



Pressure and Temperature Measurement

SF₆ Emission Monitoring:

State-of-the-Art SF₆ Tracking

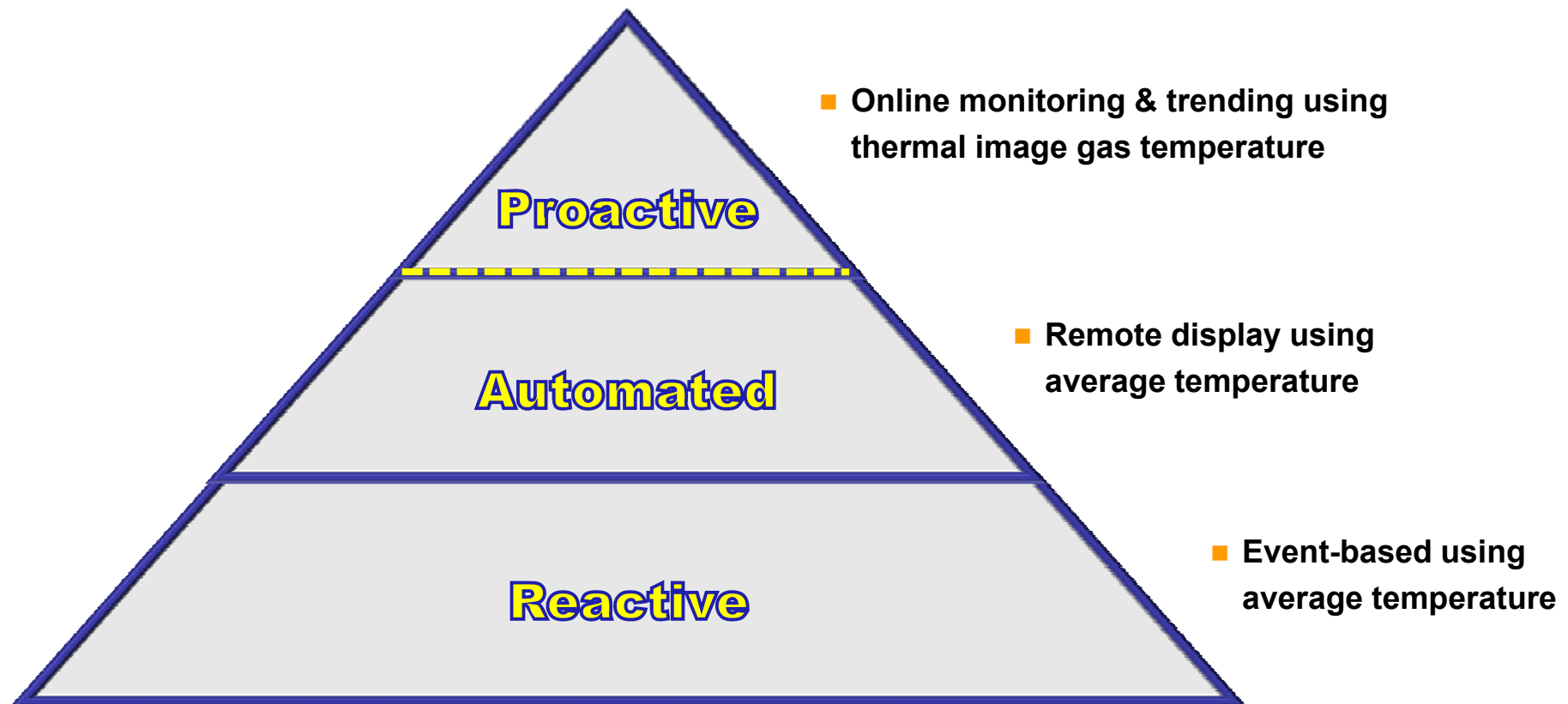
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EPA Workshop: Phoenix, AZ

February 4, 2009

www.wika.com/sf6

The SF₆ Emission Monitoring Pyramid



Emission Monitoring - Reactive

Overview Reactive Monitoring

- Infrared Camera
- Leak Locators
- Mass Balance (Inventories)
- Flow Measurement
- Temperature Compensated Pressure (Density)

For details, please speak with vendors of these products. We have omitted them due to time constraints.



Temperature-Compensated Pressure



- **Measured** *at the tank or inside the control cabinet*
- **When measured:** *Constantly, only need to manually take the reading whenever desired*
- **Cost**
 - *No material costs (hermetically sealed & temperature-compensated monitor/indicator needed)*
 - *Ongoing personnel/misc. costs*
- **Pros/Cons**
 - Instruments already required for SF₆-insulated breakers
 - Can use Leakage Calculation program to quantify emissions
 - Low/no investment cost
 - **Dials typically with temperature-compensated pressure, not density (conversion by hand or automatic via software)**

Emission Monitoring - Reactive

Temperature-Compensated Pressure

Initial Pressure (Compensated) : 90.1 PSI
Actual Pressure (Compensated) : 88.6 PSI
Initial Gas Mass 100 % : 11.520 kg
Tank Volume : 0.240 m³

Difference : 0.75 kg/m³
Lost SF₆ Mass : 0.75 kg/m³ · 0.240 m³
Lost SF₆ Mass : 0.180 kg

After 3 Years, the conclusion is:

1.6 % in 3 Years is a loss of 0.53 % of the gas mass per year

⇒ Tank lost 60 gr. / yr. or 2.116 oz/yr



Pressure and Temperature Measurement

SF₆-gas

What is known ?
☒ pressure
☐ density

language
☐ german
☒ english

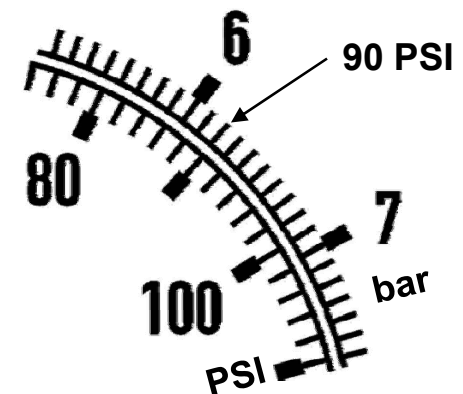
Theorie by
☒ Döring
☐ Bier

☐ absolute pressures

	temperature [°C]	pressure [bar]	density [kg/m ³]	spec. vol. [m ³ /kg]
komensation point :	20,0	6,112	47,25	0,0212
fluidisation :	-27,0			
lower values :	-20,0	4,801	-1,311	[bar] 2,546
upper values :	60,0	7,347	1,235	

pressure difference

☒ Calculate ☐ Cancel <Esc>



Emission Monitoring - Reactive

Temperature-Compensated Pressure



Pressure and Temperature Measurement

P0078 SF6 Gas Leakage Calculator

File Language Help

SF6-Gas Leakage Calculation

Filling pressure (at 20°C) psi ☐ Absolute pressure

Unit filling pressure

Density at filling pressure g/l

Nameplate capacity kg

Tank volume known ☒ Yes ☐ No

Tank volume l

Date / Time

Pressure psi psi

Unit pressure

☐ Absolute pressure ☐ Absolute pressure

Density g/l g/l

Emitted gas mass g

Mass-flow g/yr

Leakage rate %/yr

Basis data

Substation

Substation manufacturer

Type of switch

Customer ID-code

Inspector

Date

Measurement ID-code

Summary Reactive Monitoring

- All processes are time-intensive, requiring regular time investment
 - Data has to be measured and information calculated
 - More frequent measurements require additional time commitment
- Up-front investment cost varies depending on the solution
- Not designed to notify of small leaks early-on for proactive maintenance

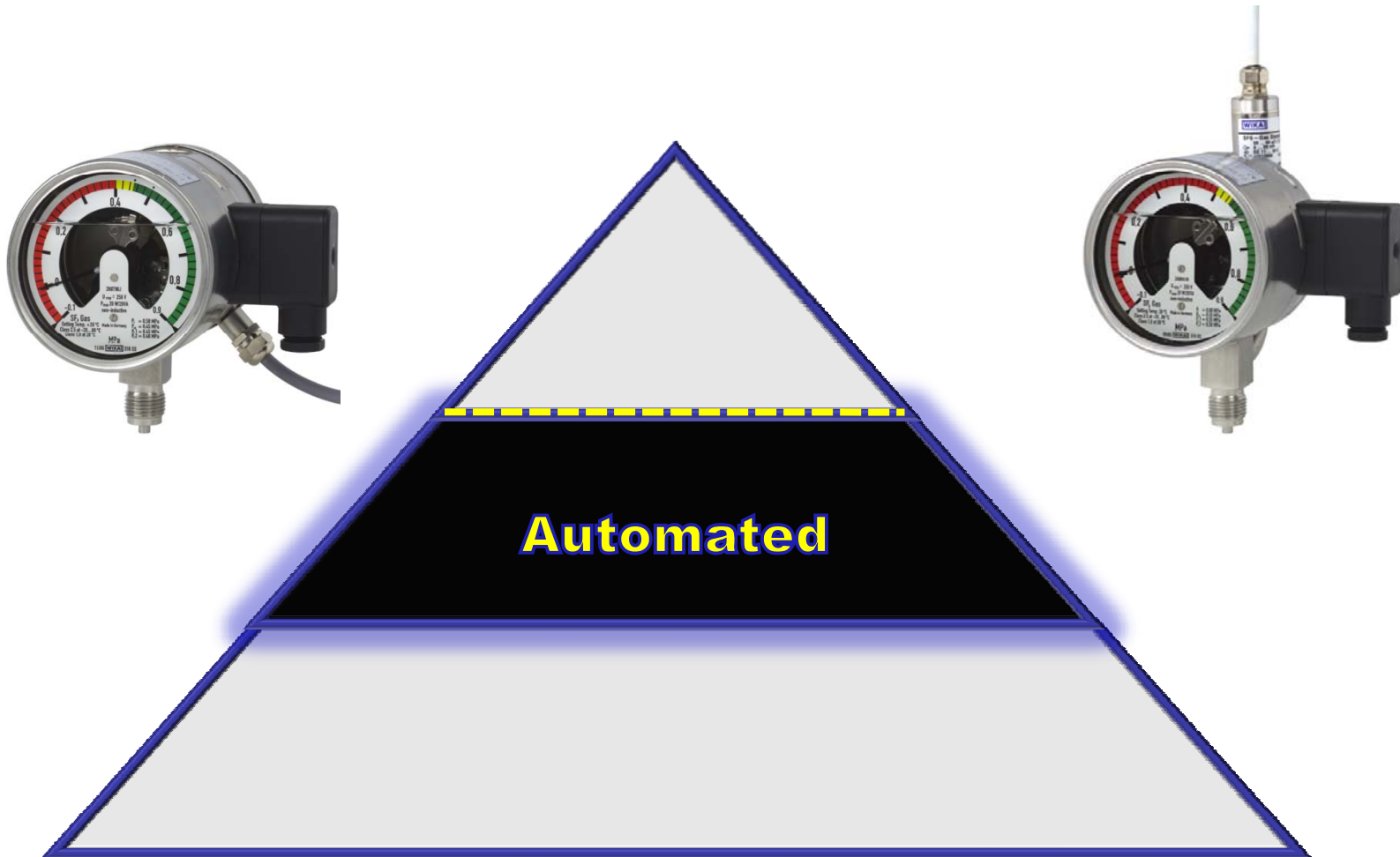
NOTE: Case study “Costs of Reactive Monitoring” available at www.wika.com/sf6 in the “Gas Management For the Smart Grid” archived presentation

The SF₆ Emission Monitoring Pyramid

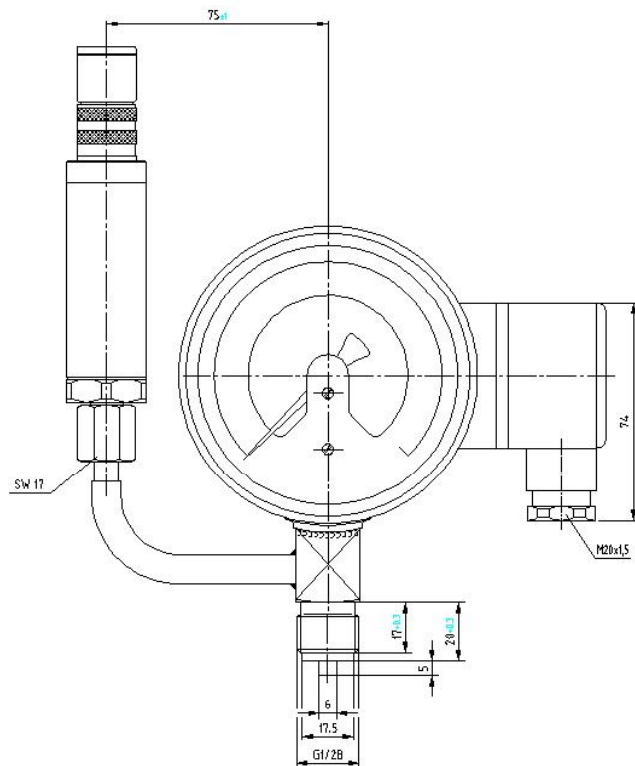
Emission Monitoring Solutions - Automated



Pressure and Temperature Measurement



Emission Monitoring Solutions - Automated



- **Measured** *at the tank with remote signal (density)*
- **Communicated** *away from the tank*
- **Analysis** *of the raw signal is done manually*
- When measured: **Constantly**
- Cost (New & Retrofit)
 - **Low, only change of spec needed for instrument**
- +
- infrastructure changes (wiring/piping/communication)**
- Pros/Cons
 - Information is sent remotely
 - Better maintenance planning
 - Emission reduction potential through knowledge of actual grid situation
 - **Quantifying emissions requires personal analysis or custom software**
 - **Change of engineering spec needed**

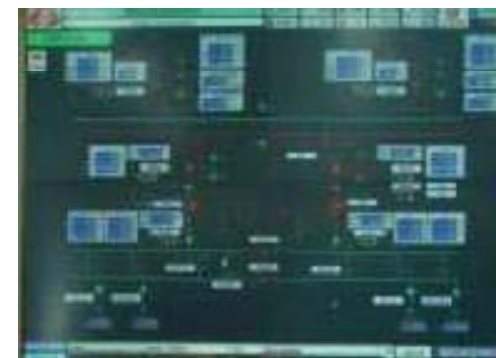
Emission Monitoring – Automated

Automated Emission Monitoring - Illustration



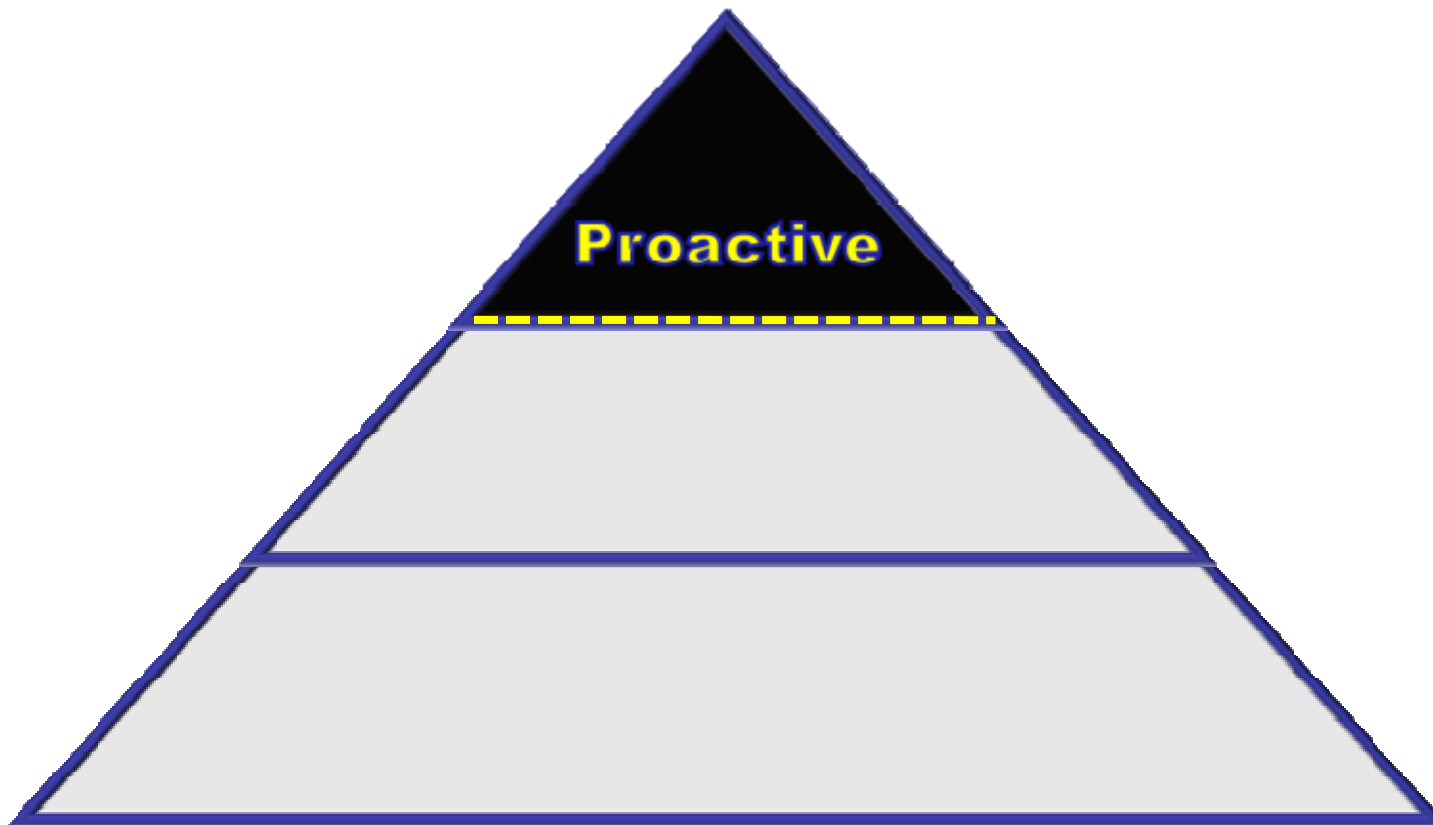
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Pressure and Temperature Measurement



SF6 GAS Density [kg.f/cm ²]	
CB	Section 5.62
Main Bus	Section 5.06
상부ES	Section 5.29
하부DS/ES	Section 5.11

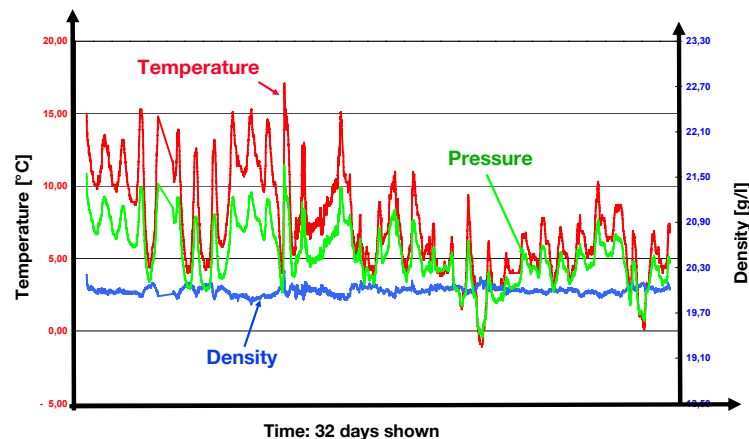
Proactive Monitoring using a SF₆ Gas Management System



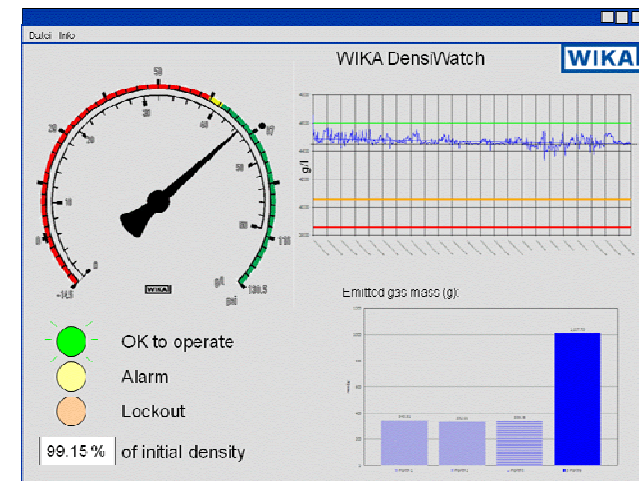
What is a Gas Management System?

- A GMS has core components that operate according to the “**MCA**-principle”
 - **M**easurement at the tank (including thermal image of the gas temperature)
 - **C**ommunication away from the tank to a remote location
 - Data acquisition and **A**nalysis tools to display real time information

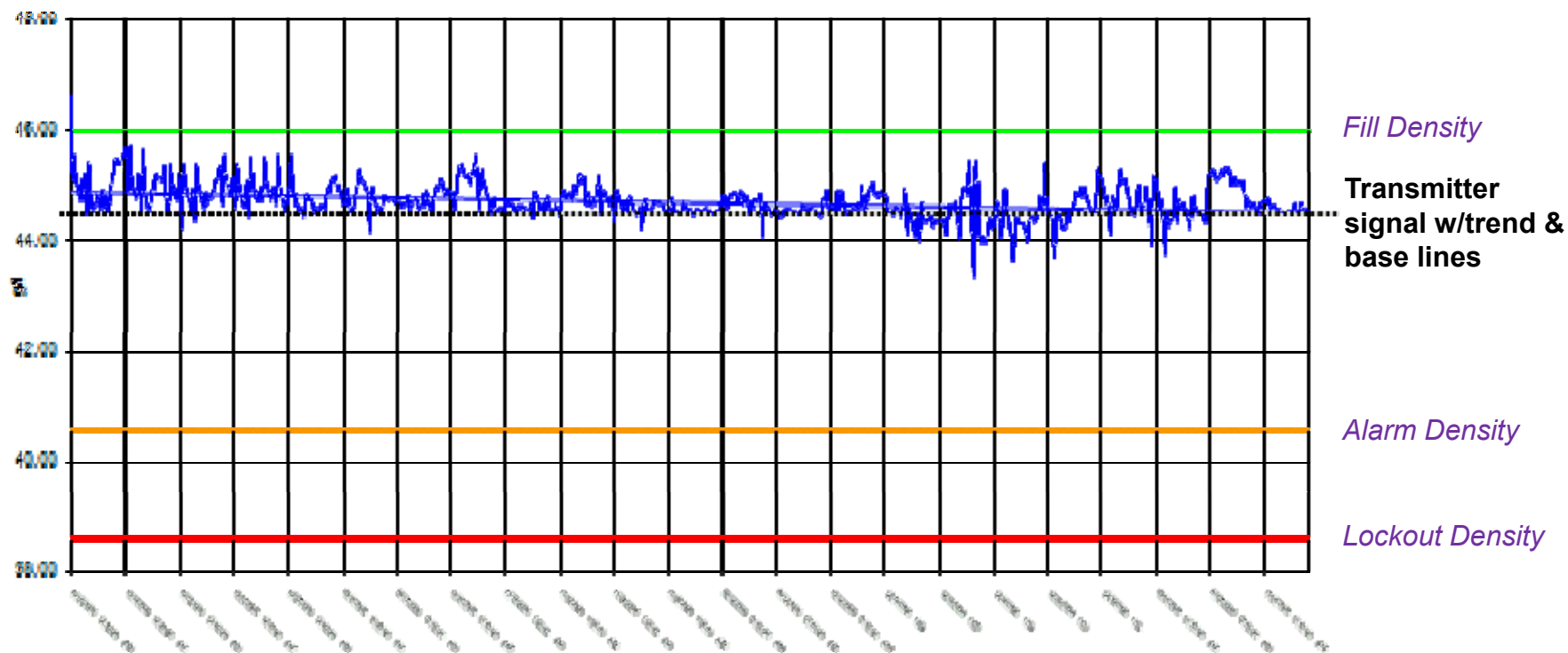
Raw data



Analyzed data

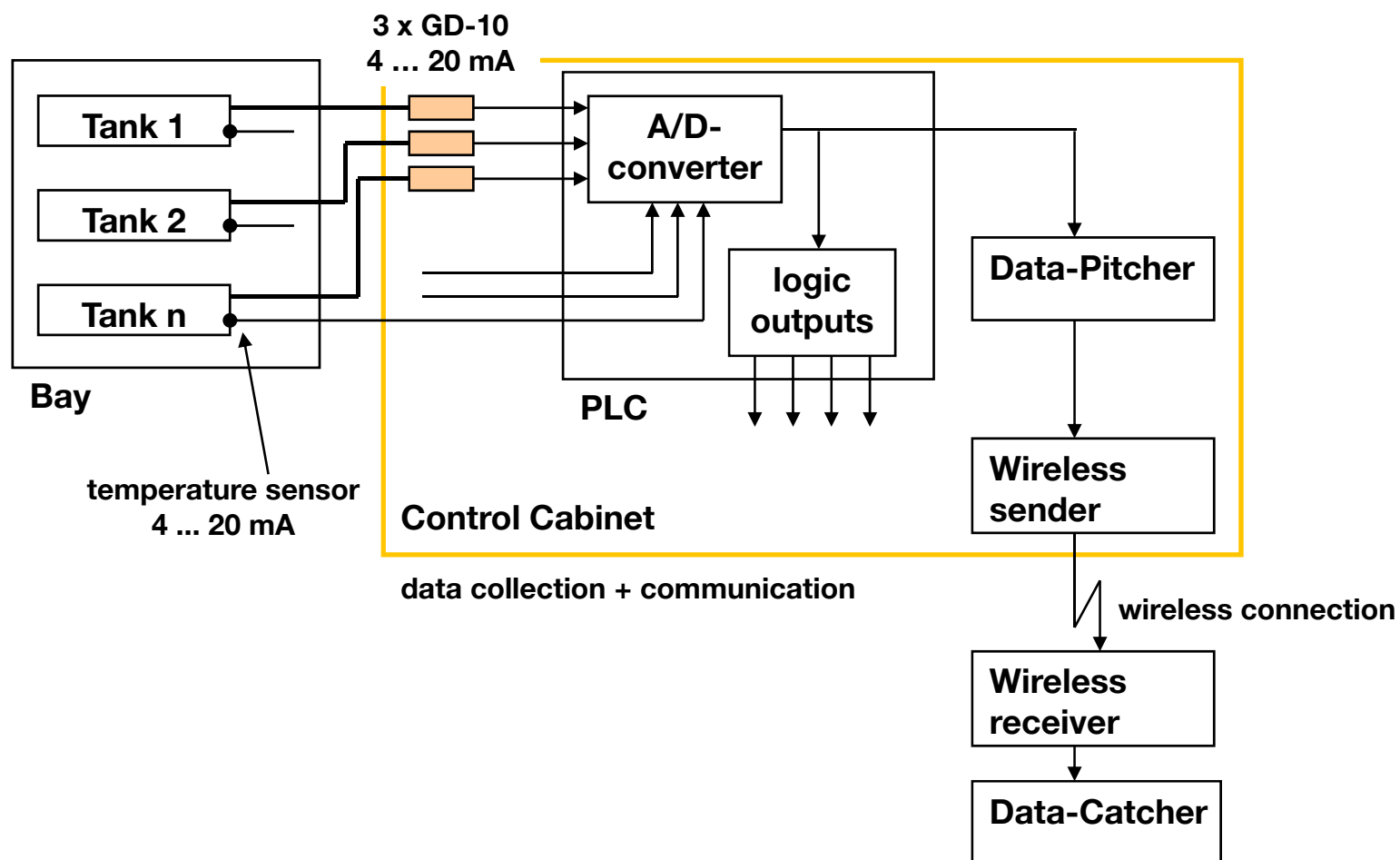


Gas Management Live



NOTE: mount transmitter directly on the tank for best results

Sample Layout of Wireless GMS



SF₆ Gas Management System

- **Measured** *at the tank with remote signals (density & thermal tank temperature)*
- **Communicated** *away from the tank*
- **Analysis** *of raw signals minimizes any temperature disbalance (i.e. cabinet heaters) & calculates emission trends*
- When measured: **Constantly**
- Cost (new & retrofit):
 - *Change of spec needed for instrument + scope of GMS Communication & Analysis (including possible wiring/piping/communication infrastructure)*
- Pros/Cons
 - Proactive grid maintenance possible
 - Emission reduction potential through knowledge of actual grid situation
 - External influences compensated via software
 - Fully customizable for retrofit or new installations (including wireless communication)
 - **Change of engineering spec needed**
 - **Long-term, value added mindset needed**

The SF₆ Emission Monitoring Pyramid



Pressure and Temperature Measurement

Reaching the Summit

