Milan

SIGMAFINE SUMMIT 2019 ™

engineering data for digital transformation

Lost with Losses

The Hidden Impact of Measurement Technology in Closing Mass Balances

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Agenda

Role of Field Instrument accuracy in Production Accounting and Losses

Business Challenges

Using Sigmafine to Identify Measurement Issues

Current Measurement Technologies and Standards

Recommended Practices for Improvement

Typical Refinery Losses

- With **poor** instrumentation and procedures: 1.5-2.5% mass
- With **average** instrumentation and procedures: 0.7% - 1.5% mass
- With good instrumentation and procedures: < 0.5 % mass
- Good information enhances business functions:
  - Planning and scheduling
  - Process Operations
  - Management Decision

Mass losses for the overall refinery must be less than 0.5% to meet Solomon Index reporting requirements

Why Mass Balances Matter

Profitability

- Not overpaying for what you buy or getting underpaid for what you sell
- You are getting paid for on what your custody measurement is reading not on your reconciled measurement
- Assurance, control, and validation of movements (i.e. theft prevention)

HSE

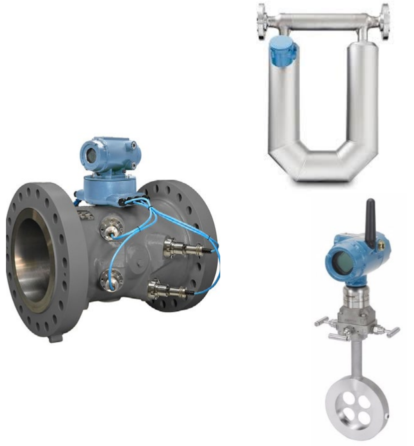
- Accurate emission reporting to avoid overpaying fines
- Accurate reporting of Energy Intensity Index (EII)
- Ensure not operating above design limits

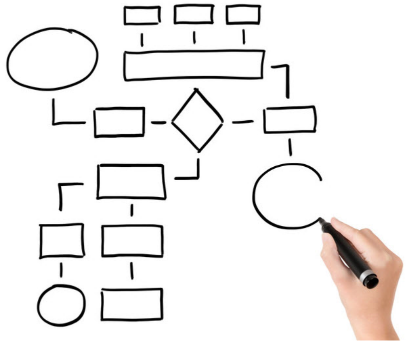
Process Optimization

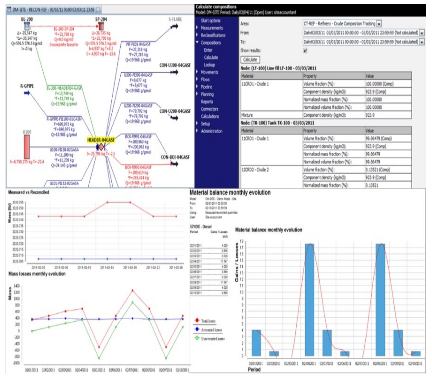
- Pinpointing of losses early
- Identification and minimization of unaccounted losses
- Unit performance optimization by calculating efficiencies, catalyst conversions and yields

Savings of $2-10 million per year for an averaged sized refinery

Refinery Loss Control Process







Measurement → Business Practices → Data Reconciliation Software (Sigmafine) → Production Accounting → Loss Control Programs

Flow measurement is the foundational step for production accounting and loss control

Case in Point

Scale of theft at Shell's Singapore refinery much greater, court documents show

Around $150 million worth of oil was stolen from Shell's biggest global refinery over several years, Singapore court documents reviewed by Reuters show, far more than reported when police first revealed the heist earlier this year.

"Fuel is both ubiquitous and untraceable, making its theft a seemingly low-risk criminal operation compared to something like drug smuggling or arms trafficking, where the concern about being caught is much higher," said Ian Ralby, a maritime crime expert who works with both the U.N. and the U.S.-based

Shell has taken measures to avoid repeat incidents:

"These include closer monitoring of products moving in and out of Bukom, tightening vessel management procedures, and stepping up ethics and compliance training," the spokeswoman said in an emailed statement to Reuters on Thursday.

Fuel theft could be worth $113 billion a year globally, according to industry estimates

Challenges With Closing Mass Balances

- Data Entry Errors
- Measurement Errors
- Missing Data

Measurement Error Sources:

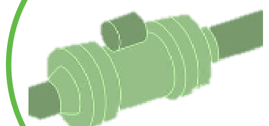
- Instrumentation Accuracy
- Maintenance and Calibration Practices
- Changes in process conditions and compositions of materials being measured

Accurate flow measurements are key to accurate mass balances

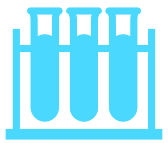
Refinery Plant Wide Mass Balance Challenges

Flow Measurement Challenges

Process conditions differ from design conditions



Volumetric measurements are impacted by changes in density



No online density measurements results in the need to obtain lab samples

Sources of Error

1. Crude Import Custody Transfer Measurement
2. Density Measurements
3. Natural Gas Measurements
4. Fuel Gas
5. Inventory Changes

Additional Sources:

1. Coke
2. Flare

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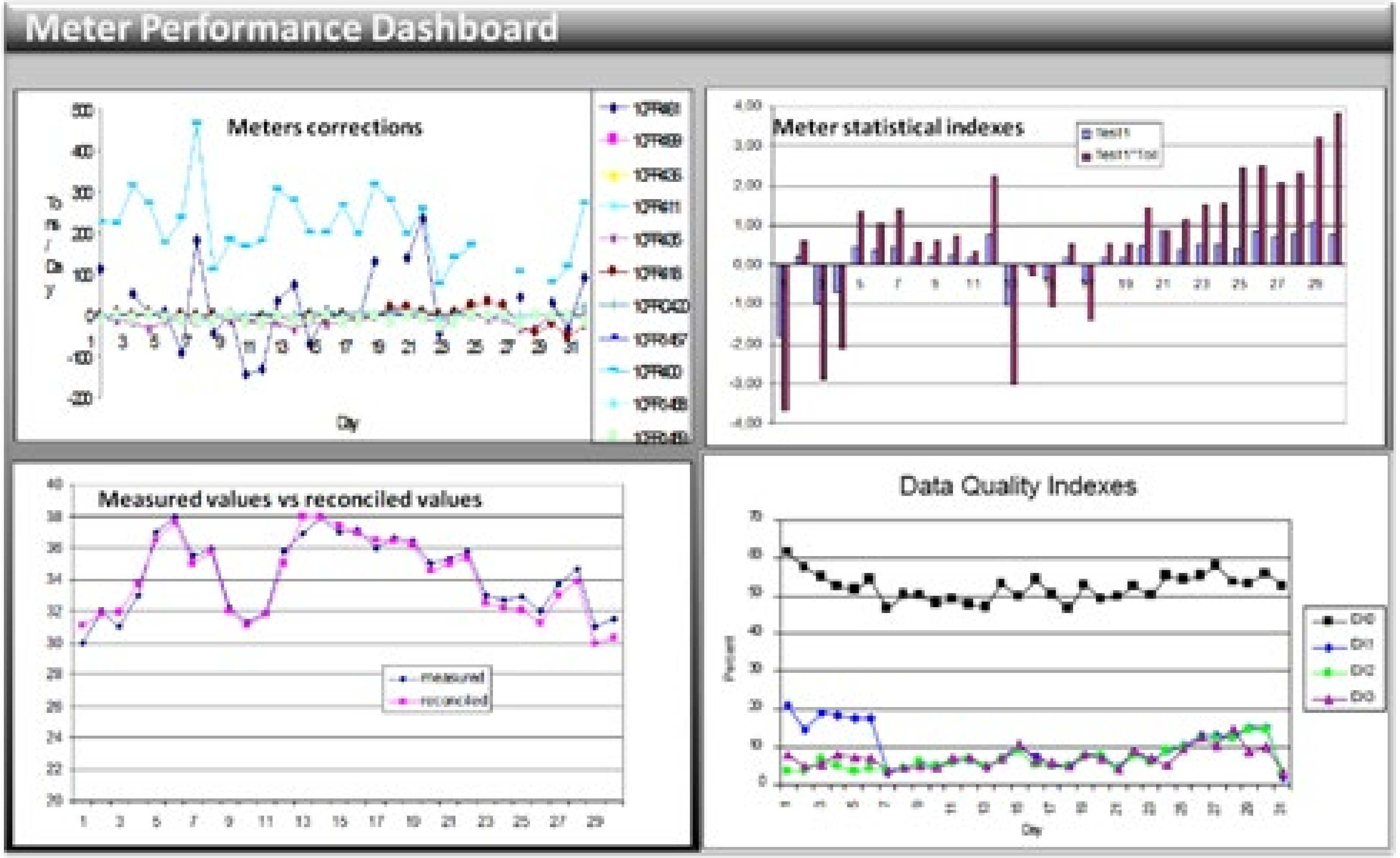
Meter Performance from Sigmafine



How Sigmafine® works

Build Model

- How the process information is related
  - Plant, Process unit, Business Unit, Unit operations, Equipment, Process, etc

Apply Engineering Principles

- Automate calculations
  - Simple - PT Compensations/UOM/M to V conversions
  - Comples - Eq. of state (e.g. Peng Robinson), Property estimation (e.g. Klosek McKinley)

Apply Conservation Principles & Analysis Rule(s)

- Σ In- Σ Out + Σ Generation + Σ Consumption- Σ Accumulation = 0
  - Analysis Rules: Mass, Energy, Composition, Properties

Solve Model for minimal error

- Error Minimization (SSR)

$$\text{Minimize} \sum_{i=1}^{N} \left(\frac{\text{Raw}_i - \text{Reconciled}_i}{\text{Absolute Tolerance}_i} \right)^2$$

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Data Quality KPI - Case

DX Indicator	Value	Used for assessing
DX0 – Redundancy	> 85 %	Sufficiency of flow measurements
DX 1 – Imbalance	< 10 %	Overall quality of a set of measurements
DX 2 – Reconciled Correction	< 5 %	How much correction required to reconcile
DX 3 – Tolerance	DX3 > (DX2, DX1)	How well the tolerances are assigned
DX 4 – Reconciled Difference	< 0 (negative)	Level of distortion between reconciled and measured

➔ Generate prescriptions for improving data over time

- Classic example: stack ranking of bad meters

Data Quality KPI - Case

DX0 – Non redundant data quality indicator

- DX0 = 1 – Σ Absolute Redundant Mass flows / Σ All absolute mass flows
- Overall percentage of data excluded from the redundancy check

DX1 – Imbalance indicator

- DX1 = RMS (Imbalances) / RMS (Redundant Flows)
- Overall percentage of imbalance in the redundant measurements

DX2 - Reconciled Correction Indicator

- DX2 = RMS (Corrections) / RMS (Redundant Flows)
- Amount of adjustments that the solver had to do to satisfy all balances in the plant

DX3 – Tolerance Indicator

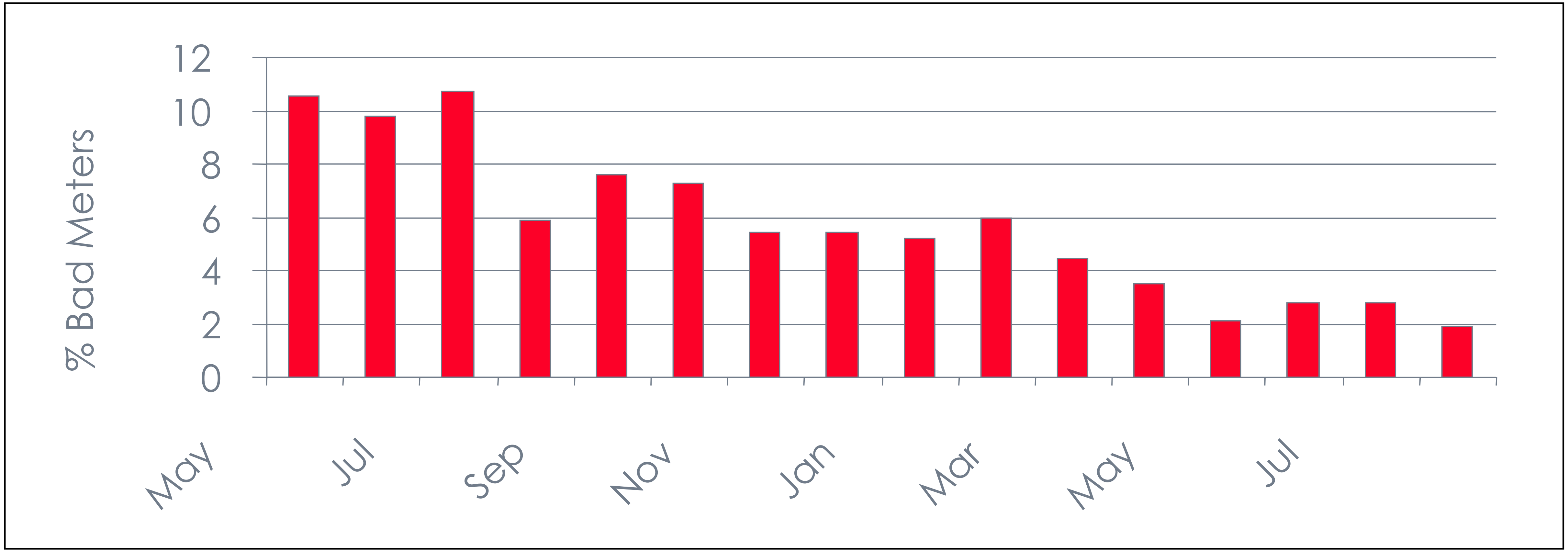
- DX3 = RMS (Tolerances) / RMS (Redundant Flows)
- Expected level of overall correction for each day's measurements

DX4 – Reconciled Difference Indicator

- DX4 = RMS (Reconciled Flows) / RMS (Redundant Flows) - 1
- Distortion between the reconciled and measured flows

Indirect Benefits of Sigmafine

- Improving & sustaining meter reliability



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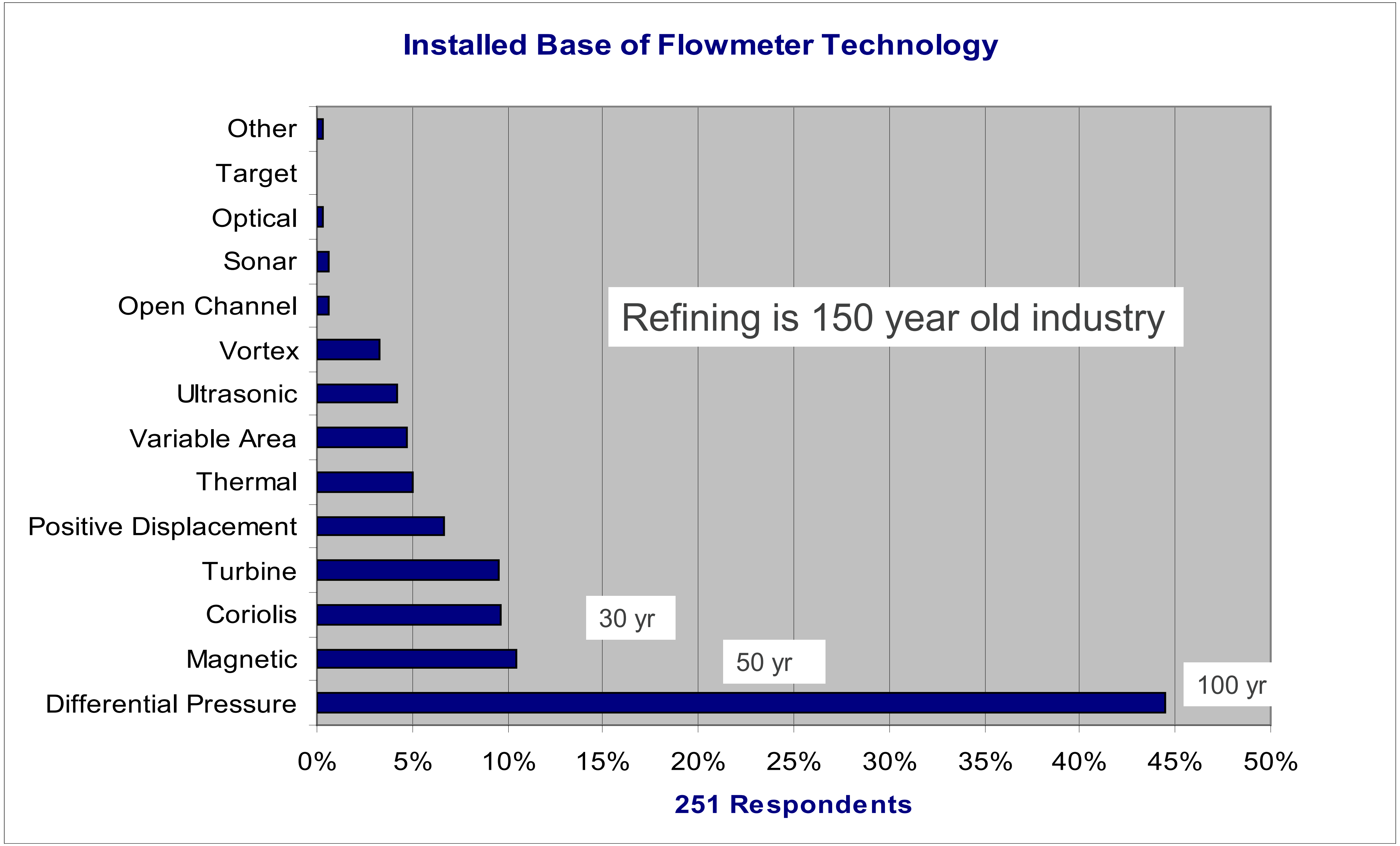
Custody Measurement Types

- Mass and Volumetric Flow Meters
- Automatic Tank Gauges (ATG)
- Marine Vessel Gauging
- Manual Gauging
- Truck and Rail Car Outages
- Weigh Scales

Distribution of Flowmeter Technology



Historical Practice for Mass Balance Meters – Use Volumetric Technologies

Orifice dP Meters for Process Applications

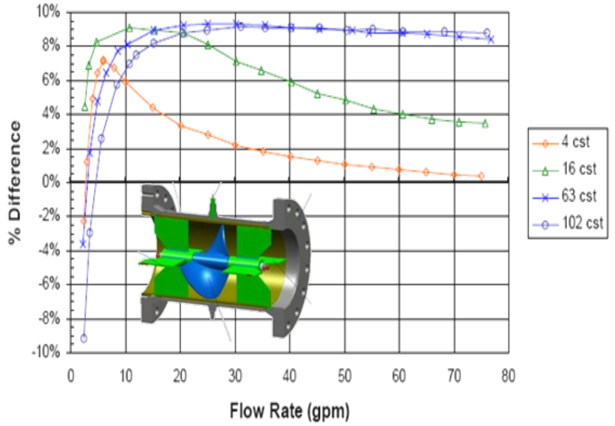
Advantages
- Greatest application flexibility
- Low purchase price
  - Independent of line size
  - Cost effective for larger line sizes

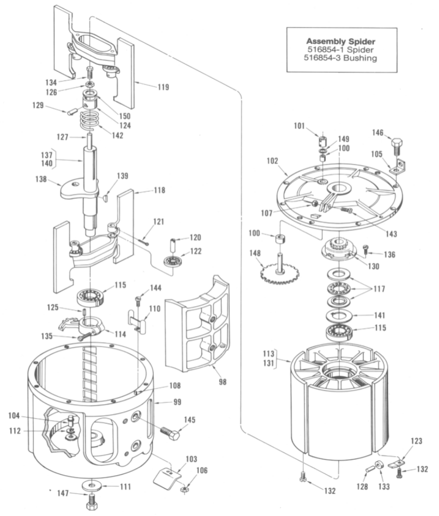
Limitations
- Poor accuracy when uncompensated, 1-5%
- Moderate accuracy when compensated: 0.5-1.5%
  - Having a **known fluid density** is the key to achieving this accuracy
- Accuracy degraded by orifice plate wear, difficult to detect
- Impulse lines can plug

Mechanical Meters for Custody Transfer Applications

- Metering performance affected by fluid properties
- Extensive moving/wearing parts
  - High maintenance
  - Meter factor shift
- NEED to be frequently checked and adjusted

Meter Factor Shift

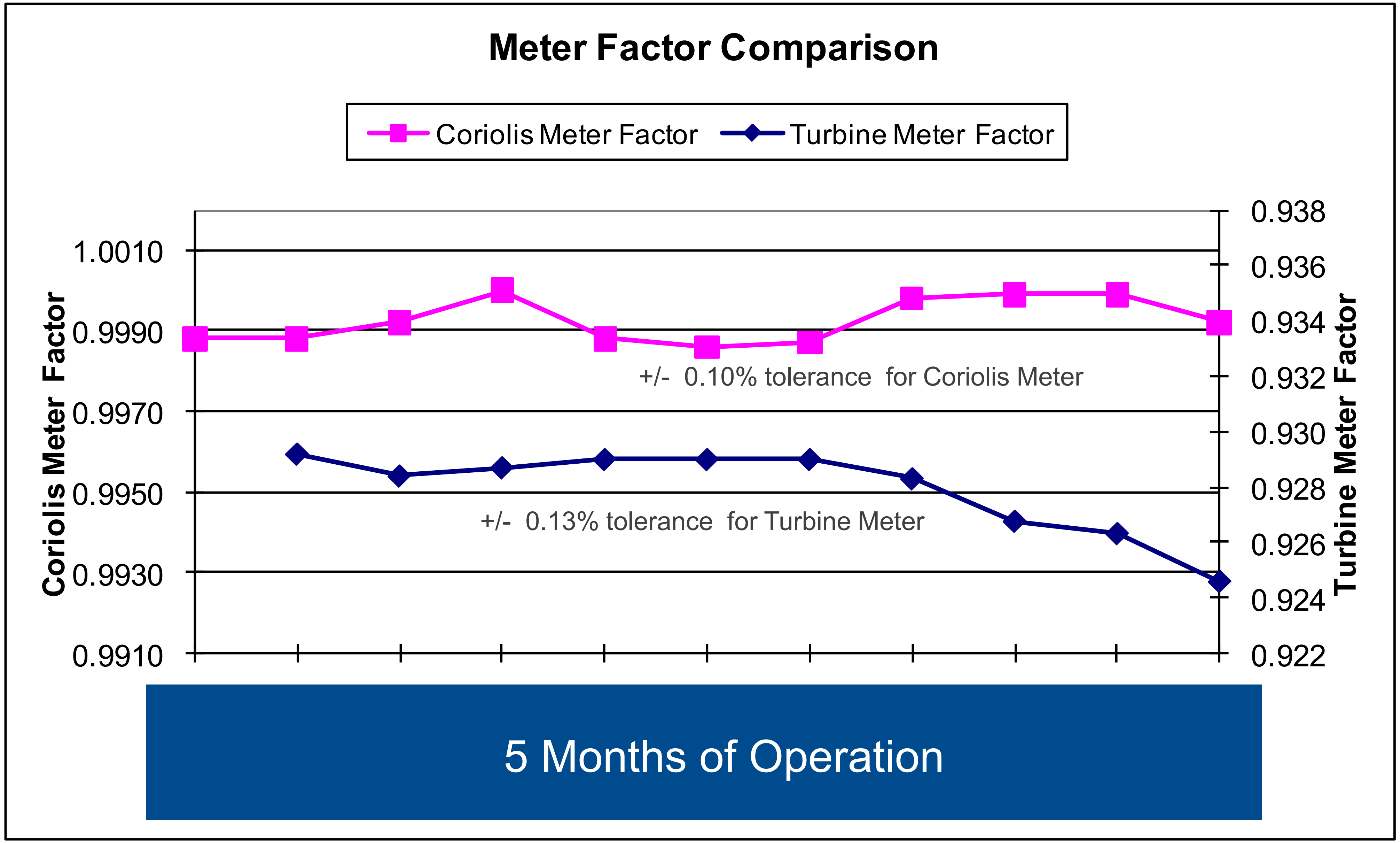




Coriolis Meters Eliminate The Largest Sources of Measurement Error in Mass Balance and Custody Transfer Applications

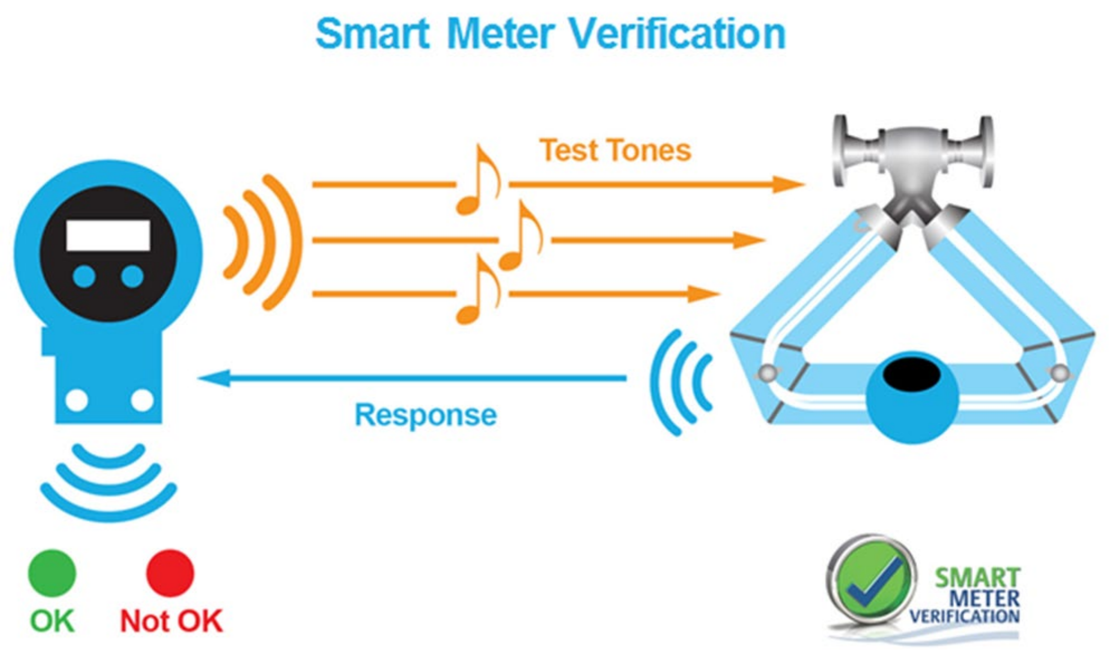
- **Direct Mass and Density Measurement**
  - Not affected by changes in composition, viscosity, temperate, pressure, conductivity
- **Rangeability**
  - 20:1 for custody
  - 100:1 for non-custody
- **Measurement accuracy**
  - At 20:1 turndown:
    - Mass Flow Rate: ±0.1 (optional 0.05 %)
    - Volume Flow Rate: ±0.1% (optional 0.05%)
- **No flow conditioning or straight runs required**
  - Not dependent on flow profile
- **Measures difficult and/or viscous fluids**
  - Liquid asphalt and molten sulfur
- **Bi-directional Measurement**
- **Low Maintenance**
  - No moving parts
- **Two-Phase Flow Indication**
  - Provides notification of the fluid being single phase, moderate entrainment, and severe entrainment
- **Smart Meter Verification (SMV)**
  - In-situation testing of meter integrity – tube stiffness, sensor components, transmitter electronics
  - Extend calibration cycles

Long Term Meter Factor Stability



Results of proving a CMF300 and 4" Turbine meters with 18" Brooks Compact Prover on LPG in refinery in Brazil .

Smart Meter Verification Delivers Confidence in Measurement



Sensor Calibration + **Electronics Performance** + **Process Effects** = **Measurement Confidence**

Sensor Calibration
- Accuracy
- Flow Calibration Factor
- Stiffness

+

Electronics Performance
- Electronics failure
- Zero verification
- Configuration changes
- Custody transfer security breach
- Temperature sensor

+

Process Effects
- Multiphase
- Operating flow rate
- Coating

=

Measurement Confidence

Standards for Coriolis Meters

Manual of Petroleum Measurement Standards
Chapter 5—Metering

Section 6—Measurement of Liquid Hydrocarbons by Coriolis Meters

Measurement Coordination

FIRST EDITION, OCTOBER 2002

American Petroleum Institute

Helping You Get The Job Done Right.[SM]

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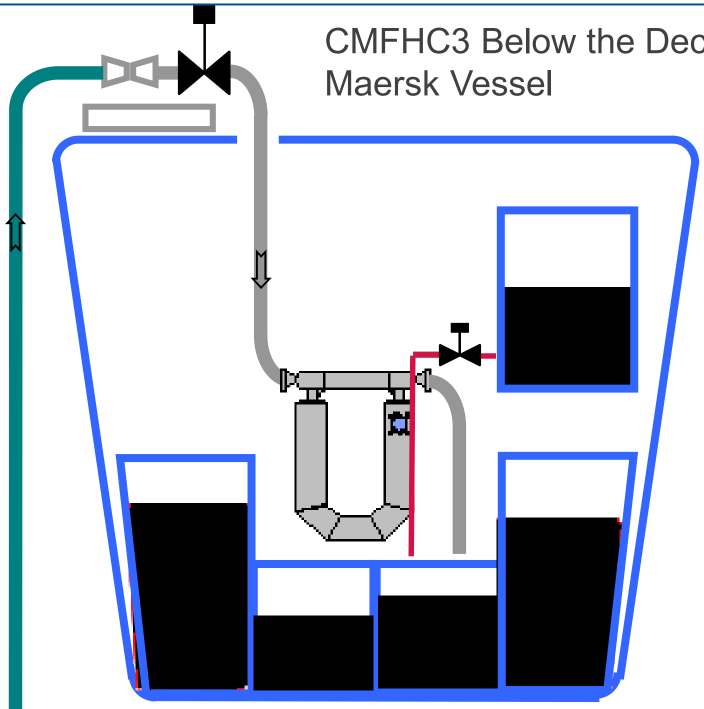
Example: Tanker Lightering using Coriolis

Barge

CMFHC3
On Barge Deck

Hose



CMFHC3 Below the Deck of Maersk Vessel

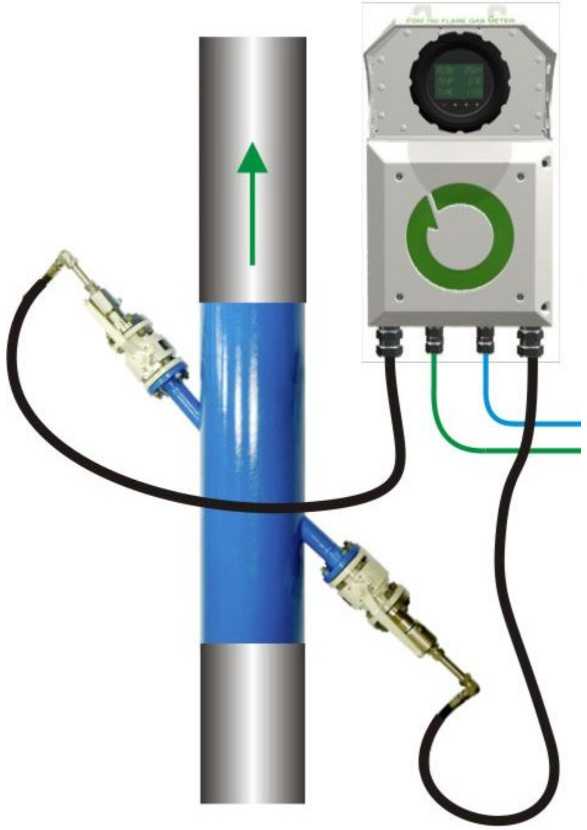
Day Tanks

D-Class
Maersk Vessel

Common Sources of Error for Refinery Mass Balance
Flare Measurement

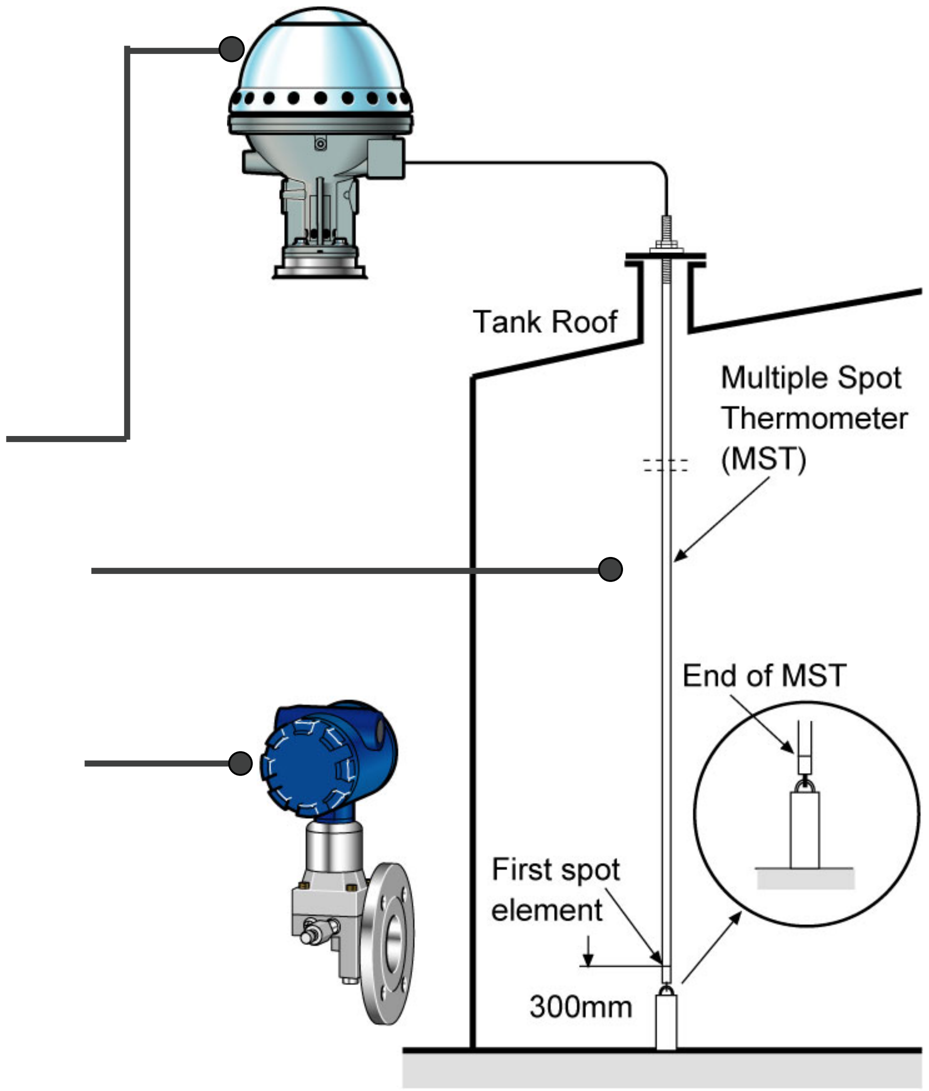
Flare

- Losses through flare are typically the largest source of identifiable loss
- Measurement challenges:
  - Wide turndown requirements
  - Widely changing compositions
  - Very low gas pressure
  - Fully developed flow profile at low end difficult
- Uncertainty is often above 10% at the low end but technology advances can significantly improve that performance
- Measurement technology:
  - Ultrasonic meters + Gas composition analysis either by lab sampling, GC or Mass Spectrometry
  - Technology enhancements for ultrasonic meters resulting in improved accuracy
    - MW calculations using sound speed of the gas
    - Correction factors from computational fluid dynamics

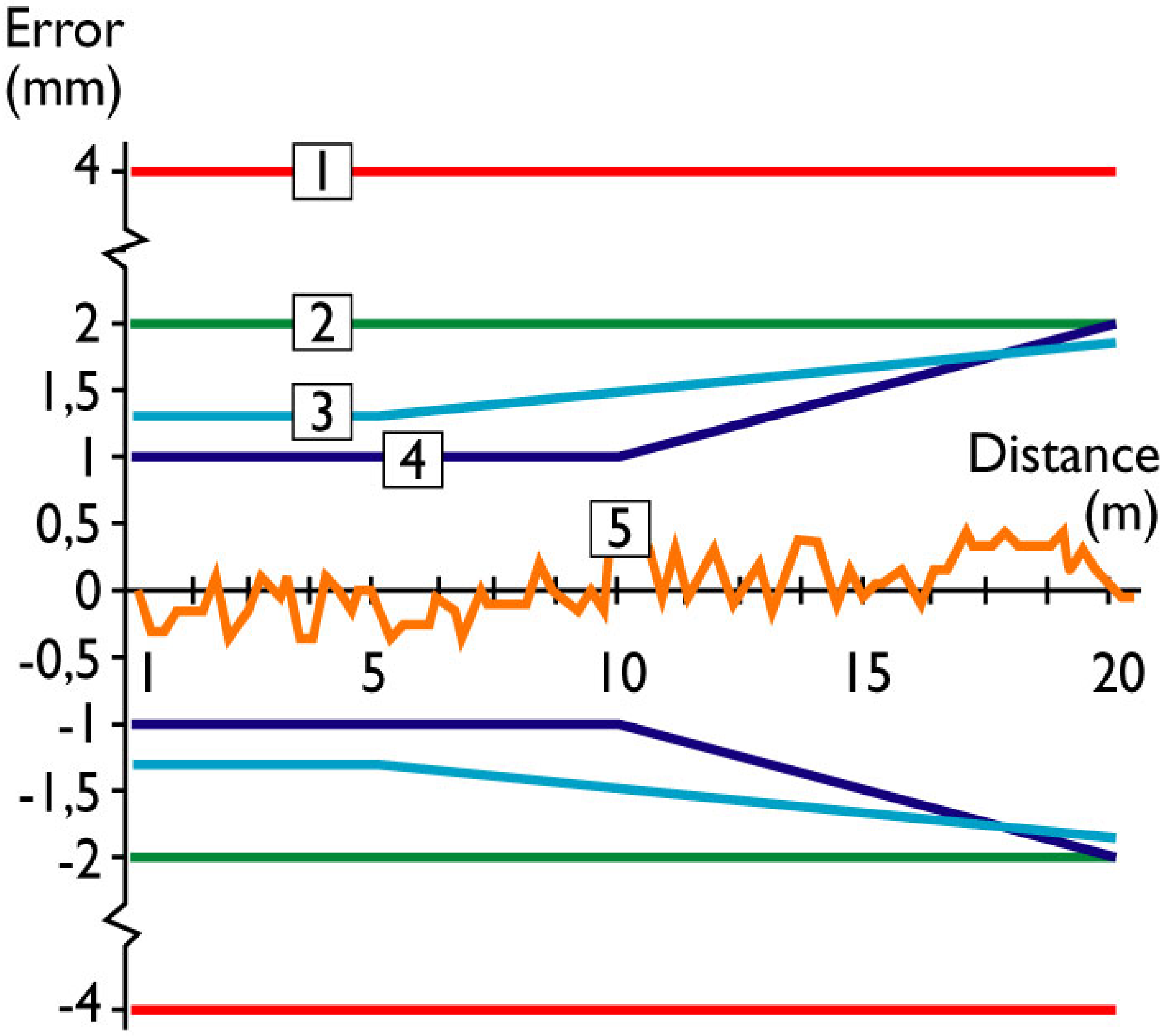


Custody Transfer and Inventory Tracking – ATG (Radar)

- For the calculation of a transferred quantity the tank gauging system requires:
  - Level, at start and end of transfer
  - Average product temperature, at start and end of transfer
  - Density (or API gravity), at start and end of transfer.
  - Base Sediment & Water
  - Tank Strapping Table



Accuracy of Automatic Tank Gauging



1 API ± 3/16" (4 mm)

2 PTB, Germany

3 NMi, Netherlands

4 OIML, International

5 TankRadar

Manual of Petroleum Measurement Standards
Chapter 3—Tank Gauging

Section 1B—Standard Practice for Level Measurement of Liquid Hydrocarbons in Stationary Tanks by Automatic Tank Gauging

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005

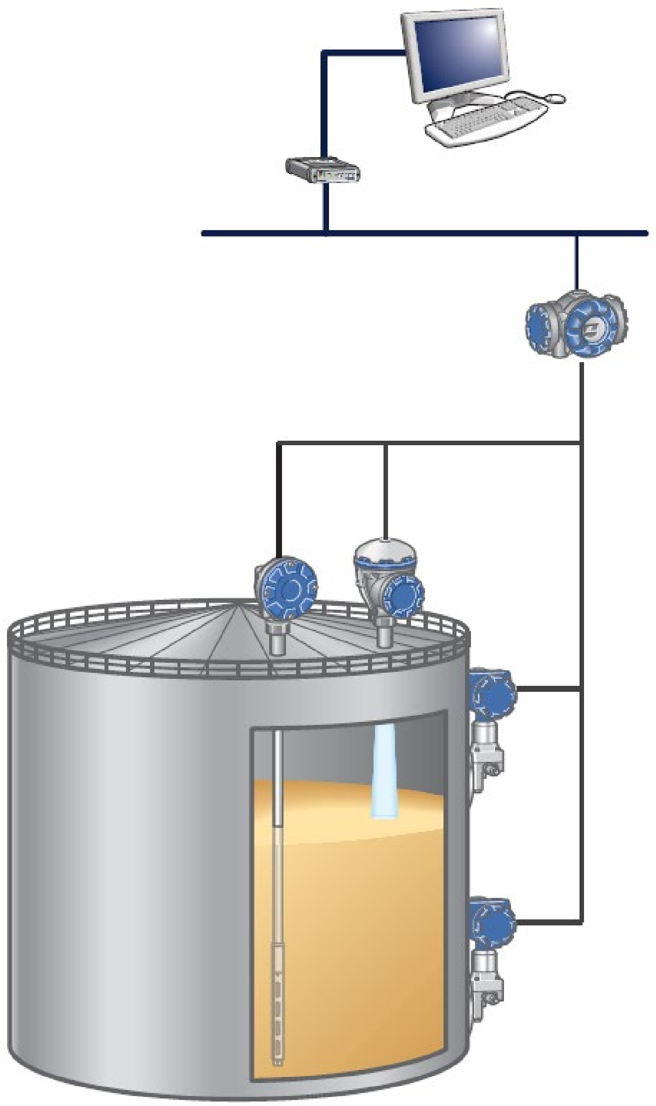
APPENDIX B—ACCURACY REQUIREMENTS FOR ATG
(See Note)

Requirement	Custody Transfer	Inventory
Factory calibration	1 mm (1/16 inch)	3 mm (1/8 inch)
Effect of installation	3 mm (1/8 inch)	n.a.
Initial verification	4 mm (3/16 inch)	25 mm (1 inch)
Subsequent verification	4 mm (3/16 inch)	25 mm (1 inch)
Frequency of verification	monthly	quarterly

Note: This table is for reference only. Please refer to the entire document.

Uncertainty of Tank Volumes and Mass is highly dependent on instrumentation and maintenance of the tank

- Tank Gauging System Installation Method
- Uncertainty in Tank Capacity Table
  - Calibration method
  - Maintenance of strapping table
- Uncertainty in Average Product Temperature
  - Multi-spot
- Uncertainty in Density Measurement
  - Manual sampling (sampling procedure and laboratory)
  - Automatic (precision of the pressure transducer)
  - Stratification of fluid in the tank



How to Improve Mass Balances

- **Evaluate your current closure of your mass balances**
  - How does your refinery wide balance compare to your target or expected benchmarks?
  - Are there some process units that are more difficult to close?

- **Use Sigmafine to identify measurement issues**
  - KPI's to evaluate current systems and help to prioritize

- **Critical balance points to prioritize**
  - Crude import
  - Crude charge to the crude unit
  - Conversion unit feed rates
  - Primary products for accurate yield data
  - Unconverted bottoms

- **Perform an audit of prioritized measurements**
  - Understand contributions to measurement uncertainty and the overall accuracy and possible biases

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Key Takeaways

- Need to understand where there are missing or inaccurate measurements through the use of Sigmafine
- Using traditional technology in mass balance applications result in inaccuracies
- Accurate data is needed to make better operational decisions that in return result in better reconciliation, reducing losses, process optimization, and savings
- Emerson combined with Sigmafine have the technologies and expertise to help you improve your mass balances

Thank You