Coriolis flow measuring technology for the oil industry

Certified solutions for your custody transfer applications – cost-effective and precise

Endress+Hauser

People for Process Automation

Endress+Hauser process automation

Solutions for the oil industry

Endress+Hauser is a world-leading supplier of measuring devices, services and solutions for industrial process engineering. We offer a wide range of measuring technologies to meet the requirements of the oil industry optimally – whether the application is exploration, production, refining, custody transfer or logistics.

Our devices for level, pressure, flow, temperature, analysis and registration are manufactured according to the highest quality standards. Endress+Hauser stands for continuity, industry-specific expertise and long-term customer relationships.

In custody transfer with hydrocarbons the practical and qualitative requirements are very challenging. Therefore, our foremost objective is to create trust with practicable solutions. In addition, our global network of over 600 experts and sales/service engineers ensures that everything works perfectly on your end.

For more information about Endress+Hauser, visit:
www.endress.com

For more information about your industry, visit:
www.endress.com/oil-gas

Flow measurement as competence

Within the Endress+Hauser group, Endress+Hauser Flowtec AG ranks internationally as one of the leading producers of industrial flowmeters for liquids, gases and steam. As a competence center, we have achieved a top position in global markets for over 40 years. Endress+Hauser Flowtec AG currently employs a workforce of more than 1800 at six production facilities in Reinach (Switzerland), Cernay (France), Greenwood (USA), Aurangabad (India), Suzhou (China) and Itatiba (Brazil).

Reinach, Switzerland

Cernay, France

Greenwood, USA

Aurangabad, India

Suzhou, China

Itatiba, Brazil

Your partner for custody transfer

Save time and money – with precise measurement and accurate billing

Worldwide, the consumption of crude oil and refined hydrocarbons is over 90 million barrels or 14.4 billion liters per day. This corresponds to a volume of a pipe with a diameter of 1 meter and a length of 18 200 kilometer (11 310 miles).

Whether in the offshore or onshore sector – this huge quantity of hydrocarbons is transported, stored, treated, received, and finally sold to a wide variety of customers. It is transported to tank farms, refineries or export ports using oil tankers, trucks, rail tank cars or via pipelines.
Each transaction within these process and supply chains occurs with a certain measurement error. Therefore, discovering potential losses – and thus facilitating more accurate billing of delivered/received product quantities – is of the highest priority in the oil industry.

As a result, the “heart” of any custody transfer (fiscal) measuring point is a meter that will provide years of reliable service – measuring flow with the best accuracy regardless of environmental influences and fluid properties. Any measuring inaccuracy, no matter how small, results in enormous losses for the supplier or buyer. Precisely for such applications, can you fully rely on Endress+Hauser as your partner:

- Many years of experience in consulting and in engineering of custody transfer measuring systems
- High-precision Coriolis flow measuring technology – optimized for your application
- Traceable and accredited hightech calibration rigs – even for high-viscosity hydrocarbons
- Worldwide service network for support of custody transfer measuring points over the entire life cycle

Index

Flow measuring technology

"What flow measuring technology does Endress+Hauser offer for custody transfer in the oil and gas business?"

Our Coriolis flowmeters can be integrated perfectly into your application to ensure maximum accuracy and robustness.

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Planning measuring points for custody transfer

"Planning custody transfer measuring points requires a lot of know-how. Does Endress+Hauser have this level of expertise?"

We are there to support you, from the planning phase to the ready-for-use measuring point and over the entire life cycle.

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Viscosity and Reynolds number

"Any flow measurement is affected by various fluid properties. How does Endress+Hauser handle the influence of the Reynolds number, for example for highly viscous hydrocarbons?"

All of our Coriolis flowmeters have a patented Reynolds number correction.

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Your questions – our answers

Planning – metrology – service

Factory calibration with hydrocarbons

“Often, there are legal regulations which require custody transfer measuring points to be verified with oil, which is expensive and time-consuming – either on site or via an external official calibration facility. Does Endress+Hauser have a better solution?”

Minimize costs and project risks thanks to our state-of-the-art hydrocarbon flow calibration offered in Reinach (Switzerland).

▸ Page 11 – 13

“What services does the new hydrocarbon calibration rig from Endress+Hauser offer?”

Our calibration rig is accredited, traceable and allows measurements with different viscosities (15 to 300 cSt) and flows (2 to 1200 m^3/h; 8.8 to 5283 gal/min).

▸ Page 15 – 17

Service worldwide

“Does Endress+Hauser have accredited calibration facilities to verify and confirm the measuring accuracy of my custody transfer measuring system on site as well?”

Yes! Endress+Hauser has a dense network of accredited flow calibration facilities and is available for you at more than 50 locations worldwide.

▸ Page 22

Testing using “volume prover”

“Right now, I use turbines and positive displacement flowmeters for custody transfer. Can I also use my current on-site verification infrastructure for Endress+Hauser Coriolis flowmeters?”

Thanks to the fastest signal processing, our Coriolis flowmeters can be checked with a volume prover trouble-free.

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Coriolis flow measuring technology

Precision, robustness, long-term stability – independent of fluid properties

Each custody transfer measuring point in the oil industry is a kind of "cash register." After all, a lot of money is at stake. Long-term stability, high repeatability, accuracy and robustness – these are only a few of the benefits why Coriolis flowmeters are increasingly the solution of choice in custody transfer.

Even though the properties of liquid hydrocarbons, such as density and viscosity, vary greatly and thus can affect accuracy, Coriolis measuring technology from Endress+Hauser has proven to be the best current method for metering viscous fluids or fluids with entrained gas reliably. For this reason, Coriolis technology is being used more and more frequently for verifying installed flowmeters and is even used by metrology authorities as a transfer standard for on-site calibrations.

Advantages at a glance

- Minimal measurement uncertainty – highest repeatability and long-term stability
- Multifunctional – simultaneous measurement of mass, volume, density and temperature
- Reliable measuring technology – insensitive to fluctuating process conditions, pipe vibrations and external pipe forces
- Maintenance-free – cost-effective operation
- Reliable – no blockages or measured value drift as is the case of mechanical meters
- Heartbeat Technology – traceable device verification during operation (TÜV-certified)
- Versatile in use – Promass flowmeters are fully compatible with installed calibration references on site such as small volume provers, volume standards, etc.

Promass F
For universal use

- Excellent measuring performance for liquid hydrocarbons, even under fluctuating process conditions
- High level of proven performance: over 400 000 measuring devices installed since 1999
- DN 8 to 250 (3/8 to 10")
- Suitable for custody transfer

Promass Q
For challenging applications

- Highest mass, volume and density measuring accuracy
- Multi-frequency technology for unmatched accuracy in challenging applications, e.g. for fluids with entrained gas
- DN 25 to 250 (1 to 10")
- Suitable for custody transfer

Promass X
For maximum flow
(up to 4100 t/h; 150 649 lb/min)

- Four-tube measuring device with exceptional performance in onshore and offshore applications
- Profitable and high-precision measurement of large quantities with a single instrument
- DN 300 to 400 (12 to 16")
- Suitable for custody transfer

Promass O
For highest process pressures

- Robust high-pressure measuring device (PN 250/Cl 1500) for onshore and offshore applications
- Maximum corrosion resistance: pipe material made of H_2S-resistant material
- DN 80 to 250 (3 to 10")
- Suitable for custody transfer

Promass Q – The top specialist for challenging applications

Coriolis mass flowmeters are commonly used only for single-phase fluids because evidence exists that the measuring accuracy can be affected by a two-phase flow. It is known that various sources of error arise in such cases, for example through the significantly higher compressibility of a fluid with entrained gas. In many cases, however, when measuring highly viscous heating oil, crude oil or cryogenic fluids (e.g. liquefied natural gas), accidental introduction of dissolved gas or air cannot be eliminated 100 percent.

Therefore, Endress+Hauser has developed Promass Q. This completely new type of Coriolis sensor significantly compensates – thanks to innovative Multi-Frequency Technology (MFT) – for measuring errors caused by entrained gas, e.g. errors due to leaking pump gaskets, down pipes or outgassing due to pressure reduction.

Watch the Promass Q video

Heartbeat Technology – device verification without process interruption

Many times, flowmeters or measuring points for custody transfer are verified on site at defined time intervals to ensure their integrity. Between intervals, however, there is often no information about the performance of a device. Possible measurement errors due to malfunction then remain unidentified.

Heartbeat Technology from Endress+Hauser gives you the possibility to verify Proline flowmeters quickly and reliably during operation – without interrupting the process. This function, which is integrated as standard into the Proline measuring electronics, enables a comprehensive verification of the entire measuring signal chain. This enables you to identify deviations within the verification intervals immediately, thus avoiding possible imbalances:

- TÜV-certified verification
- No presence in the field required – verification can be activated e.g. via a control room
- Traceable verification
- Documentation can be created according to ISO 9001

Osborne Reynolds (1842–1912)
British Physicist and Engineer

Osborne Reynolds was born as the son of a teacher and headmaster in Belfast, Northern Ireland. After studying mathematics at the Queen's College of the University of Cambridge (UK), he worked for one year at an engineering office in London before receiving a professorship in 1868 for Civil and Mechanical Engineering at Owens College, which later became the University of Manchester. Thanks to his groundbreaking research work, he became one of the world's leading scientists in fluid mechanics.

He is the namesake of the Reynolds number which is mainly used in fluid mechanics to characterize flow patterns in pipelines (laminar, turbulent). The Reynolds number not only takes flow or velocity into consideration, but also fluid properties and dimensional/geometrical characteristics of the flowmeter.

The Reynolds number (Re) is defined as the ratio between flow velocity (v), pipe diameter (D) and the kinematic viscosity (ν), which is the quotient of dynamic viscosity (μ) and the fluid density (ρ).

$$Re = v \cdot D / \nu = v \cdot D \cdot \rho / \mu$$

Various fluids, such as water or hydrocarbons, can thus be compared to each other if they have the same Reynolds number. In such a case, corresponding levels of measurement uncertainties – for example for a calibration with water or with hydrocarbons – can be compared to each other and transferred.

Automatic Reynolds number correction

For Promass flowmeters

For custody transfer measuring systems in the oil industry, national and international standards (OIML R117, API, etc.) require that a flowmeter be calibrated with a fluid whose properties are identical to the fluid being measured on site. This is to ensure that the maximum permissible error (MPE) is not exceeded in the respective application. Each flow measuring principle has, however, an innate measurement error that depends on process parameters such as flow velocity, temperature, pressure, density and viscosity of the fluid. The "sum" of these process parameters can be described by what is known as the Reynolds number (see info box "Osborne Reynolds").

Automatic Reynolds number correction
Unlike other flow measuring technologies, it was long believed that the accuracy of Coriolis flowmeters was not affected by the properties of the fluid and the installation conditions. However, more recent studies have shown – driven by the desire of the oil industry for even higher performance, indeed the best that is technically possible – that even the accuracy of Coriolis flowmeters is influenced by low Reynolds numbers. This is especially true for very challenging, viscous fluids in custody transfer applications in the oil industry, such as for crude and heavy oil.

Therefore, Endress+Hauser has conducted comprehensive test measurements on certified hydrocarbon calibration facilities to quantify the possible effect of the Reynolds number for fluids with different density and viscosity. As a result, Endress+Hauser has developed a patented method for Reynolds number correction that is integrated as standard into each of its Coriolis flowmeters.

With this automatic correction, the Reynolds number is calculated continuously through simultaneous measurement of all influencing variables (flow rate, temperature, density and viscosity), and included in the measurement. This guarantees that the most stringent requirements of OIML R117 for a maximum permissible error of less than ±0.2% is fulfilled without the flowmeter first having been calibrated with oil.

i This has been confirmed by NMi Certin B.V., the notified body, in the form of an Evaluation Certificate.

Calibrating with hydrocarbons

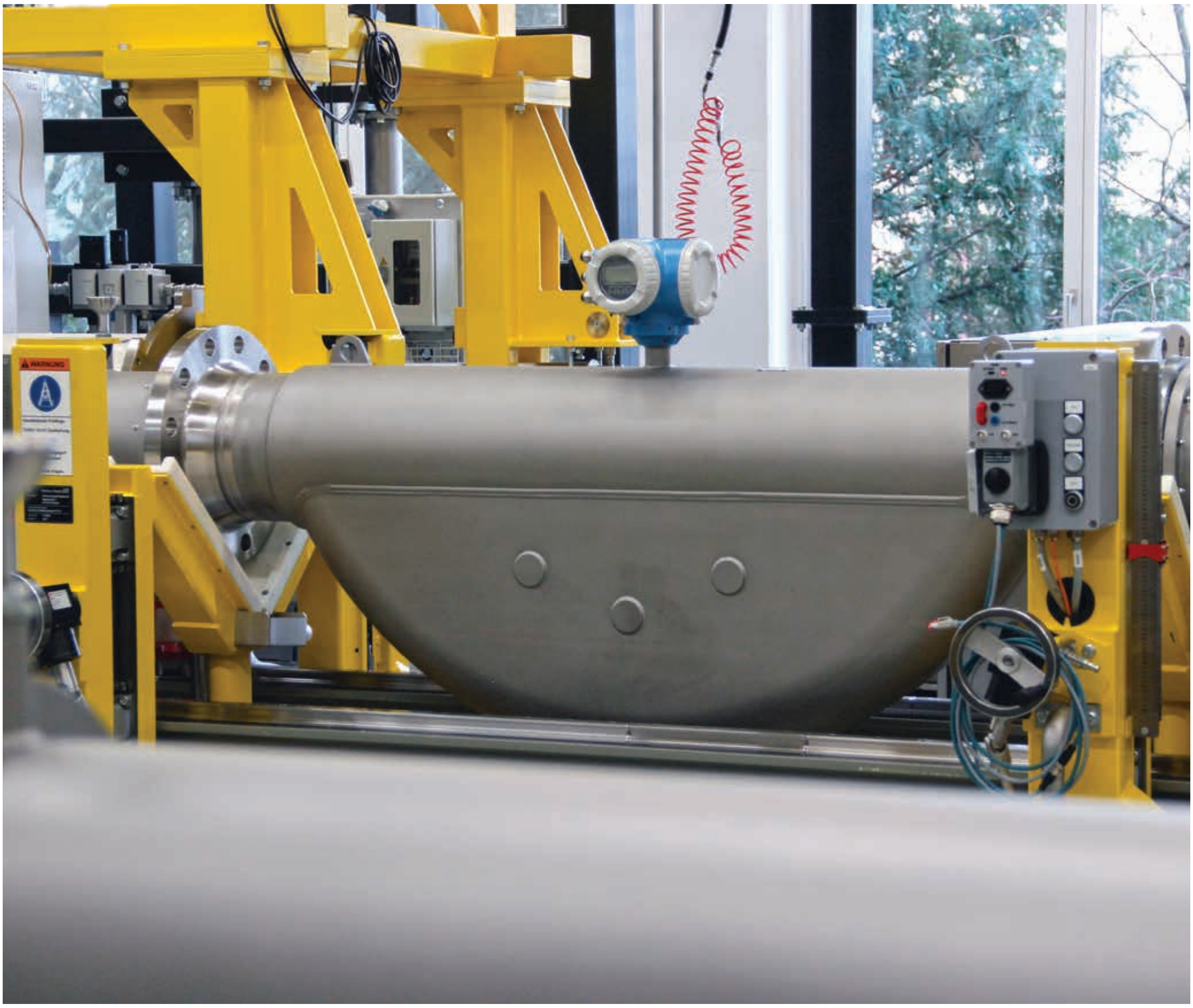
Our service from the factory – customized for your fluid

Because of national calibration laws and international standards (OIML R117, API, etc.), it is common practice in the oil industry for custody transfer measuring points to be verified on site using a reference – for example a master meter, volume prover or truck scale. Depending on the capacity and location of the measuring point, such verifications are very complex, costly or impossible because of practical reasons.

In addition, a flowmeter that fails to pass an on-site verification can cause unwanted project delays. Therefore, customers in the oil industry often request a pre-calibration with hydrocarbons. Endress+Hauser is one of the few manufacturers to offer such calibrations with hydrocarbons directly from the factory (Reinach, Switzerland).

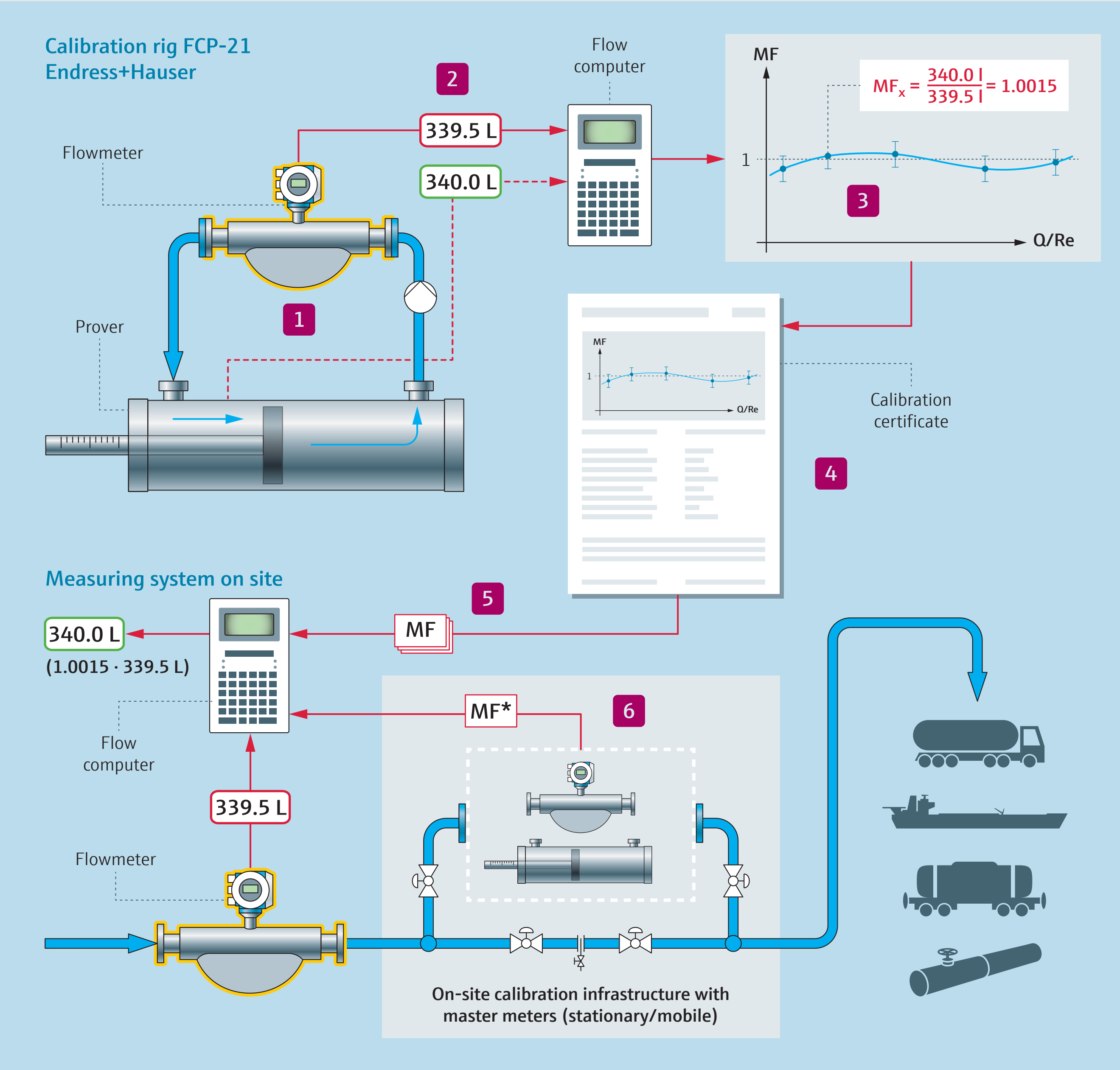
Advantages at a glance

- Massive time and cost savings compared to on-site verifications, particularly in applications with large flow volumes (loading/unloading ships, quantity measurement in pipelines, etc.)
- Best possible accuracy thanks to device-specific tuning using oil as the calibration fluid
- Significantly reduced project risk thanks to additional "quality milestone" in the form of a hydrocarbon flow calibration at the factory
- Reliable high measurement performance thanks to the complete traceability of our hydrocarbon flow calibration rig (ISO/IEC 17025) to the Swiss National Standards.



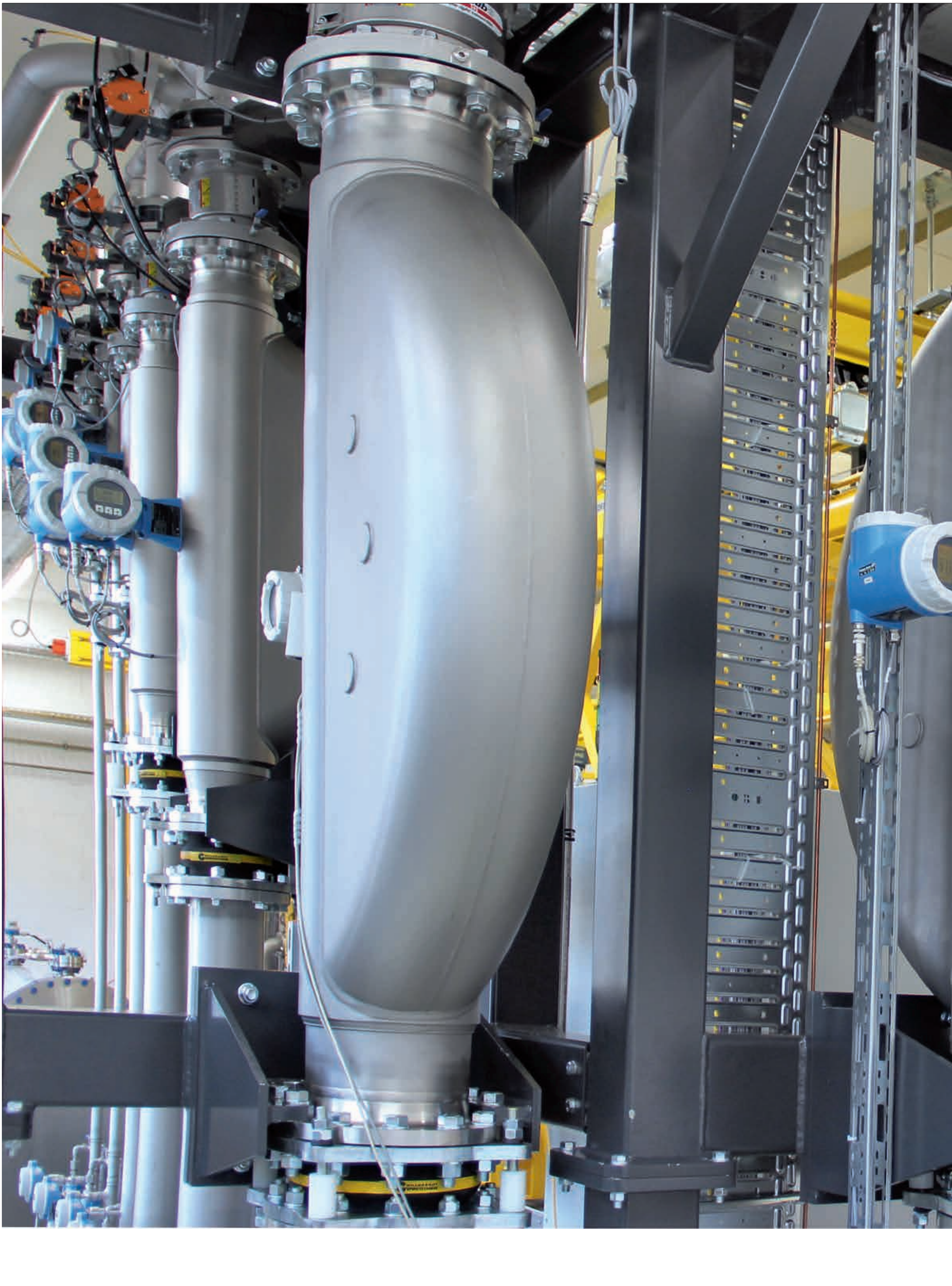

DEMAG
KBK 1250 kg

Transferring the meter factors from laboratory calibration to the measuring system on site



1. **Calibrating the flowmeter** with hydrocarbons at the factory. Measuring points at various flow rates (Q_1 to Q_x) and viscosities (v_1 to v_x).
2. **Comparing** the quantity displayed by the flowmeter with the reference quantity according to the piston prover.
3. **Evaluating** the calibration measurements in the form of meter factors (MF) depending on the flow rate (Q) and the Reynolds number (Re).
4. **Creating** a corresponding calibration certificate
5. **Entering** the meter factors (MF) into the flow computer of the measuring system on site.
6. **Option: On-site calibration** using a mobile or permanently installed calibration infrastructure, which uses, for example, provers or Coriolis flowmeters as master meters. The meter factors (MF*) thus determined are transferred into the flow computer of the measuring system.

! Thanks to the fast signal processing of the Promass meter electronics, the calibration infrastructure used for mechanical meters on site can also be used for Promass Coriolis flowmeters without any problems.



Technical data – Hydrocarbon flow calibration rig FCP-21/22

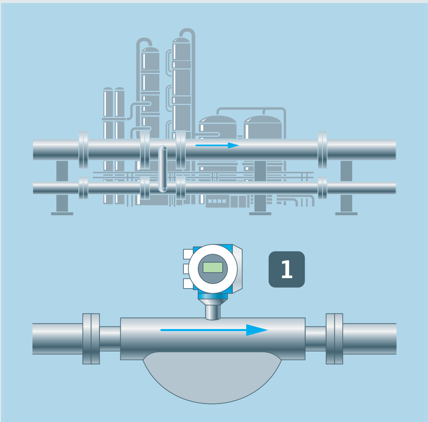
- Flow range:
  - FCP 21 rig: 2 to 1200 m^3/h (8.8 to 5283 gal/min)
  - FCP 22 rig: 2 to 800 m^3/h (8.8 to 3523 gal/min)
- Viscosity range:
  - FCP 21 rig: 15 to 32 cSt
  - FCP 22 rig: 100 to 300 cSt
- Nominal diameters (FCP-21/22): DN 50 to 400 (2 to 16")
- Expanded measurement uncertainty: ±0.05% o.r.
- Primary reference devices: piston provers
- Accredited by the Swiss Accreditation Service (SAS) according to ISO/IEC 17025
- Calibration optionally according to OIML R117 or to API MPMS Ch. 4.8

Trust thanks to traceability

The hydrocarbon flow calibration rig FCP-21/22 Accredited according to ISO/IEC 17025

Flow measurement

Flow in the pipeline
vs.
Flowmeter



Plant operator (Customer)

Flow measurement
Coriolis flowmeter (1)
e.g. Promass F/O/Q or X

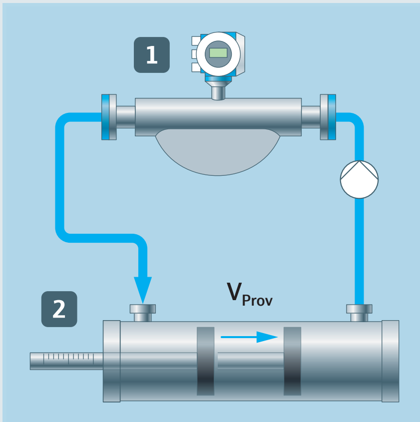
Measuring tasks
- Mass/volume measurement, e.g. for custody transfer (loading/unloading)
- Accounting
- Process monitoring
- Reference measurement (on-site calibration)

Repeatability
±0.025% (API MPMS Ch. 4.8)

Accuracy class
±0.2% (OIML R117, class 0.3)

Calibration

Flowmeter
vs.
Piston prover



Endress+Hauser Reinach, Switzerland

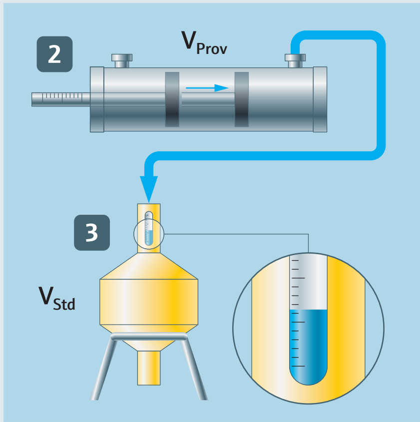
Test equipment
Hydrocarbon calibration rig with piston prover (2) for verifying the flowmeter (1)

Calibration procedure
Comparison of the volume flow ($V = m/\rho$) calculated by the Coriolis flowmeter from the measured mass (m) and density (ρ), and the reference volume delivered by the piston prover (V_{Prov}).
- Calibration measurement takes place with fluids of different viscosity (ν) and for different flow rates (Q)
- Calibration result:
  - – Meter factors for various flow rates (Q_1 to Q_x) depending on the viscosity (ν_1 to ν_x).
  - – Meter factors depending on the Reynolds number (Re).

Measurement uncertainty (calibration rig)
±0.05% (prover)
±0.08% (master meter)

Calibration

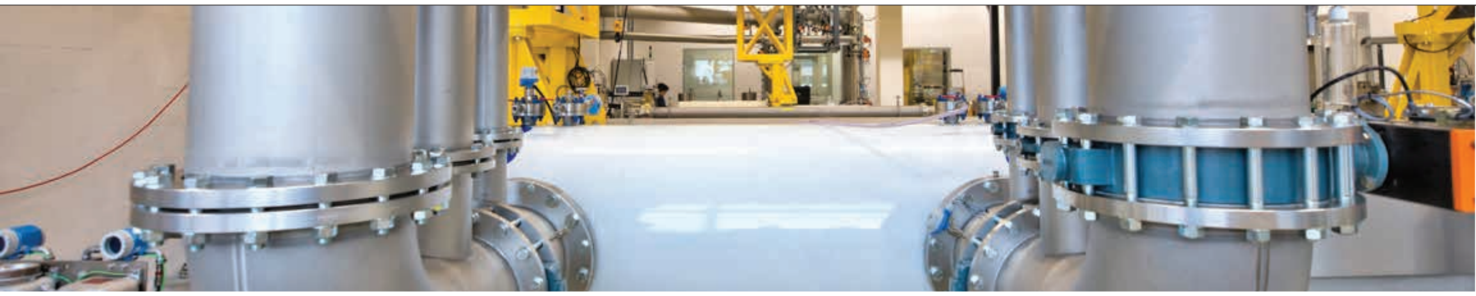
Piston prover
vs.
Volume standard



Test equipment
Volume standard (3) for calibrating the piston prover (2)

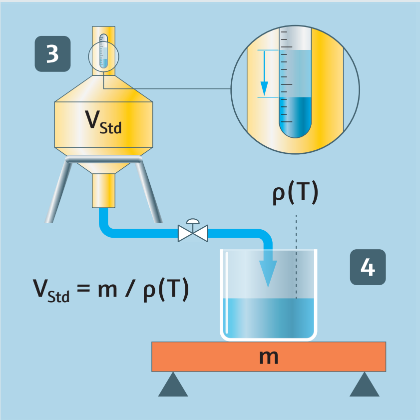
Calibration procedure
- The calibration is carried out by the so-called water draw method. In this case, water of known temperature and density is poured from the compact prover into a volumetric standard (V_{Prov}).
- After the corresponding process corrections have been made, the displaced water volume can be determined very accurately by referring to the volumetric standard.

Measurement uncertainty (volume standard)
±0.02%



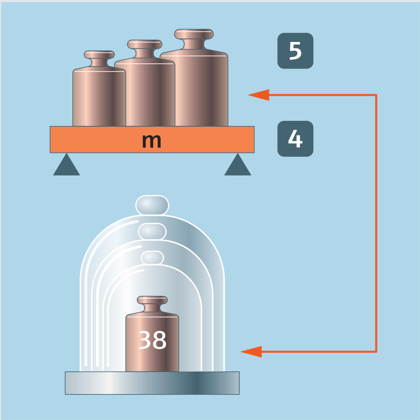
Calibration

Volume standard
vs.
Weighing scale



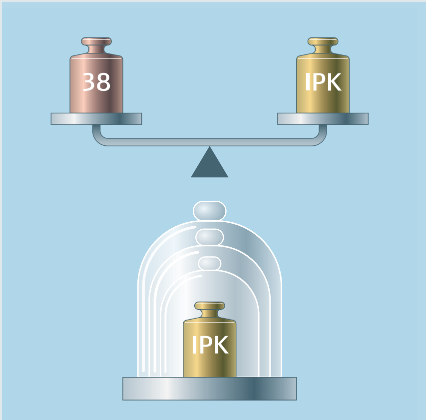
Calibration

Weighing scale
vs.
National reference weights
(vs. Duplicate prototype kilogram No. 38)



Comparison measurement

Duplicate prototype kilogram No. 38
vs.
International Prototype
of the Kilogram (IPK)



Swiss Federal Institute for Metrology (METAS)
Bern, Switzerland

Bureau National des Poids et Mesures
(BIPM) – Sèvres, France

Test equipment
Weighing scale (4) for calibrating the volume standard (3)

Calibration procedure
1. Filling the volume standard (V_{std}) with distilled water to a prescribed level (volume).
2. Emptying this volume into a vessel for weighing (m).
3. Measuring the water temperature (T) to determine the water density (ρ[T]) needed for volume calculation.

Measurement uncertainty (scale)
±0.01%

Test equipment
National reference weights (5) for calibrating the weighing scale (4)

Measurement uncertainty (reference weights)
±0.001%

i Every 10 years, there is a periodic check of the national reference weights (5) against the Swiss duplicate prototype kilogram (No. 38) using a mass comparator.

International Prototype of the Kilogram (IPK)
Global reference and base unit for the mass. It is stored at the International Bureau of Mass and Weight (BIPM) in Sèvres near Paris (France). The bureau was founded in 1875.

Test equipment
Mass comparator

Verification interval
In 1950, 1991 and 2003, comparison measurements took place between the IPK and the Swiss duplicate prototype kilogram (No. 38).

Measurement uncertainty:
±0.000001% (±10 micrograms)

i Currently, a worldwide effort is underway to redefine the IPK so that it can be derived from fundamental constants of physics.

Measuring systems for custody transfer

Turnkey solutions – from engineering to custody transfer approval

Endress+Hauser supplies customized systems for custody transfer with all required components. Our measuring systems and solutions are designed to be integrated optimally into your process control and monitoring systems. All partners we collaborate with in developing and designing these measuring systems are ISO 9001-certified and undergo regular audits from us.

Our scope of delivery
When planning and commissioning custody transfer measuring systems, you can fully rely on our specialists:

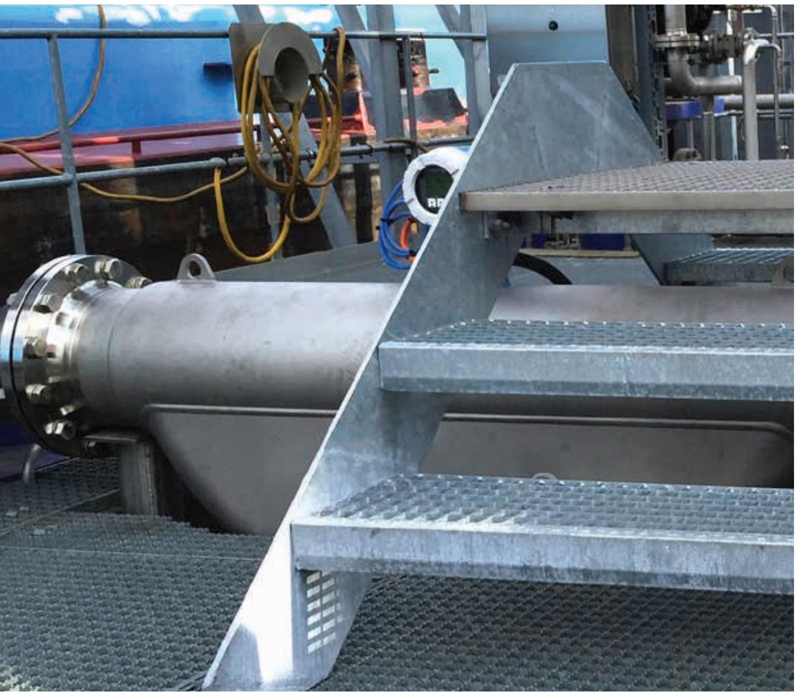
- Clarifications and individual consulting on site
- Engineering and construction of custody transfer measuring systems with all components:
  - Coriolis flowmeters
  - Pressure and temperature measuring devices
  - Flow computers including operating software (unloading/metering control system, diagnostic functions, etc.)
  - Control valves, vent valves, mixers, etc.
  - Master meters and provers
- Mobile or stationary measuring systems
- Skid manufacturing
- Certified conformity according to internationally valid standards (OIML, API)
- Coordination with metrology and/or calibration authorities
- Coordination of commissioning and on-site verification
- Assistance with custom approval process
- Project documentation: wiring diagrams, drawings, installation instructions, operating manuals, approvals, etc.

Measuring two-phase hydrocarbons

Our solution creates maximum transparency

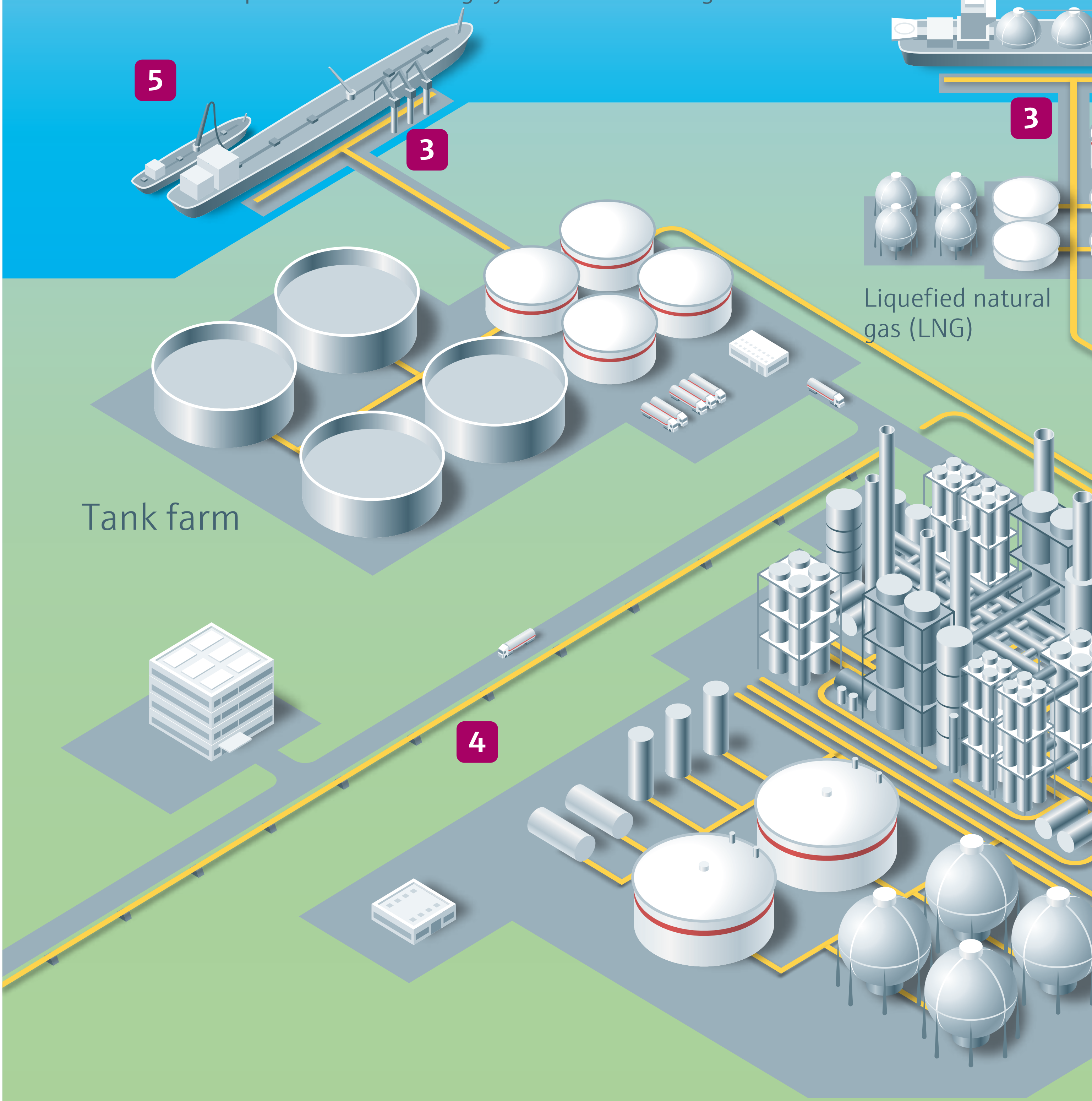
It is well known that traditional volume measurement can be associated with a high level of uncertainty, for example due to air pockets caused by tank stripping during bunkering ("cappuccino effect"). Level measurement in a tank farm – immediately after filling a tank – is also problematic because the motion of the fluid surface does not settle for hours, and only then is a level measurement possible at all. For precisely such cases, Endress+Hauser has developed a patented "Two-phase measuring system" that enables reliable, real-time measurement of quantities and volume of liquefied hydrocarbons – even in very confined spaces.

- Certified measuring system according to MI-005
- High measuring accuracy (±0.5%) for mass and volume
- Real-time, accurate measurement of transferred quantities for loading and unloading ships, rail tank cars or trucks
- No additional deaerator installation necessary

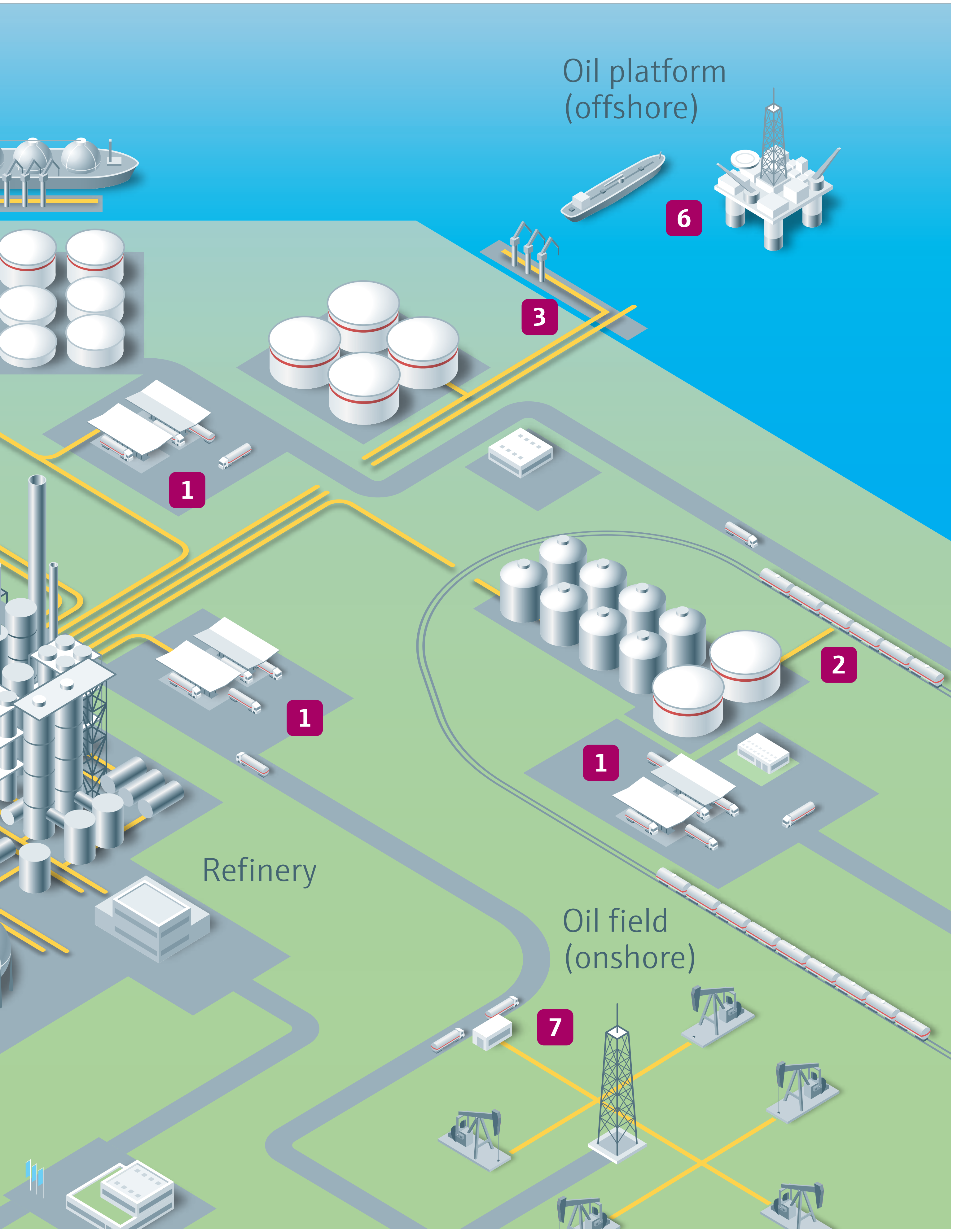


Custody transfer in the oil industry

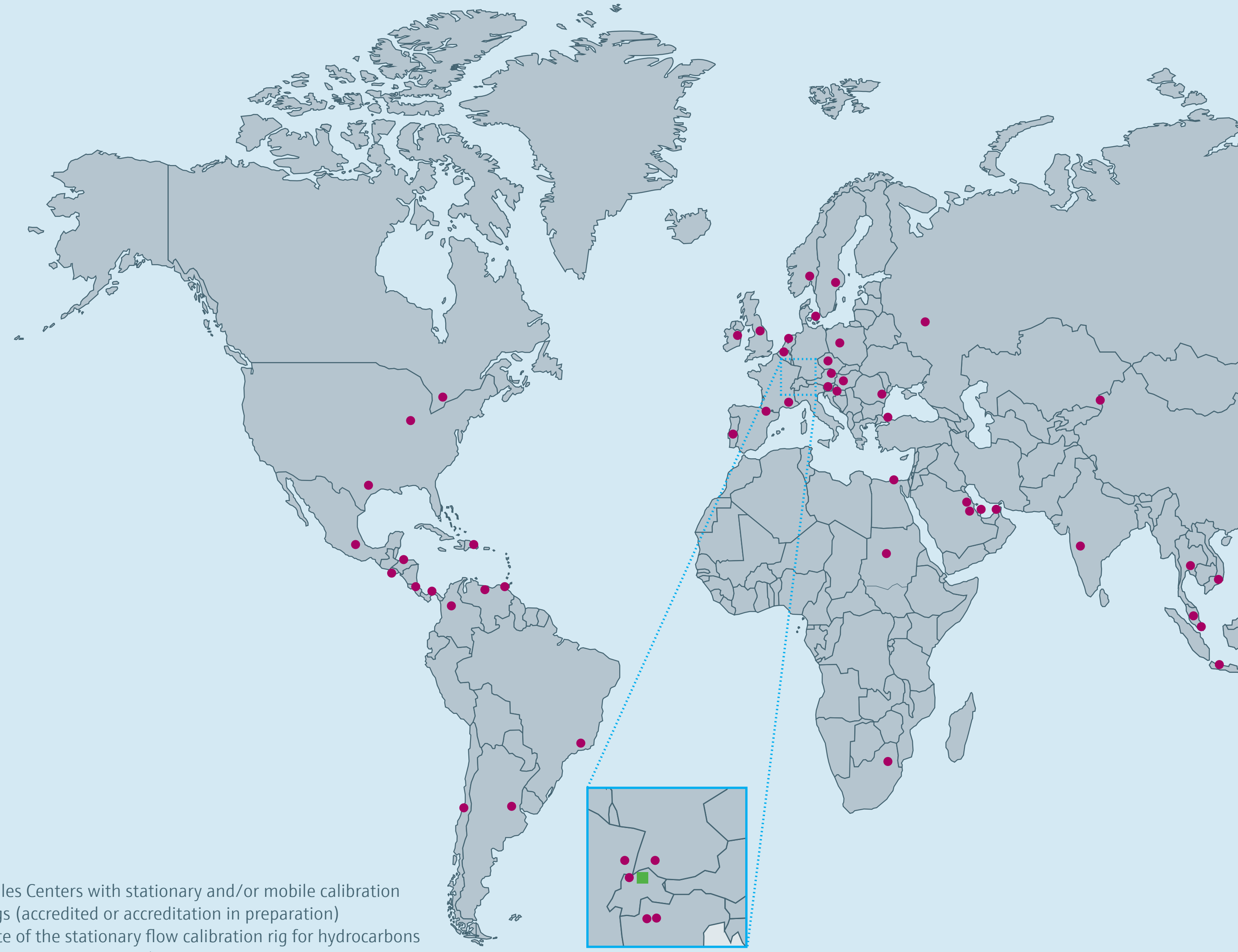
Endress+Hauser provides measuring systems from a single source



Loading and unloading trucks **(1)**, rail tank cars **(2)** or ships **(3)**
Quantity measurement in pipelines **(4)**
Quantity measurement for bunker oil transfer **(5)**
Quantity measurement in offshore applications, e.g. oil platforms **(6)**
Quantity measurement by means of LACT units (Lease Automated Custody Transfer) **(7)**


Oil platform
(offshore)
6
3
1
1
2
1
Refinery
Oil field
(onshore)
7

Our Sales Centers – always at your side worldwide

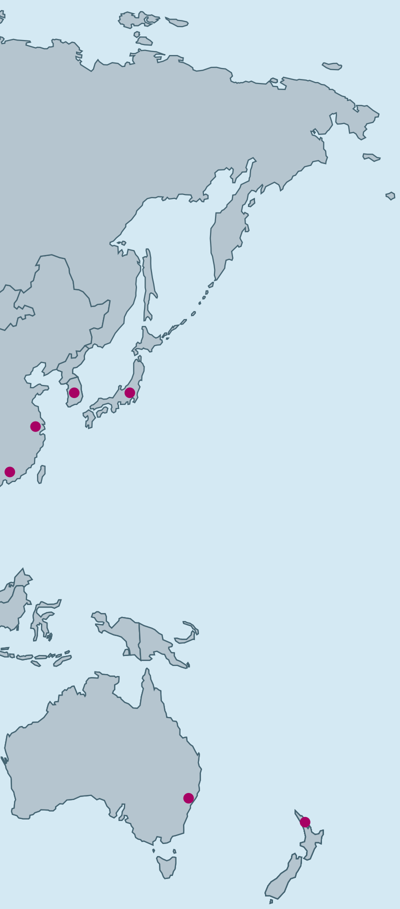


● Sales Centers with stationary and/or mobile calibration rigs (accredited or accreditation in preparation)

■ Site of the stationary flow calibration rig for hydrocarbons (Reinach, Switzerland)

Our services at a glance

- Professional management of national and international projects
- Planning and consulting from experts on site
- Planning, engineering and design of custody transfer measuring points
- Installation, commissioning and configuration
- On-site verifications/calibrations
- Testing of master meters
- Recalibration at the factory
- Repair and spare parts
- Troubleshooting
- Maintenance (maintenance contracts)
- Support in audits and acceptance procedures from metrology and customs authorities
- Training seminars and training sessions



Worldwide service

Throughout the entire life cycle of your custody transfer measuring points

Very advanced practical and qualitative requirements exist for custody transfer operations with hydrocarbons. Planning and designing custody transfer measuring points is one thing. Providing expert consultation and maintenance for these measuring systems throughout their entire life cycle is another.
Therefore, you can rely on Endress+Hauser's worldwide network of over 40 service centers that provide support in all matters related to custody transfer. Our experts on site make sure that everything goes smoothly at your end. They also ensure that the solution – for example in an emergency – is only a phone call away.

www.addresses.endress.com

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Endress+Hauser

People for Process Automation