Gas Density Monitoring Equipment

EPA-Conference on SF₆ & the Environment, 2006, San Antonio

Thomas Heckler, WIKA Germany
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WIKI in the T&D world
Purpose of Gas Density Monitoring

Gas Density Monitors furnish proof of...

- the safe operating condition of a breaker
- the filling process of a breaker
- the situation of the actual density in a tank
Application | Portfolio of Products

High Voltage

Electricity is generated by power stations, and the voltage is stepped-up for nationwide transmission.

Medium Voltage

Electricity is carried at 132 kV by the distribution system run by regional electricity companies. Transformers step down from 400 to 132 kV.

Secondary Distribution

A second transformer steps down the voltage for local use. Lines and cables then run to individual users.

Primary Distribution

Transformers step down from 11 kV for distribution to residential users, at 240 V.

GDS

GDM

GDT

GDI
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
SF₆ Real Gas Law
Accuracy
Quest for higher Accuracy
Spherical View of SF\textsubscript{6} (Reference = True Values)

real gas law (virial equation):
\[ p = \rho \times R \times T \times (1 + B(T) \times \rho + C(T) \times \rho^2) \]

with
\[ B(T) = B_0 + \frac{B_1}{T} \times \frac{B_3}{T^3} \times \frac{B_5}{T^5} \]
\[ C(T) = C_0 + C_1 \times T + C_2 \times T^2 \]

\(\delta\) = 47.91 g/l

Please Note: Example only not in scale
Pressure-Temperature Chart of SF₆ Standard GDM

Example: Errorband of Instrument with Range of 10 bar and calibrated for 6,20 bar (47,91 g/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 $\text{SF}_6$

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

$p_{\text{TANK}} = 6,20 \text{ bar}_\text{rel}$

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

High Voltage:

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

Voluntary Commitment:

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

$m_{\text{SF6}} = \delta_{\text{TANK}} \times V_{\text{TANK}}$

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

1,0 %/year:

$\Delta m/\text{year} = 119,8 \text{ g/year} \Rightarrow \Delta \delta/\text{year} = 0,48 \text{ g/l} \Rightarrow \Delta p = 0,065 \text{ bar/year}$

0,5 %/year:

$\Delta m/\text{year} = 59,9 \text{ g/year} \Rightarrow \Delta \delta/\text{year} = 0,24 \text{ g/l} \Rightarrow \Delta p = 0,032 \text{ bar/year}$
Compensation
What can WIKAI do to improve the Errorband @ $p_{cal}$

- Standard: 3.9% | 1.87 g/l
- 1.6% | 0.75 g/l
- ± 1.0% | 0.48 g/l

47.91 g/l = 100%

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
Gas Density Monitors

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

<< 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

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

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

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

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

$$
\Delta p_{\text{REF}} = \frac{q_{pV(\text{REF})} \cdot \Delta t}{V_{\text{REF}}} = \frac{5 \cdot 10^{-9} \text{ mbar l} \cdot \text{sec} \cdot 31536000 \text{ sec}}{0,0251}
$$

$$
\Delta p_{\text{REF}} = 6,3 \text{ mbar/Year}
$$
Gas Density Switches drift of reference chambers vs. Gas Density Monitors without compensation drift

\[ \Delta t_{\text{ideal}} = \frac{p_1 - p_2}{\Delta p_{\text{TANK}}} \]
\[ = \frac{200 \text{ mbar}}{41,15 \text{ mbar}} = 4,854 \text{ a} \]

\[ \Delta t_{\text{suboptimum}} = \frac{p_1 - p_2}{\Delta p_{\text{TANK}} - \Delta p_{\text{REF}}} = \frac{200 \text{ mbar}}{(41,20 - 6,31) \text{ mbar}} = 5,732 \text{ a} \]

Delay:
- \( 135 \text{ cm}^3 \)
  - \( \Delta t_{\text{delay}} = 0,146 \) years = 53.3 days

- \( 25 \text{ cm}^3 \)
  - \( \Delta t_{\text{delay}} = 0,878 \) years = 320.5 days

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

T-Sensor

P-Sensor

Tank Side

appr. 24 mm

Diaphragm Separates Gas from Sensor „Double Sealed“

Please Note: Example only not in scale
Gas Density Transmitters Errorband for customized $p_{\text{Cal}}$

- Standard
  - 1.5% = 0.6 g/l
  - 1% = 0.4 g/l
  - 0.5% = 0.2 g/l

100% = 40 g/l

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## Comparison of Errors in Density Measurement Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Compensation</th>
<th>Ambient Pressure (Erratic)</th>
<th>Altitude (Systematical)</th>
<th>Disbalance of Temperature (Erratic)</th>
<th>Reading Error of Operator (Erratic)</th>
<th>Drift (Systematical)</th>
<th>Potential Opportunities for Errors (Instrument)</th>
<th>Potential Opportunities for Errors (Method)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Gauge</td>
<td>None</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Unlikely</td>
<td>None</td>
<td>3</td>
<td>5</td>
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<tr>
<td>Temperature Gauge</td>
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<td>None</td>
<td>None</td>
<td>Yes</td>
<td>Unlikely</td>
<td>None</td>
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<td>1</td>
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<td>P-T-Chart</td>
<td>None</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>Most likely</td>
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<tr>
<td>Gas Density Indicator</td>
<td>Bimetal</td>
<td>None</td>
<td>None</td>
<td>Yes</td>
<td>Unlikely</td>
<td>None</td>
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<tr>
<td>Gas Density Monitor</td>
<td>Bimetal</td>
<td>None</td>
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<td>Yes</td>
<td>Unlikely</td>
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<tr>
<td>Gas Density Monitor</td>
<td>Tank Sensor</td>
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<tr>
<td>Gas Density Switch</td>
<td>Reference Chamber 135</td>
<td>None</td>
<td>None</td>
<td>Yes</td>
<td>N.A.</td>
<td>1.2 mbar / Year</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Gas Density Switch</td>
<td>Reference Chamber 25</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>N.A.</td>
<td>6.3 mbar / Year</td>
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<tr>
<td>Gas Density Transmitter</td>
<td>Electronics</td>
<td>None</td>
<td>None</td>
<td>Yes</td>
<td>N.A.</td>
<td>None</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

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 Acquisition System**
Join us to become:

Visionary Vanguards
Visionary Vanguards

Emission Indicator

High precision instrument to detect:

\textit{low leak rates}

Purpose:

- Provide information of actual tank gas emission
- Trend Analysis
- Emission levels : 0.25 \ldots 0.50 \ldots 1.00 \%
Rome: 1st 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