance of temperatures eliminated by tank temperature sensor

Gas Density Switches

- Hermetically sealed (no erratic influences)
- Integral tanktest feasible
- Excellent long-term stability (St./St)
- Full vacuum proof

Big size reference chamber (135 cm³)

Errorband: -20/60 °C ±0,8 % (standard ±0,080 mbar)

Switch for low pressure applications available (RMU)

Stainless Steel

Glass Bushings used

Stainless Steel Gas Density Switches

Hermetically sealed (no erratic influences)

Large reference chamber (135 cm³)

Errorband: -20/60 °C ±0,080 bar (standard)

⇨5 • 10 $^{-9}$ mbar l / s; 135 cm³; drift: 1,2 mbar / year

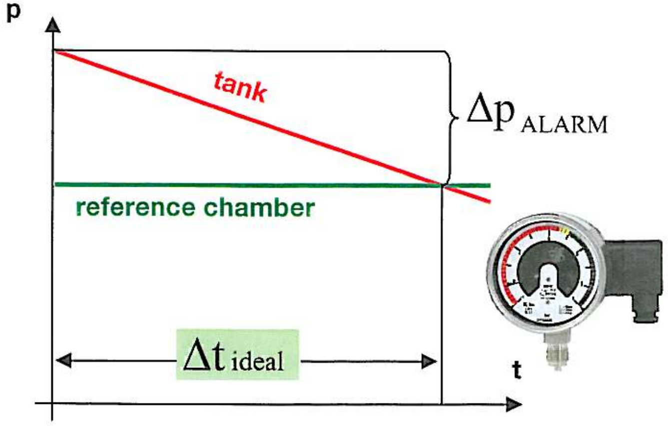
⇨5 • 10 $^{-9}$ mbar l / s; 25 cm³; drift: 6,3 mbar / year

Products with small reference Chamber (25 cm³….33 cm³)

$$\Delta p_{REF} = \frac{q_{pV(REF)} * \Delta t}{V_{REF}} = \frac{5 * 10^{-9} \frac{\text{mbar*l}}{\text{sec}} * 31536000 \text{ sec}}{0{,}025 \text{ l}}$$

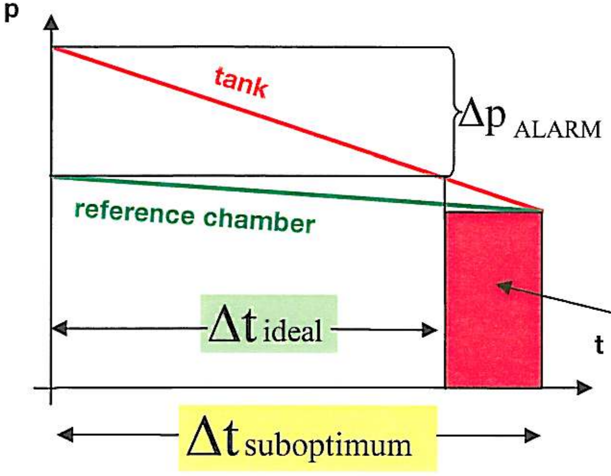
$$\Delta p_{REF} = 6{,}3 \text{mbar/Year}$$

Gas Density Switches drift of reference chambers vs. Gas Density Monitors without compensation drift



$$\Delta t_{ideal} = \frac{p_1 - p_2}{\Delta p_{TANK}}$$

$$= \frac{200 \text{ mbar}}{41{,}15 \text{ mbar}} a = 4{,}854 \text{ a}$$



$$\Delta t_{suboptimum} = \frac{p_1 - p_2}{\Delta p_{TANK} - \Delta p_{REF}} =$$

$$= \frac{200 \text{ mbar}}{(41{,}20 - 6{,}31) \text{ mbar}} a = 5{,}732 \text{ a}$$

Delay:

135 cm³

Δt_{delay} = 0,146 years

= 53,3 days

Products with small reference Chamber (25cm³....33cm³)

25 cm³

Δt_{delay} = 0,878 years

= 320,5 days

Gas Density Transmitters

Hermetically sealed (no erratic influences)

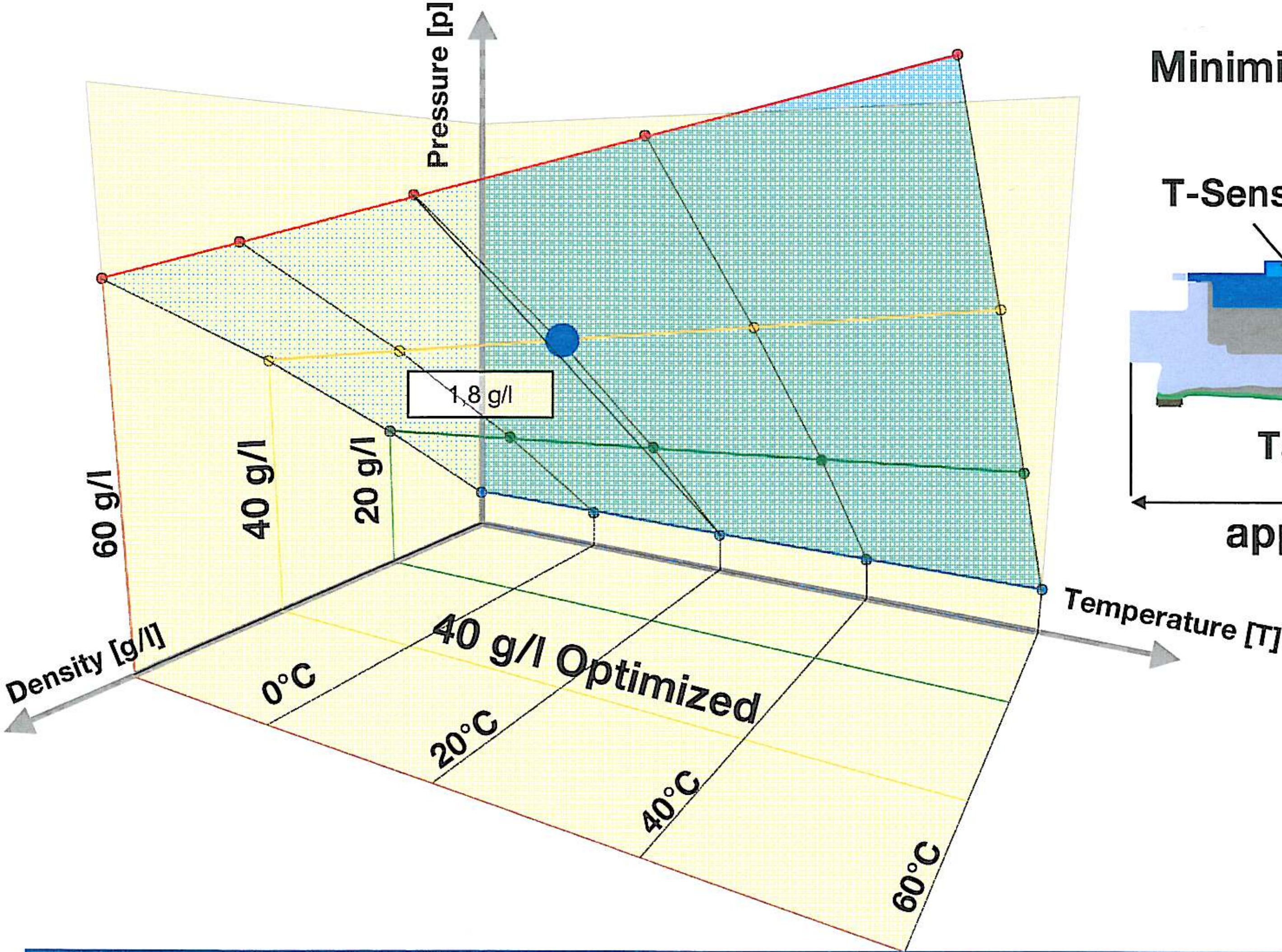
Analog „passive“ compensation: No Microprocessors needed

Temperature compensated with a 4 ... 20 mA Output over the 3-D-behavior of the real gas (Online monitoring)

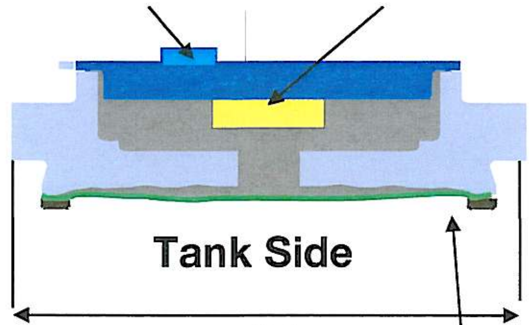
Measurement of fast transients (pressure) possible (Arc – detection)

Minimized version ⇨ Ideal for integration into the tank

Gas Density Transmitters: „Surface of Accuracy“



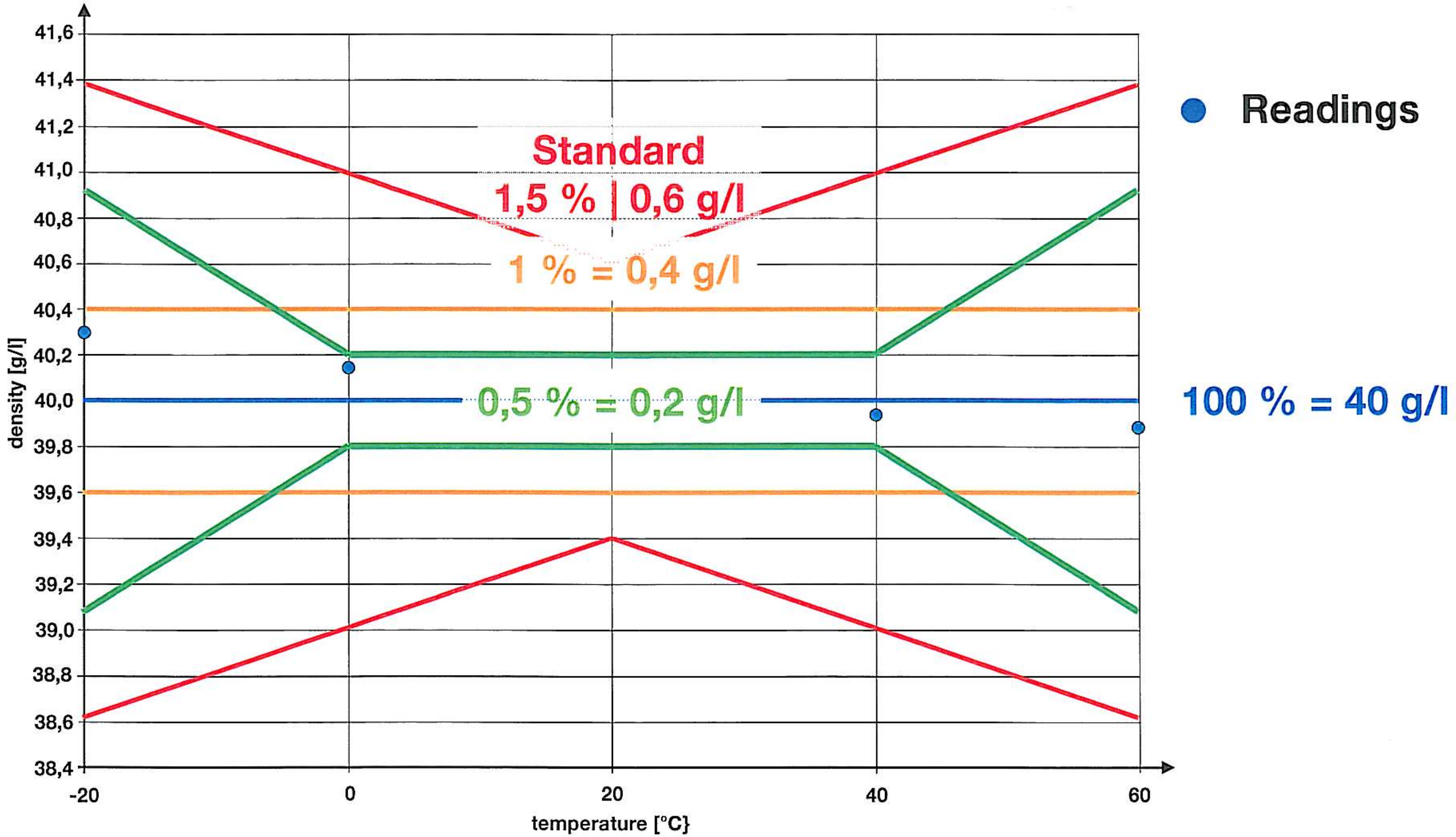
Minimized Sensor



Diaphragm
Separates
Gas from Sensor
„Double Sealed“

Please Note: Example only not in scale

Gas Density Transmitters Errorband for customized p $_{Cal}$



Comparison of Errors in Density Measurement Methods

Method	Compensation	Ambient Pressure (Erratic)	Altitude (Systematical)	Disbalance of Temperature (Erratic)	Reading Error of Operator (Erratic)	Drift (Systematical)	Potential Oportunities for Errors (Instrument)	Potential Oportunities for Errors (Method)
Pressure Gauge	None	Yes	Yes	Yes	Unlikely	None	3	5
Temperature Gauge	None	None	None	Yes	Unlikely	None	1	
P-T-Chart	None	N.A.	N.A.	N.A	Most likely	None	1	
Gas Density Indicator	Bimetall	None	None	Yes	Unlikely	None	1	1
Gas Density Monitor	Bimetall	None	None	Yes	Unlikely	None	1	1
Gas Density Monitor	Tank Sensor	None	None	None	Unlikely	None	0	0
Gas Density Switch	Reference Chamber 135	None	None	Yes	N.A.	1,2 mbar / Year	2	2
Gas Density Switch	Reference Chamber 25	Yes	Yes	Yes	N.A.	6,3 mbar / Year	4	4
Gas Density Transmitter	Electronics	None	None	Yes	N.A.	None	1	1

All current methods are designed for **High Level Leak Detection .....**

What should be done and what is next ?

Eliminate the erratic influences

- Ambient pressures by WIKA's sealing concept
- Altitude and related pressure by WIKA's sealing concept
- Temperature disbalance between tank and compensation by GDM with external tank temperature sensor

Improve the filling process with adequate instrumentation

- Use of GDM or GDI's to monitor the filling process
- Ask WIKA for certified instrumentation done by accredited laboratory

Improve the accuracy of the instrument

- Ask WIKA for customized GDM's with 0,5 ..0,8 % f.s.d. accuracy

Ask WIKA for a Emission Detector

What could we do with new innovative Instrumentation ?

With an Emission Indicator you could:

- Measure low level leak rates

- Obtain clear information of emission levels for specific breakers

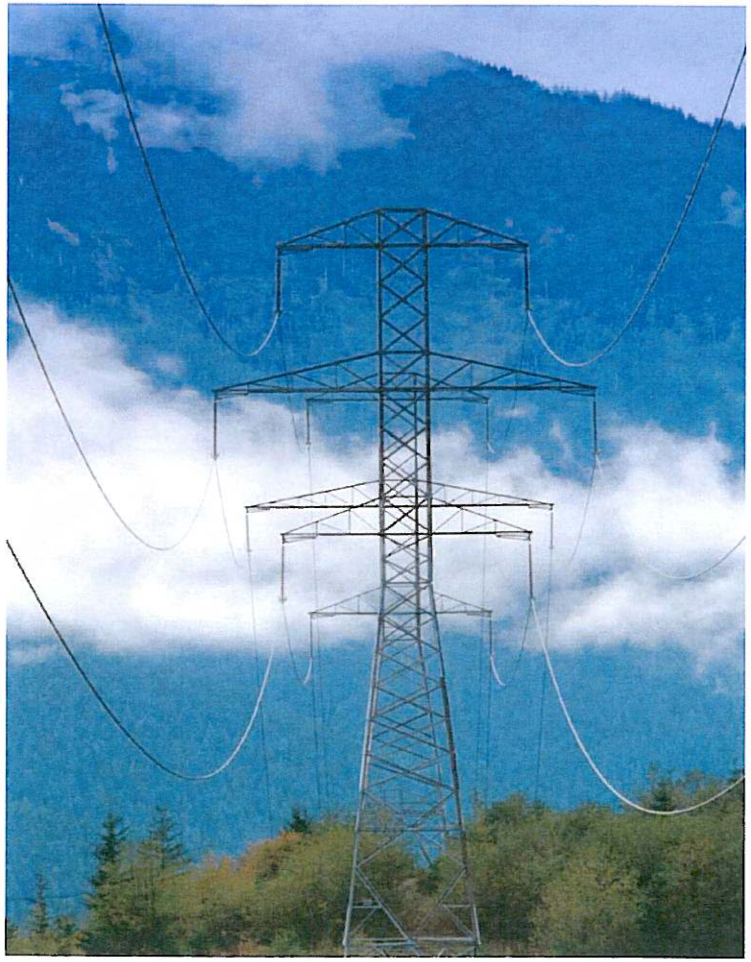
- Detect leaks early

- Monitor commitments / emission rates
  ⇨ Provide sound data for Emission Trading

- Improve tank filling procedures (Tier 3 Method's improved)

- Issue emission certificate for breakers

Emission Data Aquisition System



Join us to become:

Visionary Vanguards

Visionary Vanguards

Emission Indicator

High precision instrument to detect:

low leak rates

Purpose:

- **Provide information of actual tank gas emission**
- **Trend Analysis**
- **Emission levels : 0,25 ... 0,50 ... 1,00 %**

Rome: 1 st. century before Christ

„The price of product is matched,

by the value the buyer is prepared to pay"

Publius Syrus, Roman writer first century before Christ

Gas Density Monitor Equipment:

Insurance protecting:

- Lives
- The environment
- Tens of thousands of dollars in switchgear