Fundamentals of Flare Gas Measurement

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Energy Nexus | Annual Technical Conference
Fuelling the Future

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Speaker Bio

Florian Karl, 38 years old
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Various Roles in Process Automation – Application Engineering, Sales, Project Management
Passionate Outdoorsman

Agenda

1. What is Flare Stack Gas Measurement (Definition)
2. Facts and Figures around Flare Stack Gas Measurement
3. Regulatory Environment for Flare Stack Gas Measurement
4. Flare Stack Gas Measurement using Ultrasonic Flow Meters

General Definition

A **gas flare**, alternatively known as a flare stack, flare boom, ground flare, or flare pit, is a **gas combustion device** used in places such as

- **petroleum refineries, chemical plants (CPR)**
- **natural gas processing plants**
- **oil & gas extraction/production sites** having oil wells, gas wells, offshore oil and gas rigs and landfills.

Source: Wikipedia

Different Types of Flares

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Industrial Plant Flare – Refineries, Chemical Plants

- When industrial plant equipment items are over pressured, the pressure relief valve is an essential safety device that automatically releases gases and sometimes liquids
- The released gases and liquids are routed through large piping systems called flare headers to a vertical elevated flare. The released gases are burned as they exit the flare stacks
- Steam is very often injected into the flame to reduce the formation of black smoke however when too much steam is added, a condition known as "oversteaming" can occur resulting in reduced combustion efficiency and higher emissions
- A specific BTU value is to be maintained for example in chemical plants to ensure combustion efficiency

Source: Wikipedia, webwire

Different Types of Flares

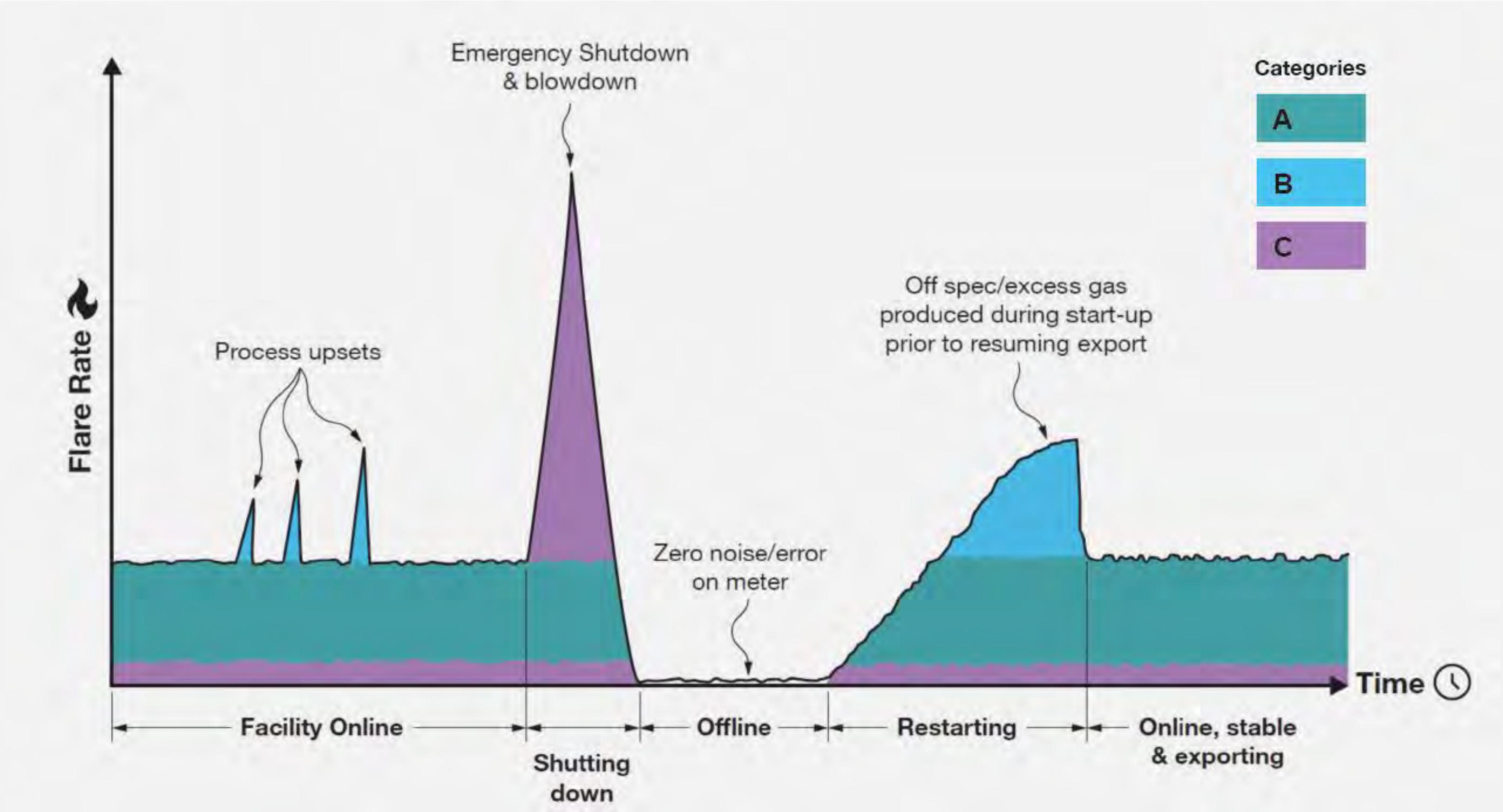
Oil & Gas Flares – Production & Processing Plants

- When crude oil is extracted and produced from oil wells, raw natural gas associated with the oil is brought to the surface as well
- Said gas can either be

1. recovered for processing and sale
2. used for re-injection into the well (EOR) to increase well pressure
3. burned off as waste gas – Flared.

Source: Wikipedia, capital.de

Flaring Categories



Source: Flaring and venting guidance - NSTA

- **Category A:**
  - Flaring at safe operation at optimum efficiency
- **Category B:**
  - Flaring during normal operation but beyond optimum
  - e.g.: Start-up; Flaring for maintencance; Instrument failure etc.
- **Category C:**
  - Emergency flaring & blowdown

Industry and Application View

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Why Flaring?

- For safety
  - Event based flaring to prevent harmful situations for people and assets
- Reduce GHG effect
  - Combustion of hydrocarbons less environmental damaging

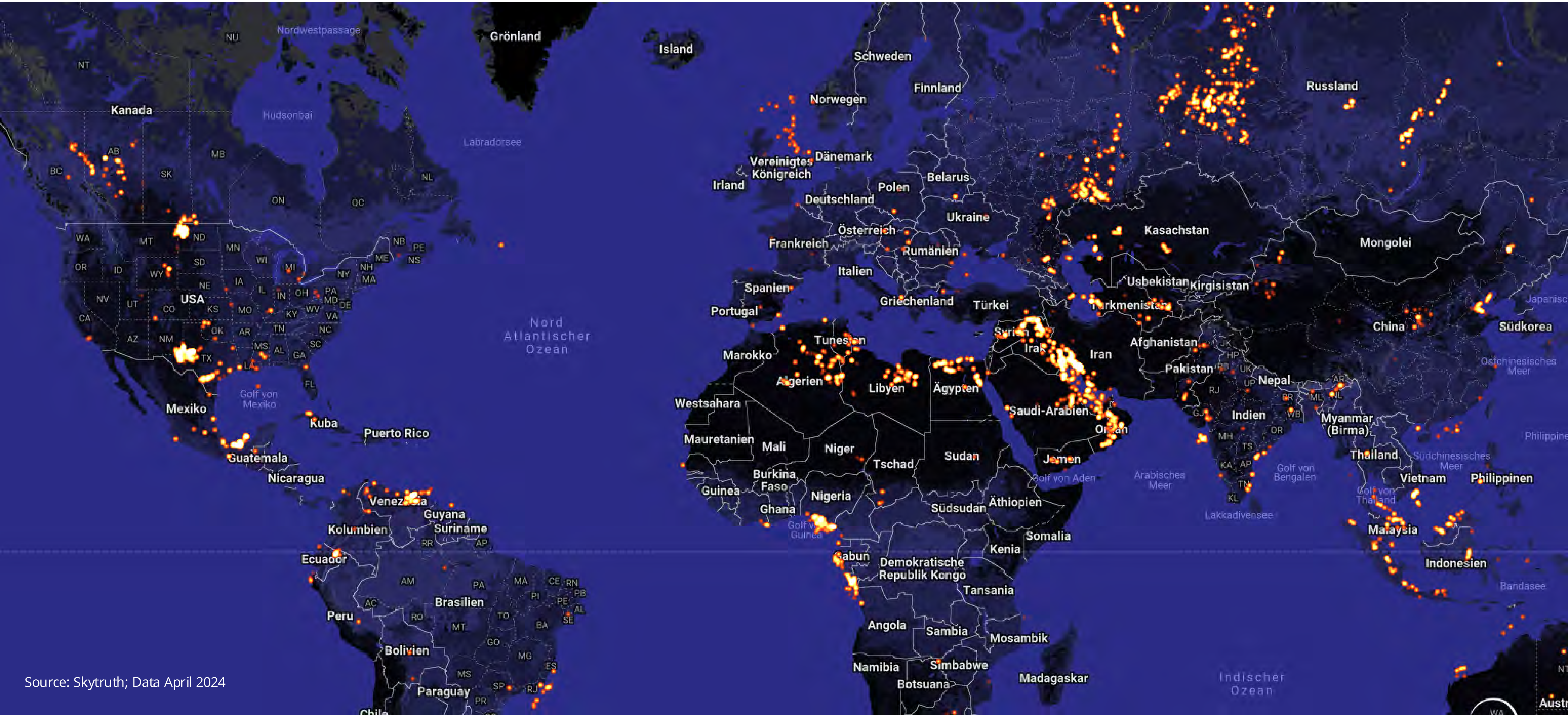
Purpose of Flare Gas Measurement?

- Global environmental regulations get more stringent
- CO_2 / CH_4 emissions have to be reported
- Measuring of volume flow / mass flow of flare gas is basis for calculation of CO_2 / CH_4 mass

Source: iStock, Microsoft CoPilot

Global Natural Gas Flaring

Skytruth – satellite detected flaring observation



Source: Skytruth; Data April 2024

Facts and Figures around Flare Stack Gas Measurement

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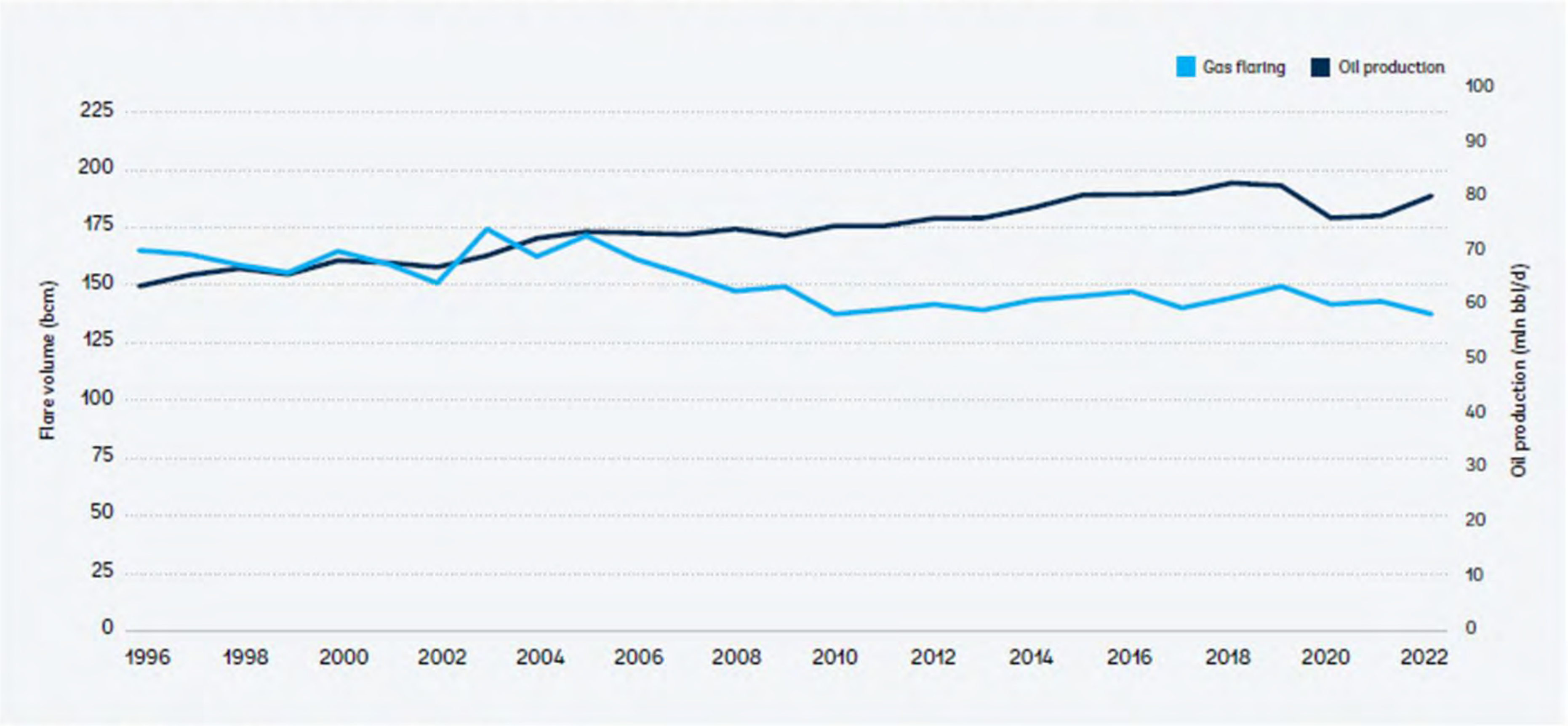
The World Bank - 2022 Global Gas Flaring Tracker Report

Figure 1 Global gas flaring and oil production 1996 to 2022 (flaring at upstream oil and gas and LNG plants only)



Source: NOAA, Payne Institute and Colorado School of Mines, EIA, GGFR

Facts and Figures around Flare Stack Gas Measurement

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The World Bank - 2022 Global Gas Flaring Tracker Report

Percentage reductions in flaring intensity 1996 to 2021: global average, GGFR and non-GGFR partner countries

Source: NOAA, Payne Institute and Colorado School of Mines, EIA, GGFR

Due to increased focus, regulatory changes and measurement

GGFR-
Global Gas Flaring Reduction

Focus on Emission reduction

Attention rises – requirements increase

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Politics

"Zero Routine Flaring by 2030" Initiative endorsers

THE WORLD BANK
IBRD · IDA

GGFR
Global Gas Flaring Reduction Partnership

Governments (35) Oil Companies (54)

COP28 UAE

COP28: 50 oil companies pledge to almost end methane emissions by 2030

The methane emissions charge in IRA starts in calendar year 2024 at $900 per metric ton of methane, increases to $1,200 in 2025, and increases to $1,500 in 2026. The charge remains at

O&G companies

ExxonMobil

Investing approximately $17 billion to reduce emissions - through 2027

bp

Install methane measurement at all our existing major oil and gas processing sites

Net zero operations | Reducing methane | Net zero production

2050 or sooner

Authorities

North Sea Transition Authority

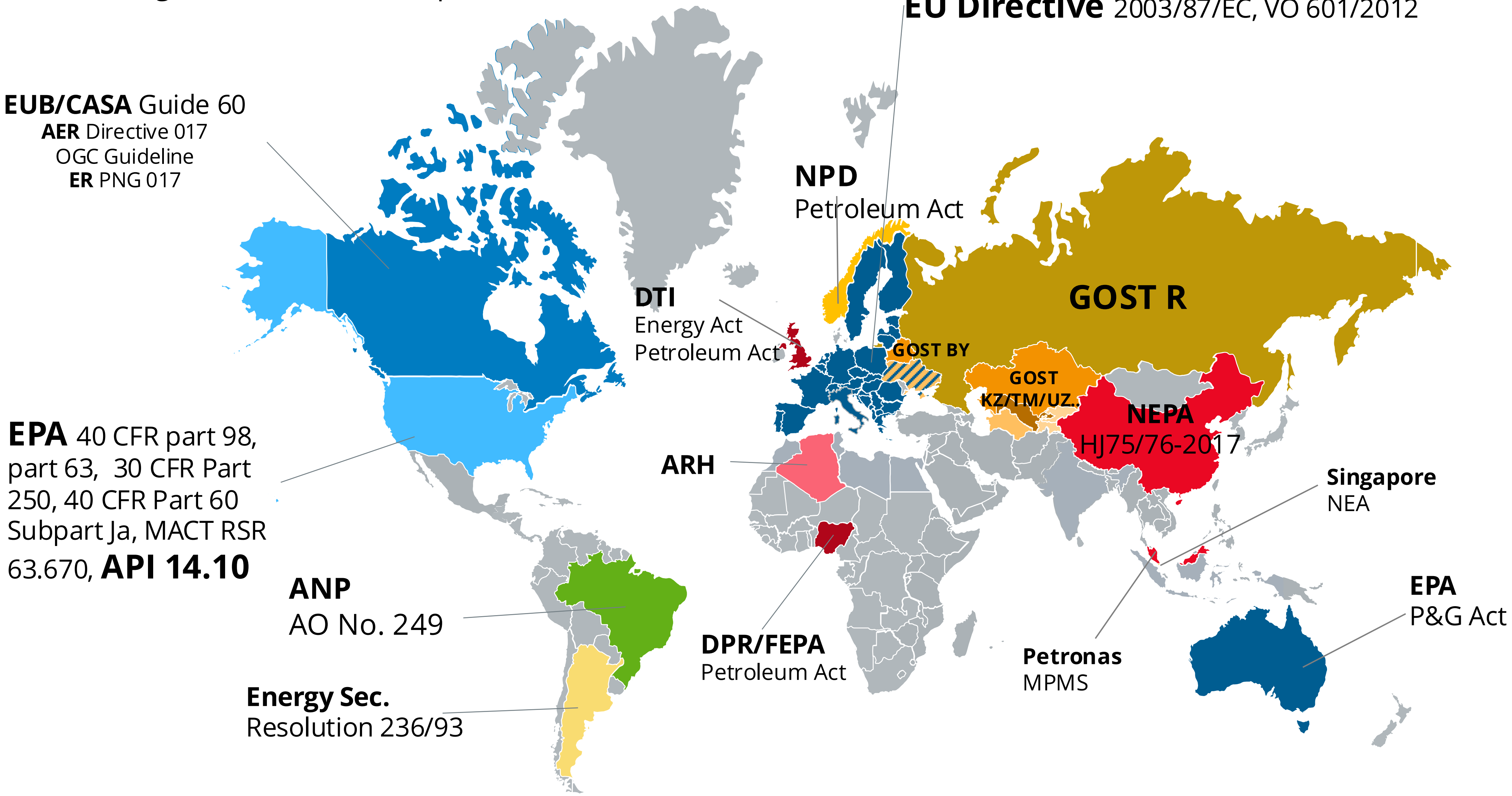
Demand: ZERO routine flaring by 2030

Adoption of fiscal metering approach

Source: Euronews, NSTA, World Bank, BP, ExxonMobil

Evolving Global Flare Regulatory Landscape

SICK is a global leader in Compliance



Government Regulations

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BLM 43 CFR 3160 - Onshore Oil and Gas Operations

BLM 43 CFR 3170 - Onshore Oil and Gas Production

BLM 43 CFR 3179 - Waste Prevention and Resource Conservation

BSEE 30 CFR Part 250 - Oil and Gas and Sulphur Operations in the Outer Continental Shelf

EPA 40 CFR Part 60 Subpart OOOO

› Subpart OOOOa Standards of Performance for Crude Oil and Natural Gas Facilities for which Construction, Modification or Reconstruction Commenced After September 18, 2015

› Subpart OOOOb Standards of Performance for Crude Oil and Natural Gas Facilities for which Construction, Modification or Reconstruction Commenced After November 15, 2021

› Subpart OOOOc—Emissions Guidelines for Greenhouse Gas Emissions from Existing Crude Oil and Natural Gas Facilities

EPA 40 CFR Part 98 – Mandatory Greenhouse Gas Reporting

EPA MACT 40 CFR RSR 63.670 – Requirements for Flare Control Devices

EPA MACT 40 CFR 10 CSR 10-6.220 - Restriction of Emission of Visible Air Contaminants

Industry Standards

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MPMS API 14.10 – Natural Gas Fluids Measurement – Measurement of Flow to Flares

- December 2021 2nd Edition / Manual of Petroleum Measurement Standards Chapter 14.10 Natural Gas Fluids Measurement - Measurement of Flow to Flares, Second Edition

MPMS API 22.3 – Testing Protocol for Flare Gas Metering

- August 2015 1st Edition / Testing Protocol for Flare Gas Metering

HM 58 - Guidelines for determination of flare quantities from upstream oil and gas facilities

- July 2017 2nd Edition / Energy Institute - Guidelines for determination of flare quantities from upstream oil and gas facilities

ISO 17089-2:2012 – Measurement of fluid flow in closed conduits – ultrasonic meters for gas

- Measurement of fluid flow in closed conduits - Ultrasonic meters for gas
- Part 2: Meters for industrial applications
- This standard will be replaced by ISO/AWI 17089-2

Flare Stack Gas Measurement using Ultrasonic Flow Meters

Challenges of flare gas flow metering

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1. Low flow performance

› Ability to measure smallest gas velocities

95 % operating time <1 m/s | <3 ft/s

in 2 seconds

2. High flow measurement

› Availability of measurement in shutdown conditions.

5 % operating time (up to 120 m/s |394 ft/s)

Measurement with a single device!

Flare Stack Gas Measurement using Ultrasonic Flow Meters

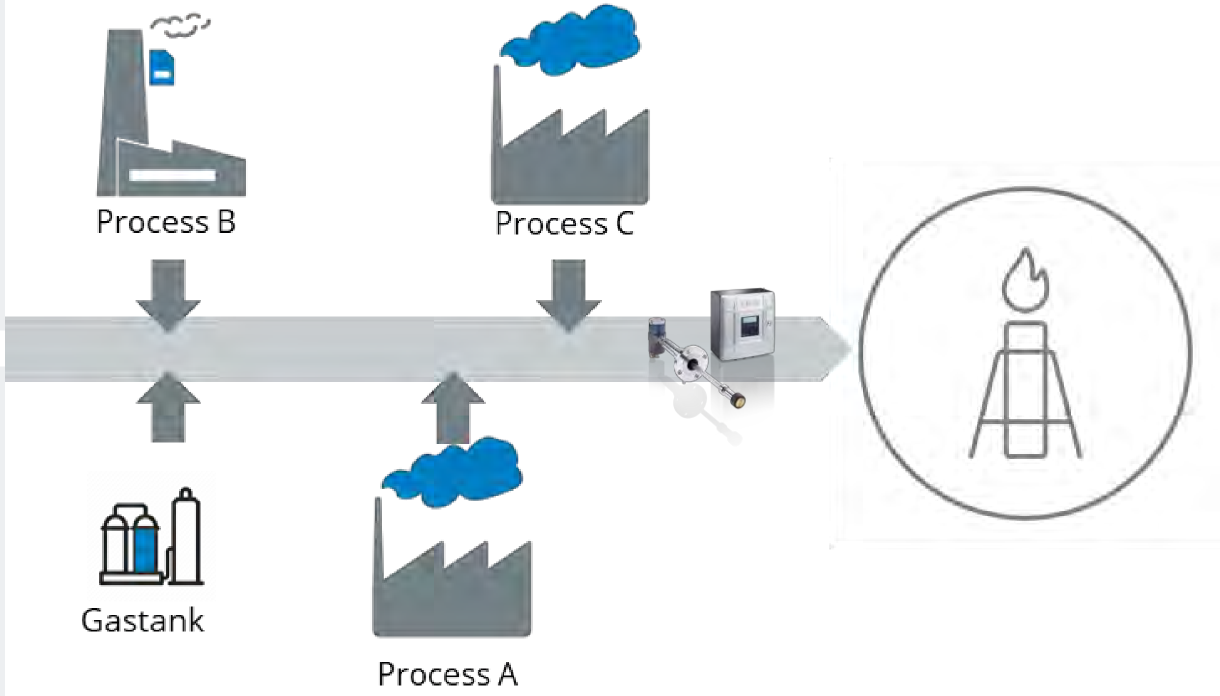
Challenges of flare gas flow metering

3. Measurement availability in "difficult" gases and conditions

- Gas matrix changing quickly
- Attenuative gases like H_2 or CO_2

4. Adapted installation capabilities

- Offshore installation
- Limited accessibility to piping



Finding the right measurement solution requires experience

Error of changing gas composition on FLOW Meters

API 14.10 Standard

10.4.3.1 Three Examples of the Composition Effect

The approximate measurement error caused by using a fixed composition of 1% CO_2, 0.9% H_2S, 97% methane, 1% ethane and 0.1% propane when the flare composition changes to:

- Case 1—0.53% CO_2, 0.47% H_2S, 51.08% methane, 0.53% ethane and 47.39% propane.
- Case 2—0.4% CO_2, 0.36% H_2S, 38.8% methane, 0.4% ethane and 0.04% propane and 60% hydrogen.
- Case 3—12% CO_2, 0.8% H_2S, 86.22% methane, 0.89% ethane and 0.09% propane are shown in Table 5. (To simplify the calculation all flowing conditions are held constant and only the composition is changed.)

Table 5—Errors Related to Use of Fixed Composition for Different Meter and Calculations Types (Absolute Value of Error)

Case 1—Propane Increased	Actual Volume	Standard Volume	Mass
Differential Pressure Meter	~ 34%	~ 34%	~ 25%
Thermal Flow Meter	~2% to 15%	~2% to 15%	~35% to 45%
Velocity Meter (Optical, Ultrasonic, Vortex)	~ 0%	~ 0%	~ 44%

Case 2—Hydrogen Added	Actual Volume	Standard Volume	Mass
Differential Pressure Meter	31%	31%	45%
Thermal Flow Meter	~100% to ~300%	~100% to ~300%	~300% to ~700%
Velocity Meter (Optical, Ultrasonic, Vortex)	0%	0%	112%

Case 3—CO_2 Increased	Actual Volume	Standard Volume	Mass
Differential Pressure Meter	~9%	~9%	~8%
Thermal Flow Meter	~2% to ~5%	~2% to ~5%	~15% to ~20%
Velocity Meter (Optical, Ultrasonic, Vortex)	~0%	~0%	~15%

Notes:

1. Based on composition errors caused by using fixed composition, the user needs to evaluate the need for composition measurement and correction.
2. Thermal flow meter errors are expressed as a range due to the composition effect being velocity dependent.

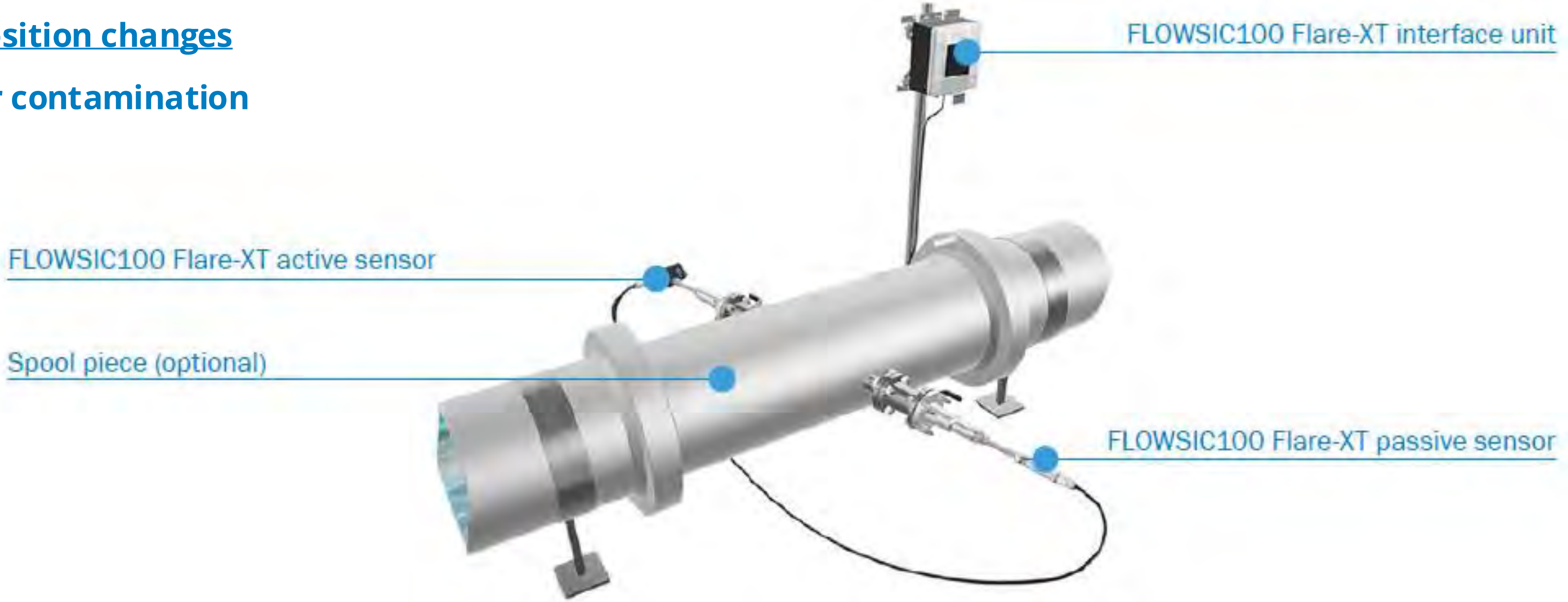
Source: API MPMS 14.10

Flare Stack Gas Measurement using Ultrasonic Flow Meters (UFM)

Key Features

- Flare gas monitoring is essential for compliance with environmental regulations.
- **Ultrasonic** Measurement is the **right** technology
  - **Availability**
  - **Low measurement uncertainty**
  - **High turn down ratio up to 1:4000**
  - **Immune to gas composition changes**
  - **Resistant to fouling or contamination**

Source: SICK



Challenges for UFM

Installation effect awareness

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Source: SICK

All **major** flare gas measurement **standards emphasize the critical importance** of installation effects as " … one of the **dominant uncertainties** for flare gas meters" *

API MPMS 14.10.

HM 58*

ISO 17089-2

Regulators closely monitor flare gas measurement systems and **pay attention to installation effects.**

EPA

Canada Energy Regulator

Challenges for UFM

UFM performance influenced by Installation

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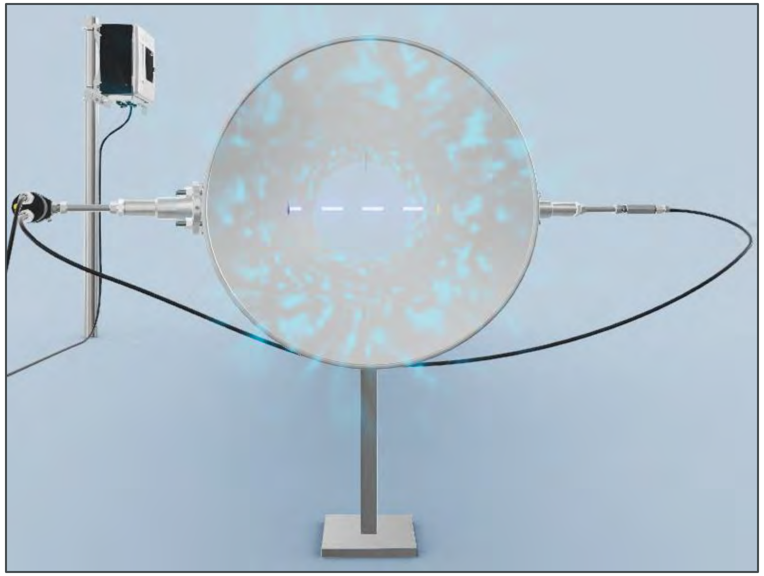
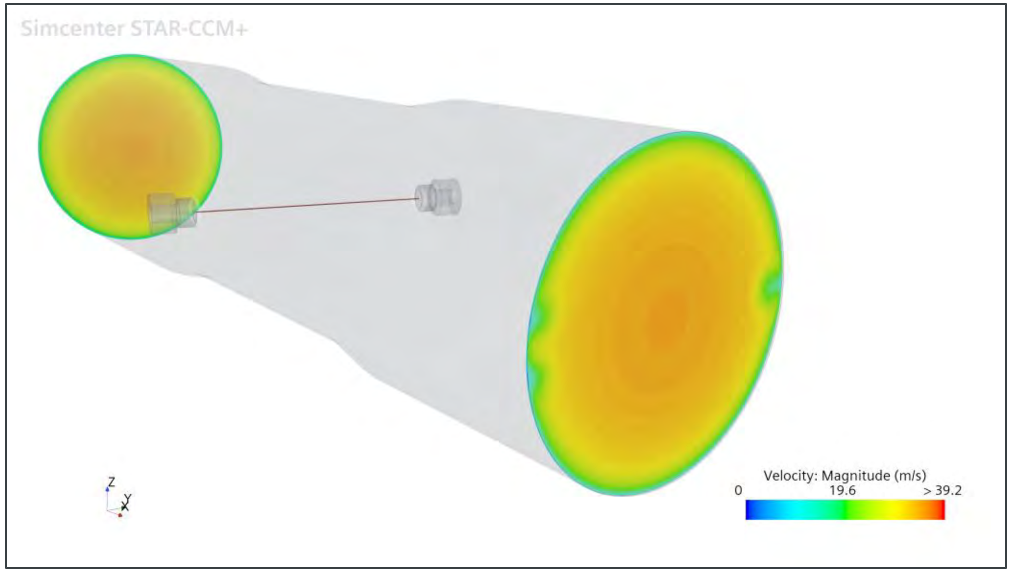




- Ultrasonic Flare Flow Meters measure on an acoustic path.
- They assume a „**fully developed symetrical flow profile**“
- Typically this is found after a straight inlet of **at least 20 x Pipe-diameter**

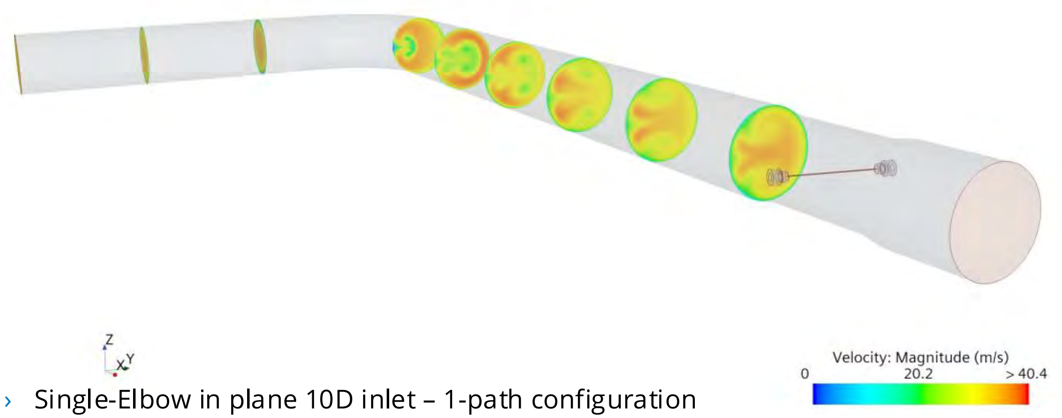
Installation effects

UFM performance influenced by Installation

Installation effect refers to how the physical setup and environment around an UFM impact its accuracy.

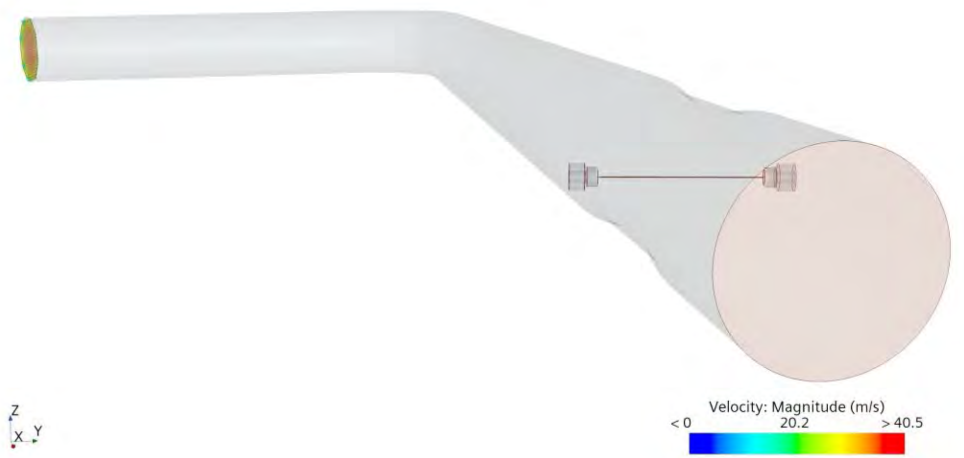
This includes factors like **pipe configuration, upstream and downstream conditions and the specific installation position**.

› Contour plots



› Single-Elbow in plane 10D inlet – 1-path configuration

› Animation



› Installation effects **lead to disturbed flow profiles** – resulting in **severe additional** measurement **uncertainties**

› Flow conditioners are not allowed in flaring (safety concern due to pressure drop)

Solutions for already Installed Flare Flow Meters

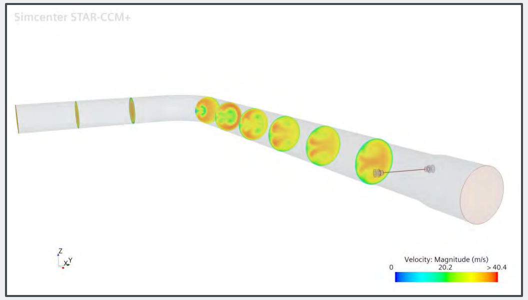
Bring to Compliance

› **Approach: Derive compensation factors**

Replicate piping setup in **calibration** facility

- (+) Drastically reduction of installation effect error
- (+) Individual piping setup can be replicated
- (−) Pipe size and length of inlet limitations
- (−) Disturbance generating valves, fittings not considered
- (−) Changing gas composition not considered
- (−) High in effort and cost

Modeling piping setup with computational fluid dynamics (**CFD**)



- (+) Drastically reduction of installation effect error
- (+) Individual piping setup can be modeled
- (−) CFD models are based on specific boundary conditions and assumptions, which may not cover all real-world scenarios
- (−) CFD models are static and may not adapt well to dynamic changes in flow conditions or gas composition.

› **CFD** and **calibration** effectively compensate for major portions of errors induced by installation effects, but their effectiveness is limited to the calibration conditions and CFD model boundary conditions.

Solutions for new Flare Flow Meters

Correction or Compensation

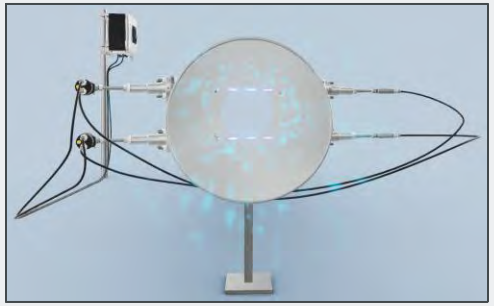
› Approach: Real in-situ correction

Multipath Flow Meter – similar to custody transfer

- (+) Best reduction of installation effect error
- (+) Real in-situ correction of flow disturbances instead of simulation
- (+) Flow profil deformation due to gas composition changes are directly corrected
- (+) Path redundancy for highest measurement uptime
- (–) Potentially high in cost due to involved hardware

› Approach: Derive compensation factors

1 or 2 path Flow meter + CFD



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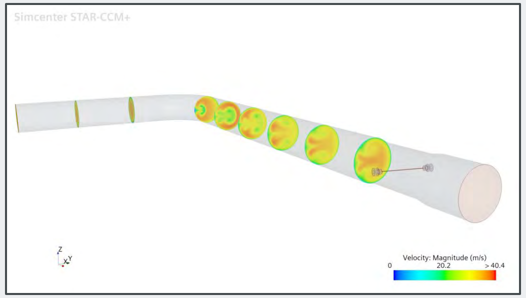

- (+) Drastically reduction of installation effect error
- (+) Individual piping setup can be modeled
- (–) CFD models are based on specific boundary conditions and assumptions, which may not cover all real-world scenarios
- (–) CFD models are static and may not adapt well to dynamic changes in flow conditions or gas composition.

› The selected approach must be discussed and approved by the regulator to ensure it meets all compliance standards.

Flare Stack Gas Measurement using Ultrasonic Flow Meters

Flow uncertainty

- Typical flow uncertainty
  - **5% for > 1 fps**
  - **20% for < 1 fps**
- SICK is one of the leading custody transfer meter manufacturers – **we know what it takes to accurately measure**.

SICK Flare gas measurement solution

- Multiple measurement paths
- Highly accurate spool pieces
- Calibration, CFDs

- Individual application evaluation is key

Summary

Compliance & SICK Flare Gas Measurement

- Global **Regulations getting stricter** – you need to **measure accurately** to control your emissions
- Flare gas flow is a challenging measuring task
- **Ultrasonics is the optimal technology**.

- **Compliance** is key:
- **Installation effect** correction or compensation
- **Lowest uncertainty** with superior sensor technology and calibration
- **SICK** will **individually evaluate** your application + find the best fit solution incl. **performance overview**