Hybrid Tank Measurement Systems for Mass Calculation

Combination of level, temperature and pressure for precise inventory measurement in storage tanks
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1 Introduction to Tank Gauging

Tank Gauging is the generic name for the static quantity measurement of liquid products in bulk storage tanks. It can be used for inventory measurement, i.e. to determine the amount of product in the tank, and for custody transfer applications, i.e. for the buying and selling of product or tax payment evaluation. Two methods are used: volume-based and mass-based measurement.

In a volume-based tank gauging system, quantity measurement is based on level and temperature measurement. In a mass-based system, the measurement of the hydrostatic pressure of the liquid column is used.

Whatever method is used, a high degree of reliability and accuracy is of paramount importance when the data is used for inventory control or custody transfer purposes.

Measurement accuracy is the key factor for good inventory measurement. However, accuracy is only one of the many aspects involved in tank gauging. Reliability to prevent product spills and safety for the environment and personnel are equally important.

General requirements for tank gauging systems:
- Safety
- Accuracy and repeatability
- Reliability and availability
- Compatibility with operations
- Stand-alone capabilities
- Operator friendly
- Maintenance friendly
- Expandability

Additional requirements for tank gauging systems:
- On-line diagnostics
- Accepted for custody transfer
- Seamless integration with host computers and onwards to DCS
- Upgradability
- Service and spare parts
- Acceptable price/performance ratio
- Vendors quality control procedures
- Manuals and documentation

Tank gauging is required for the assessment of tank contents, tank inventory control and tank farm management. The system requirements depend on the type of installation and operation. The following types of operation, each having its own specific requirements, can be defined:
- Inventory control
- Custody transfer
- Oil movement and operations
- Leak control and reconciliation
2 System structure

With Endress+Hauser's inventory management system, all major types of measurement instrumentation can be integrated into one system, ensuring that storage tank parameters, including level, temperature, pressure, density, water bottom, alarms, gross and net standard volume, mass and rate of flow are displayed at your local operator workstation.

The choice of gauging method, radar, servo or mechanical, is based upon the application requirements and on the applicability and performance of the technique in a given application.

The system diagram below shows the application of different technologies to a different product or tank and the communication of the measurement data to the RTU and then to Inventory Management software.
3 Volume Measurement

Inventory measurement can be performed through volume-based calculation, based on level and temperature measurement, or mass-based calculation, based on density calculations using hydrostatic pressure measurement.

3.1 Tank Capacity Table (TCT)

The way inventory is measured is somewhat complex. A typical tank gauging system utilises level measurement and the Tank Capacity Table (TCT) to calculate volume. Level measurement is the basis for volume calculation. Level is converted into an 'observed volume' via the TCT.

3.2 Volume Correction Factor (VCF)

Next, in order to calculate the temperature corrected volume or standard volume, the product temperature and the thermal expansion coefficient, volume correction factor (VCF), of the product in the tank are required. Typical hydrocarbons are not ideal liquids. The exact composition is normally unknown, and due to the fact that the product contains many different complex molecules - some short - some extremely long, makes it difficult to predict the exact VCF for each product.

3.3 API tables

For most hydrocarbons and chemicals, the so-called API tables must be used, providing formulas (and derived printed tables) based on so called 'generalized' product categories, like crudes, refined products, etc. Basically, they are 'averaged' values based on a set of experimental data. These tables are used by entering a reference density value (based on a product sample and some other API corrections) and the measured product temperature in the relevant tank.

The entire operation is somewhat complicated but this is the accepted industry standard, making volumes comparable and products tradable.
4 Mass measurement

Today, most hydrocarbons in the western world are bought and sold using volume measurement. However, in many eastern countries and in some specialised industries, product are sold based on mass due to traditions in particular markets, so mass calculation can be important in those areas of trade. Mass-based measurement offers other advantages, since mass is independent of product temperature and other parameters. For custody transfer, high accuracy tank gauging is required, and mass-based calculation is often used.

4.1 Hydrostatic Tank Gauging

The advantage of HTG is that it provides direct mass measurement with only pressure transmitters to measure hydrostatic pressure in determining density via a fixed distance and vapour pressure. Therefore, it is a low-cost solution for mass measurement. However, there are substantial disadvantages:

- Level and volume measurements are less accurate, especially when density stratification occurs.
- Density is only measured at the bottom of the tank.
- Difficult to verify, commission and calibrate

Note!
The middle or P2 transmitter is unique to Hydrostatic Tank Gauging.
4.2 Hybrid Tank Measurement Systems

A Hybrid Tank Management System (HTMS) is a combination of conventional level gauging, enhanced with one or two pressure transmitters for continuous measurement of the actual observed density in a bulk liquid storage tank. Or otherwise stated, it is a combination of level and hydrostatic pressure measurement. Pressure measurement, combined with level, provides true average density measurement over the entire product level height. Normally, the vapour (top) pressure is identified as $P_3$ and the hydrostatic (bottom) pressure is identified as $P_1$.

Advantage of HTMS
- Accurate level measurement
- Continuous density measurement
- Excellent mass and volume measurements

\[
D_{obs} = \frac{P_1 - P_3}{L - Z}
\]
5 Technical data of the system

5.1 General Technical Data

A typical volume-based measurement system consists of either a radar or servo gauge for level measurement and a Prothermo NMT53x for average temperature measurement.
A typical HTMS system consists of either a radar or servo gauge and one pressure transmitter for the measurement of the hydrostatic head – the pressure exerted by the column of liquid product in tanks. An additional pressure transmitter must be added for those tanks where the gas or vapour pressure – the pressure in the empty part of the tank – is not ambient, for example, for cases where the tank is not open to the atmosphere.

**Typical HTMS configuration with Micropilot level radar**

**Typical HTMS configuration with Proservo level gauge**
5.2  **Accuracy and uncertainty**

The actual accuracy of the final volume and mass calculation depends on the type of measurement instrumentation, the installation, including the tank, and the application. It is not entirely obvious how all these effects interact with each other.

How important is accuracy? What difference can a 2 mm level change make?

**Examples**
- 30 m tank diameter = 1414 l
- 60 m tank diameter = 5656 l
- 150 m tank diameter = 35350 l

"Accuracy" is related to measurement and how well measurements line up with reality, i.e. how close the measurement is with the actual value. If a measurement ("assessment") is more complex, like with volume or mass calculation - multiple external influences will affect the final result. In the industry, there is a standardised procedure to determine an "uncertainty", which allows us to assess the quality of a measurement. You could say that uncertainty is a best guess or prediction of the accuracy – only when you know the true value can you state the accuracy. Therefore, expressing the possible errors when calculating Inventory, like volume and mass, we prefer to use 'uncertainty'.

It is accepted in the industry to use the so called 'Root Means Square' method for assessing the total uncertainty for a certain inventory calculation.

Standardisation bodies, such as ISO and OIML, agreed on the need for a normalised approach and today include uncertainty calculation examples in the related standards. API provides accuracy standards and most countries, worldwide, follow these standards. For example, API recommends an accuracy of 0.05% for pressure transmitters.

![Note!](image) It is beyond the scope of this document to describe these uncertainty calculations in detail, and the interested reader should refer to the related standards.

5.2.1  **Uncertainty related to tank accuracy**

Although the exact calculations for volume vs. mass assessment differ, they have several common factors. The most prominent common uncertainty contributor is, of course, the tank itself. For the calculation of either volume or mass, it is always required to convert the measured level into a quantity. This is done via the so-called strapping table or tank capacity table (TCT). Any uncertainty in the TCT will multiply, regardless of the accuracy of the installed measurement device.

The accuracy of a TCT is difficult to state since it depends on the tank geometry, the tank conditions (how old the tank is), the construction and of course the way it is measured. Typical uncertainty figures for vertical cylindrical tanks are in the range of 0.05-0.2% for the cylindrical part of the tank, while the more difficult bottom has an uncertainty of around 0.3%.
5.2.2 Uncertainty related to measurement instrumentation

The type of instruments required depends on the type of installed inventory measurement system. Typical accuracies for each type of instrument are detailed in the below paragraphs.

Custody transfer vs. inventory control

In the oil and gas industry, it is common to differentiate between custody transfer (CT) and inventory control (IC) applications. Custody transfer applications occur when products are traded between parties, and whenever levies, duties or taxes are involved. Inventory control is the general term for inventory measurement for operational purposes. In CT, the focus is on accuracy, while in IC, the data availability is most critical.

For most custody transfer applications, the Weights and Measures authorities will strive for a total installed uncertainty of measured or transferred volume or mass of 0.5%. For this requirement, a maximum permissible error (m.p.e.) can be calculated. Quite often there is a limitation to the quantity on the low side, as the relative error of the measurement increases inversely with the quantity or batch size. Typically, a minimum batch or inventory of at least two meters of product level is required.

Level

The uncertainty of the level reading depends on the 'instrument accuracy' of the device and the 'installation' conditions. The instrument accuracy is the accuracy specified under standard conditions. For CT gauges, Weights and Measures authorities typically require a 1 or 2 mm instrument accuracy. For IC, an instrument uncertainty of 3 to 5 mm is considered acceptable. The installed accuracy also includes the commissioning error (introduced when the gauge is 'set to level', with a manual dip as reference), and all forms of installation effects.

The most prominent installation effects are tank bulging and tank roof movement. As they can only be prevented by the use of stilling wells, it is strongly recommended to use stilling wells whenever justified and when high accuracy is desired.

For verification, it is common to accept 3-5 mm for custody transfer and up to 20 mm for inventory control.

Temperature

Temperature measurement is often neglected and the need for accuracy understated. Typical hydrocarbons have a relatively large thermal expansion coefficient when compared to chemicals and most other liquids. The required correction factor, also called Volume Correction Factor or VCF, is close to 0.1% per °C. As a result, a 0.25 °C temperature assessment error induces an error in excess of 3 mm in a 36 m diameter tank (with 15 meters of product). The temperature uncertainty is caused both by the measurement accuracy and how well the temperature sensor is installed in order to measure a representative product temperature.

Average temperature measurement with a multi-element temperature thermometer is the best solution. Modern averaging temperature sensors have up to sixteen elements, can be installed from the tank roof and have an accuracy of 0.1 °C.
Density
Automatic density measurement can be accomplished by two different methods. Hydrostatic Tank Measurement Systems (HTMS) provide continuous density and are ideal for unpressurised tanks. The best choice for pressurised tanks is the servo level gauge, which can measure density at multiple spots throughout the product height. The accuracy of the HTMS density measurement depends on the selected pressure transmitters and installation aspects (see also section on pressure). The servo density accuracy is typically around 3-5 kg/m³. It is common to be on the cautious side when specifying the density accuracy for servo gauges since the performance of the manual reference method (the only method available) is difficult to check.

The biggest advantage of servo density measurement is the possibility to reduce vapour exposure and losses.

Pressure
Pressure transmitters are typically used for three different applications in tank gauging:
- Direct hydrostatic head measurement for HTMS
- Gas pressure in pressurised storage tanks, used for LPG and chemical gasses
- Monitoring vapour pressure in fixed roof tanks with 'vapour vent relief valves'

The accuracy constraints for vapour pressure monitoring are minimal, and the measurement range can be relatively small (~ 0.3 bar or less). In pressurised tanks, it is common to measure the gas pressure out of safety aspects, and in order to calculate the amount of 'liquid in vapour'. A 0.1 to 0.25% accuracy is enough to provide acceptable results for most applications.

For HTMS applications, the focus is on accurate density and mass measurement. Here, it is absolutely essential to match the transmitter to the application (tank height and product density). For most pressure transmitters, the accuracy is presented as a percentage of upper range value (URV) or full scale (FS). It is always important to realise that this error needs to be re-assessed as absolute value or at least as a percentage of indicated value.

Modern pressure transmitters are very capable of accuracies of 0.05 to 0.075% URV.

Note!
The assessment of the final HTMS uncertainty is relatively complex, as many different factors and aspects are involved. ISO 15169 and API Chapter 3.6 offer complete detailed calculation examples for HTMS.
5.2.3 Inventory Calculations

The final objective of tank gauging is the calculation of inventory data. This can be either volume based or mass based, depending on the preference of the user and the local requirements. Out of historical reasons, it is common to use volume. In some areas, and for some applications, mass calculation is preferred.

The following terms and abbreviations are commonly used:

- **TOV**
  Total Observed Volume is volume calculated out of the measured product level by using the so-called tank capacity table (TCT).

- **GOV**
  Gross Observed Volume is the TOV minus all free water that collects on the tank bottom.

- **VCF**
  Volume Correction Factor needed to convert the volume at observed temperature (TOV) into standard volume (normally at 15 °C). The VCF is calculated by means of the so-called API/ASTM tables.

- **GSV**
  Gross Standard Volume of the temperature corrected volume at reference temperature (normally 15 °C).

- **Observed density**
  Product density at actual temperature.

- **Standard or reference density**
  Product density at reference temperature (15 °C for example).

- **Mass**
  Total weight of product in air (normally used for liquid hydrocarbons).

- **Weight in vacuum**
  Total weight of product in vacuum, normally used for products stored in pressurised tanks.

Both volume and mass-based calculations are identical up to a point. In the following two paragraphs, both methods are briefly described and discussed.
The above diagram shows the typical calculation procedure for conventional or volume-based inventory measurement.

1. It starts with the level from the automatic tank gauge (ATG).
2. By using the tank capacity table (TCT), the level is converted into the so-called Gross Observed Volume (assuming there is no water).
3. The temperature from the automatic temperature thermometer (ATT) is used to assess the product temperature needed for the VCF.
4. The density is derived from a manual grab sample, and the density is measured in the lab, by means, for example, of a hydrometer.
5. Via the API/ASTM tables, the VCF is established with the inputs of product temperature and the measured (observed) density. The API/ASTM table to be used depends on the product and the units (temperature and density).
6. Now the Gross Standard Volume (GSV) can be calculated.
7. By means of (other) API/ASTM tables, the standard or reference density can also be calculated.
8. When we multiply the GSV with the reference density, we obtain the actual mass in the tank.

Note!
The above diagram was simplified and some details were left out. Free water, sediment, certain tank corrections and vapour calculations are not shown.
HTMS or mass-based level measurement

The above diagram shows the typical calculation procedure for HTMS or mass-based inventory measurement.

1. It also starts with the level from the automatic tank gauge (ATG).
2. But then, the pressure P1 is also measured (P3 if the tank is non-atmospheric).
3. From the level and pressure, the actual observed density is continuously calculated.
4. The GOV calculation is again done using the TCT.
5. The temperature is again measured - but now it is only needed for the VCF and the reference density calculation.
6. The VCF calculation makes use of the same API/ASTM tables.
7. The largest difference is with the mass, since the mass is now calculated from the GOV and the observed density.
8. The Gross Standard Volume (GSV) is again calculated from the GOV and the VCF.
9. The standard density can also be calculated via the API/ASTM tables, but is now a continuously measured value instead of being based on a grab sample.

5.2.4 Summary

Although the conventional or volume-based and the HTMS or mass-based inventory systems have many common principles, there are some important advantages, unique for the HTMS system:

- Continuous density measurement
- Mass assessment independent of the temperature assessment, meaning that the measurement quality is not dependent on the way the product temperature is measured
- Possibility of continuous standard density calculation
- No performance loss for conventional volume assessment
6 Tank Applications

6.1 Tanks with stilling wells

Stilling wells are often installed in tanks where products that form multi-layers of liquid are stored. A radar level gauge with planar antenna is specifically designed for stilling well applications. The design has proved to be effective for accurate measurements even in older stilling wells with various designs and sizes. Customers often require the replacement of mechanical gauges with radar on tapered stilling wells. With radar there is often no need to cut or replace the existing stilling well.

![Level radar on a tapered stilling well](image)

A servo level gauge, low pressure version, performs water interface detection and can measure two interface levels between three liquids and the density of the liquids.

![Servo level gauge on a stilling well](image)
6.2 Fixed roof tanks without stilling wells

Fixed roof tanks are often used for refined products such as gasoline or diesel, but also for bitumen and asphalt. For free space applications in fixed roof tanks, a radar level gauge with parabolic antenna is recommended.

Servo level gauges can also be the choice for fixed roof tanks, providing high accuracy and meeting custody transfer requirements.
6.3 Floating roof tanks (internal and external) without stilling well

Crude oil is usually stored in external floating roof tanks. Internal floating roof tanks are used for products such as Naphtha, gasoline, diesel and other refined products. Typically, a stilling well or guide pole is used on floating roof tanks to obtain highly accurate product measurements. However, in a floating roof tank without a stilling well, radar together with a special roof reflector can measure the position of the floating roof.
A servo level gauge with a wet well is another solution for floating roof tanks where no stilling well exists.
6.4 Spherical tanks

Light products, such as LPGs are often stored in spherical tanks. For inventory control in spheres, guided wave radar (high pressure version) performs continuous level measurement and features various probe types, including coaxial, rod and rope.

The surface of liquids in spheres can often be bubbling, called "boil-off," typically occurring when drawing product out of the tank and making it difficult to determine whether the surface is liquid or gas. For high accuracy in spheres up to 25 m, a servo gauge (high pressure version) offers the advantage of reliable, direct-contact measurement and is custody transfer approved.
6.5 **Horizontal cylindrical tanks (pressurised and non pressurised)**

LPG can also be stored in horizontal cylindrical, pressurised tanks (bullets). Chemicals, such as concentrated acids, organic solvents, esters and additives are often stored in non-pressurised horizontal cylindrical tanks. These tanks (both pressurised and non-pressurised) are often good applications for guided wave radar since, often, the tanks have only small diameter nozzles available.

A servo level gauge (high pressure version) is the high accuracy solution for bullets.
7 Level gauges

7.1 Proservo NMS 53x

7.1.1 Application

The Proservo NMS 53x series of intelligent tank gauges are designed for high accuracy liquid level measurement in storage and process applications.

Proservo can monitor tank content, such as tank bottom, water dip and includes a repeatability check to confirm its measurement accuracy. It fulfills the exacting demands of tank inventory management, loss-control, total cost savings and safe operation.

Proservo is suitable for atmospheric and high pressure applications up to 2.5 MPa (363 psi). Aluminium and stainless steel versions are available, depending on the application (i.e. product type and pressure rating).

Aluminium drum housing version
- NMS 531, low pressure
- NMS 534, mid pressure

Stainless steel drum housing version
- NMS 532, low pressure
- NMS 535, mid pressure
- NMS 536, high pressure
- NMS 537, hygiene version for food industry

Inputs and outputs
- 4 – 20 mA analog output
- 4 points level alarm
- 2 points overfill protection
- 1 status input
- Various industry standard digital communication outputs
7.1.2 Features

- Measures liquid to an accuracy of +/- 0.7 mm under reference conditions
- Measures two clear interface levels and specific gravity of up to three liquid phases.
- Latest microtechnology keeps the design simple, lightweight and compact
- Wetted parts are completely separated from the electronic circuit
- Tank top mounting with 3" flange weighting only 12 kg (aluminium version)
- Wide range of output signals including V1, RS 485, WM550, M/S, Enraf BPM and HART® protocol
- Material and pressure rating of the wetted parts can be selected according to the application.
- Suitable for atmospheric and high pressure applications up to 25 bar
- Maintenance prediction of the instrument
- Direct connection of spot or average temperature probes
- Easy to program using the E+H matrix system
- Robust IP67 housing
- Built-in calibration window
7.1.3 Measurement Principle

The Proservo NMS 53x tank gauging system is based on the principle of displacement measurement. A small displacer is accurately positioned in the liquid medium using a servo motor. The displacer is suspended on a measuring wire which is wound onto a finely grooved drum housing within the instrument.

The drum is driven via coupling magnets which are completely separated by the drum housing. Outer magnets are connected to the wire drum whilst the inner magnets are connected to the drive motor. As the magnets turn, its magnetic attraction causes the outer magnets to turn as well, as a result turning the entire drum assembly. The weight of the displacer on the wire creates a torque on the outer magnets generating the change of magnetic flux. These changes generated between the drum assembly are detected by a unique electromagnetic transducer on the inner magnet. The drive motor is actuated to balance the voltage generated by the variations of magnetic flux to equal the reference voltage defined by the operating command.

When the displacer is lowered and touches the liquid, the weight of the displacer is reduced because of the buoyant force of the liquid. As a result, the torque in the magnetic coupling is changed and this change is measured by 5 sets of Hall sensors (US patent) chips which are temperature compensated. The signal, an indication of the position of the displacer, is sent to the motor control circuit. As the liquid level rises and falls, the position of the displacer is adjusted by the drive motor. The rotation of the wire drum is precisely evaluated to determine the level value which is accurate to an outstanding +/- 0.7 mm.

For more information, please refer to the Proservo Technical Information (TI006NEN).
7.2 Micropilot S FMR53x

7.2.1 Application

To meet your high-accuracy requirements, the Micropilot S-series of radar gauges is approved for custody transfer applications. The inventory control version of Micropilot S offers more antenna options and a cost-effective solution for your inventory control applications.

- The FMR 533 with parabolic antenna is excellently suited for free space applications up to 40 m (131 ft).
- The FMR 532 with planar antenna is specifically suited for stilling well applications with ranges up to 38 m (124 ft).
- The FMR 531 with rod antenna is used for highly accurate measurements of very aggressive products and in narrow nozzles.
- The FMR 530 with horn antenna is suitable for free space applications that disallow the use of a parabolic antenna due to tank/nozzle geometry.
7.2.2 Features

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<td>±0.5 mm</td>
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<td>±0.5 mm</td>
<td>±0.5 mm</td>
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<tr>
<td>Max. measuring range</td>
<td>25m (82ft)</td>
<td>20m (65ft)</td>
<td>38m (125ft)</td>
<td>40m (131ft)</td>
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<td>Process temperature range</td>
<td>V standard, Viton -20 ...+200 °C -4 ...+392 °F</td>
<td>PPS, antistatic -40 ...+200 °C -40 ...+392 °F</td>
<td>HNBR seal -40 ...+150 °C -40 ...+302 °F</td>
<td>-40 ...+200 °C -40 ...+392 °F</td>
</tr>
<tr>
<td>Process pressure range</td>
<td>40 bar 580 psi</td>
<td>40 bar 580 psi</td>
<td>25 bar 362 psi</td>
<td>16 bar 232 psi</td>
</tr>
<tr>
<td>Process connection</td>
<td>DN80...250/PN16...40 3&quot;...6&quot;/150...300lbs</td>
<td>DN50...150/PN16...40 2&quot;...6&quot;/150...300lbs</td>
<td>DN150...250/PN16...25 6&quot;...10&quot;/150...300lbs</td>
<td>6&quot;...10&quot;/150 UNI flange Flange hub</td>
</tr>
<tr>
<td>Remarks</td>
<td>Use biggest horn possible</td>
<td>Only if horn is not possible</td>
<td>Stilling well applications only</td>
<td>Ideal in free space applications</td>
</tr>
</tbody>
</table>

- ±0.5 mm accuracy under reference conditions

Note!
Free space Micropilot radar gauges provide accuracy of ±0.5 mm (2 sigma value). Micropilot FMR532 stilling well radar gauges provide accuracy of ±0.8 mm (2 sigma value).

- Weights & Measures approved by NMi and PTB and other national authorities
- OIML certified
- Applicable as stand-alone system or tied into tank gauging systems via the Tank Side Monitor NRF 590.
- Application-specific antenna selection. Planar antenna versions allow direct installation on tapered stilling wells.
- Cost-effective and simple installation via 4-wire cable with HART and 24 V DC intrinsically safe power supply.
- Gas-tight process connection (second line of defense) standard for any antenna version.
- Inventory Control Version with reduced accuracy (3 mm) available for all instrument types.
7.2.3 Measurement Principle

Time-of-Flight measurement

The Micropilot is a "downward-looking" measuring system, operating based on the time-of-flight method. It measures the distance from the reference point (process connection) to the product surface. Radar impulses are emitted by an antenna, reflected off the product surface and received again by the radar system.

The reflected radar impulses are received by the antenna and transmitted into the electronics. A microprocessor evaluates the signal and identifies the level echo caused by the reflection of the radar impulse at the product surface. The unambiguous signal identification is accomplished by the PulseMaster software based on many years of experience with time-of-flight technology. The mm-accuracy of the Micropilot S is achieved with the patented algorithms of the PhaseMaster software. The distance D to the product surface is proportional to the travel time t of the impulse:

\[ D = \frac{c \cdot t}{2}, \]

with c being the speed of light.

Based on the known empty distance E, the level L is calculated:

\[ L = E - D \]

Reference point for "E" is the lower surface of the process connection. The Micropilot is equipped with functions to suppress interference echoes. The user can activate these functions. They ensure that interference echoes (e.g., from edges and weld seams) are not interpreted as level echo.

Benefits
- No moving parts-low maintenance costs
- Independent of certain liquid characteristics such as density and conductivity
Integration via the Tank Side Monitor NRF590

The Endress+Hauser Tank Side Monitor NRF590 provides integrated communications for sites with multiple tanks, each with one or more sensors on the tank, such as radar, spot or average temperature, capacitive probe for water detection and/or pressure sensors. Multiple protocols out of the Tank Side Monitor guarantee connectivity to nearly any of the existing industry standard tank gauging protocols. Optional connectivity of analog 4...20 mA sensors, digital I/O and analog output simplify full tank sensor integration. Use of the proven concept of the intrinsically safe HART bus for all on-tank sensors yields extremely low wiring costs, while at the same time providing maximum safety, reliability and data availability.

For more information, please refer to the Micropilot S Technical Information [TI344FEN].
7.3 Micropilot M FMR23x/240

7.3.1 Application
The Micropilot M is used for continuous, non-contact level measurement of liquids, pastes, and slurries. The measurement is not affected by changing media, temperature changes, gas blankets or vapours.

- The FMR 230 is especially suited for measurement in buffer and process tanks.
- The FMR 231 has its strengths wherever high chemical compatibility is required.
- The FMR 240 with the small (1½") horn antenna is ideally suited for small vessels.

Micropilot M is also well suited for inventory control applications, providing:
- Two-wire system
- Accuracy: ±3 to 10 mm (depending on type)
- Cost-effective solution

7.3.2 Features
- Under reference conditions, the Micropilot M provides an accuracy of ±3 mm for inventory control applications.
- Cost-effective and simple installation via 2-wire cable with HART
- Non-contact measurement:
  - Measurement is almost independent from product properties.
- Easy on-site operation via menu-driven alphanumeric display.
- Easy commissioning, documentation and diagnostics via operating software ToF-Tool.

7.3.3 Measurement System
see Micropilot S
For more information, please refer to the Micropilot M Technical Information (TI345FEN).
7.4   Leveflex M guided radar

7.4.1   Application

Light products, such as LPGs are stored in spherical or horizontal cylindrical (pressurised bullet) tanks. Chemicals, such as concentrated acids, organic solvents, esters, etc. are often stored in non-pressurised horizontal cylindrical tanks. Bullet tanks are often good applications for guided radar since, often, the tanks have only small diameter nozzles available. For inventory control in spheres or bullets, the Leveflex M FMP 45 (high pressure version) performs continuous level measurement. For non pressurised bullets, the Leveflex M FMP 40 is recommended.
7.4.2 Features

- Under reference conditions, the Levelflex M provides an accuracy of ±3 mm for inventory control applications.
- Simple, menu-guided on-site operation with four-line plain text display
- Envelope curves on the on-site display for simple diagnosis
- Easy operation, diagnosis and measuring point documentation with the supplied ToF Tool operating program
- Optional remote display and operation

Coaxial probe
- Integrated stilling well
- Easy calibration and verification
- Completely independent of internals in the tank and of the installation in the nozzle
- Independent of products dielectric constant

Rod probe
- Independent of turbulent surface
- Ideal mounting in stilling well
- Easy to transport
- No fixation in tank required

Note!
For rod probe, check upper and lower blocking distance.

Rope probe
- Large measuring range – 35m (115ft)
- Effective for corrosive liquids such as acids
- Optimum rope design at all diameters

7.4.3 Measurement system

Time-of-flight forms the basis of guided radar instruments. High-frequency radar pulses are guided along a rope or rod probe. The pulses are reflected on the surface of the medium and the level is calculated from the time of flight of the pulses.

For more information, please refer to the Levelflex M FMP45 Technical Information (TI386FEN).
8 Pressure transmitters

8.1 Deltabar S

8.1.1 Application

The Deltabar S differential pressure transmitter can be used for level, volume or mass measurement in liquids. For tank gauging, API (American Petroleum Institute) recommends accuracy of pressure transmitters to be 0.05%. This cannot be achieved with diaphragm seals. Endress+Hauser’s platinum version of the Cerabar PMD75 with linearity of 0.05% fulfills this requirement. For HTMS, density measurement is accomplished with the PMD75 special tank gauging version.

Level measurement (level, volume and mass)

- Choice of three level operating modes
- Volume and mass measurements in any tank shapes by means of a freely programmable characteristic curve
- Choice of diverse level units with automatic unit conversion
- A customised unit can be specified
- Has a wide range of uses, e.g.
  - for level measurement in tanks with superimposed pressure
  - in the event of foam formation
  - in tanks with agitators of screen fittings
  - in the event of liquid gases
  - for standard level measurement

8.1.2 Features of special Tank Gauging version

- Special flanged process connection
- No diaphragm seal, i.e. no additional temperature effects
- High accuracy: better than 0.05% (platinum version) – satisfies API standards
- Process temperatures up to 120 °C
- Static pressure up to 160 bar/420 bar
- Simple and easy operation via HART protocol or connection to Profibus-PA or Foundation Fieldbus
- Connection to Tank Side Monitor NRF 590 for density calculation
- Hastelloy C measuring cell as a standard version
- Materials of Construction meet NACE material recommendations per MR01-75
8.1.3 Measurement System

Metallic measuring diaphragms used for the PMD 75

The separating diaphragms (3/9) are deflected on both sides by the acting pressures. A filling oil (4/8) transfers the pressure to a resistance circuit bridge (semi-conductor technology). The differential-pressure-dependent change of the bridge output voltage is measured and further processed.

Advantages

- Standard operating pressures: 160 bar and 420 bar
- High long-term stability
- Very high single-sided overload resistance
- Second process barrier (Secondary Containment) for enhanced mechanical integrity

For more information, please refer to the Deltabar S Technical Information (TI382PEN).
8.2 Cerabar M

8.2.1 Application
Cerabar M transmitters measure the gauge and absolute pressure of gases, vapours, liquids and dusts and can be used in all areas of process engineering. The modular design of the Cerabar M enables it to be used in all industrial environments.

8.2.2 Features

Accuracy
- Linearity better than 0.2% of set span
- Adjustable measuring range with TD 10:1
- Long-term stability better than 0.1%

Sensors
- Dry capacitive ceramic sensor up to 40 bar (600 psi) - corrosion and abrasion resistant with high overload protection and vacuum-tightness
- Piezoresistive metal sensor for measuring ranges up to 400 bar (6000 psi)

Electronics
- Analogue: low-cost and accurate with short response time especially for rapid processes
- Smart: intelligent with versatile operating procedures via HART protocol
- PROFIBUS-PA: tried and tested for digital communications

Housings
With its stainless steel housing without dead volume, the Cerabar M fulfills all the special hygienic requirements of the food and pharmaceutical industries. The polyester-epoxy coated aluminium housing has been field-proven in the process industry.
**Process connections**
All customary thread versions, hygienic connections and flanges are available.

**8.2.3 Measurement system**
The ceramic sensor is a dry sensor, i.e. its function does not require fill fluid. The process pressure acting directly on the rugged ceramic diaphragm and deflecting it a maximum of 0.025 mm. A pressure-proportional change in the capacitance is measured by the electrodes on the ceramic substrate and diaphragm. The measuring range is determined by the thickness of the ceramic diaphragm.

**Advantages**
- Guaranteed resistance to overload up to 40-times nominal pressure (max. 60 bar/900 psi)
- Extremely high chemical resistance comparable to Alloy or tantalum
- For use with vacuum
- Ideal for hygienic processes as the Al2O3 ceramic material is generally recognized as safe (FDA 21CFR186.1256)

For more information, please refer to the Cerabar M Technical Information (TI321PEN).
9 Temperature sensors

9.1 RTD spot temperature measurement

9.1.1 Application

For spot temperature measurement, Omnigrad M TR 1x temperature sensors are resistance thermometers designed for use in the fine or heavy chemicals industry but also suitable for other applications, including oil and gas. They are made up of a measurement probe with a protection well, and a housing, which may contain the transmitter for conversion of the variable measured. Omnigrad M TR 1x Thermometers hold an advanced Atex EEx-ia certification, not only for their electronics but also for the measurement probe. This is the only way to have the certainty of a design, risk evaluation, quality control and technical support, that are completely focussed on safety.

Furthermore, the TR 1x Series has been developed to ensure the best performance-service-cost ratio, from the ease of selection and ordering to the product’s maximum reliability and endurance. Based essentially on DIN norms and thanks to the variety of options, the TR 1x Series also fulfils the other international standards (ISO, ANSI, ...), which are commonly followed in the practice of engineering.
9.2 Prothermo NMT539 average temperature and water bottom interface measurement

9.2.1 Application

The Prothermo NMT 539 is an intelligent HART signal converter, with a combined average temperature sensor and water bottom interface probe. For average temperature measurement, it consists of precision multi-spot Pt100 elements. The NMT 539 is a highly capable solution for a variety of tank gauging applications and provides both constant average temperature data and water interface data via HART communication. For accurate inventory measurement, it is best suited connected to Endress+Hauser’s Proservo NMS 53x or Tank Side Monitor NRF 590 with Micropilot radar.

9.2.2 Features

- Intrinsically safe device allowing for the safest electrical configuration possible.
- Available in four different versions based on customer requirements.
- Converter is compatible with various element types in foreign manufacturer temperature probes.
- Compatible with Endress+Hauser’s user friendly ToF (Time-of-Flight) tool.
- Variety of process connections and cable entries available to meet worldwide classifications.

9.2.3 Measuring system

The Prothermo NMT 539 is available in four different versions:

- Converter only
- Converter + Average temperature probe
- Converter + Water bottom (Capacitance) sensor
- Converter + Average temp probe + Water bottom sensor

The converter only version can be retrofit without modifications onto existing foreign average temperature probes, such as Whessoe Varec 9909 and 1700 and Weed Beacon MW type probes. The average temperature probe + converter inherits all the functionality of the former Prothermo NMT 535/536/537 series. The water bottom (WB) + converter provides constant water interface level data for the host level gauge for determining the multi-layered water bottom level measurement. The average temperature + WB + converter is the ultimate multi-function sensor, transmitting temperature and water interface level data along only one pair of HART signal cables to the host the Proservo NMS 53x or NRF 590 Tank Side Monitor.

For more information, please refer to the Prothermo Technical Information (TI042NEN).
10 Field instruments and controllers

10.1 Tank Side Monitor NRF590

10.1.1 Application

The Tank Side Monitor NRF 590 is a sensor integration and monitoring unit for bulk storage tank gauging applications. It can be used with Micropilot level radars and combined with other HART compatible devices.

The Tank Side Monitor offers the following functions:
- Intrinsically safe (i.s.) power supply of the connected devices
- Parametrization of the connected devices
- Display of the measured values
- Tank calculations for accurate determination of the tank content
10.1.2 Features

- i.s. power supply and communication for Micropilot M and S level radars
- Connects up to 6 HART devices via i.s. 2 wire, for example Prothermo for average temperature measurement and Cerabar/Deltabar for HTMS density applications
- Backlit graphical LCD display; operation via 3 optical keys (touch control)
- User-friendly operating menu
- Interfaces to FuelsManager SCADA tank inventory system via RTU 8130
- Provides communication to PLC, DCS and SCADA systems
- Various industry standard communication protocols, including
  - Sakura V1
  - EIA-485 Modbus
  - Whesoematic WM 550
  - Enraf BPM
- Approved for use in explosion hazardous areas

10.1.3 Measurement System

The Tank Side Monitor is typically installed at the bottom of the tank and allows to access all connected tank sensors. It collects the measured values and performs several configurable tank calculations. All measured and calculated values can be displayed at the on-site display. Via a field communication protocol, the Tank Side Monitor can transfer the values to an inventory control system.

Tank calculations

The Tank Side Monitor can perform all necessary calculations for the following modes:
- level mode (one level sensor)
- hydrostatic mode (one or two pressure sensors)
- hybrid mode (level and pressure sensor)

Hybrid mode is used for HTMS. In hybrid mode, the level is read from a radar or other level gauge and combined with a pressure sensor located near the bottom of the tank to accurately calculate the standard density. The only purpose of Hybrid mode is to calculate the observed density based upon the level and a pressure.

Also, the Tank Side Monitor can automatically calculate the following corrections:
- Correction for the Hydrostatic Tank Deformation
- Temperature Correction for Thermal Expansion of the Tank Shell (CTSh)

For more information, please refer to the Tank Side Monitor Technical Information (TI374FEN).
10.2 RTU8130 Remote Terminal Unit

10.2.1 Application
The Remote Terminal Unit (RTU 8130) acts as a tank gauge interface for data acquisition and host gateway for tank farm, pipeline or refinery applications. Each RTU 8130 supports up to four individual expansion modules that can interface to virtually any tank gauge on the market. Each module will scan all the connected gauges for measured data such as:
- Level
- Temperature
- Density
- Water level
- Alarms

The RTU 8130 also connects to most types of sensors or actuators on your site, and to PLCs and DCS computers. All information obtained can be uploaded to the host system for inventory, alarm and control purposes.

10.2.2 Features
- Easily expandable through the use of plug-in modules - reduces cost by integrating all analog, digital and serial data inputs and outputs
- Multiple host ports - adapt to your needs and redundancy requirements
- Support of multiple tank gauge protocols - connect your existing equipment at less cost
- Digital and analog I/O connectivity - allows simple tank farm alarm integration
- Fully compatible with FuelsManager - tank inventory management made easy
- RTU and gauge configuration data can be exported to other applications, such as Microsoft Excel® or Access® - document all tank gauge equipment
- Remote configuration of your tank gauges - means less on-tank activities, resulting in less personnel risk
10.2.3 Measurement system

The Remote Terminal Unit (RTU 8130) serves as an effective solution in SCADA or standalone control applications by integrating automatic tank gauge communications. Digital, analog and serial I/O interface boards further enhance the RTU 8130 into an extremely capable and compact solution for control applications.

Intelligent Module Architecture
The RTU 8130 supports up to four modular intelligent modules. Each module has its own processor for fast and reliable field data scanning. An internal high speed serial data link communicates the data into a central database. The modules make configuration of the internal RTU 8130 database simple and straightforward. Multiple host communication ports offer windows into all the real-time data for uplinking to one or multiple host computers.

A range of intelligent modules is available for interfacing to nearly any brand of tank gauge equipment or technologies, making it possible to integrate float and tape transmitters, HTG, servo, magnetostrictive and radar gauges. This allows direct gauge communication, making communication protocol converters superfluous and combining all equipment into one tank inventory system.

Field I/O Communication
A full range of I/O interfaces is available for the RTU 8130, offering connectivity to virtually every type of signal encountered in industrial environments. The RTU 8130 uses standard transmitter signal levels to interface with:
- Analog input signals, such as 4-20 mA, 1-5 or 0-10 Volts
- Digital I/O with isolated solid state relays for connection to 5, 24 Vdc and 120 or 240 Vac
- High frequency pulse input for totalization
- 4-20 mA and 0-10 V analog outputs
Host Communication
The RTU 8130 combines with the Endress+Hauser Systems & Gauging FuelsManager software to provide an extremely cost efficient and reliable tank inventory system. It also provides three host ports and is compatible with a variety of other host systems through the industry standard Modbus™ protocol.

Hybrid calculations in RTU
The RTU support hydrostatic and hybrid tank gauging involving pressure transmitters to calculate the density of a liquid in a tank.

The RTU can operate in one of 3 modes:
- Mode=0 - Hydrostatic using P1 and P3
- Mode=1 - Hybrid Mode
- Mode=2 - Hydrostatic using P1

Hybrid Calculations: Performed if level sensor and P1 are both usable:
- Level is read from level gauge
- BotPress is read from P1 sensor
- Temp is read from the point defined by the RTU.
- Density is calculated from P1 and Level. The height of the bottom pressure transmitter is needed to define the distance from the bottom of the tank to the bottom pressure probe. StdDensity is calculated using the Correction Method and the Temperature.

For more information, please refer to the Remote Terminal Unit Technical Information (TI007GAE).
11 Inventory Management Software

11.1 FuelsManager

11.1.1 Application and architecture of software

FuelsManager is an advanced Supervisory Control and Data Acquisition (SCADA) suite of software products for tank farms, terminals, pipelines and other management facilities. This system runs under the Microsoft Windows 2000 or the Microsoft Windows NT operating systems. These multi-tasking, 32-bit operating systems allow for complete Client/Server applications. FuelsManager can operate on a single PC or as part of a network and is available in Workstation or Server configurations. In addition, FuelsManager can be networked with other PC or host computer systems.

Inventory Management Users are able to integrate all major types of tank level and mass measurement instruments, including float, radar, servo, hydrostatic, intelligent, magnetostrictive and hybrid tank gauges, into one system. Storage tank parameters, such as level, temperature, gross and net standard volumes are displayed in real-time at the local operator workstation. The system contains fuels management-specific functionality and can support most major manufacturers’ tank gauging systems and other terminal automation equipment. The system can monitor levels, temperatures, alarms, volumes, flow and other variables for up to 2000 tanks.

In addition to tank inventory management, FuelsManager is capable of controlling an entire tank farm. Programmable Logic Controllers (PLC) are used to monitor and control tank farm instrumentation and control devices, such as pumps and valves. Combining tank farm automation with tank farm inventory reduces the number of systems that operators have to manage. Complete control of pipeline receipts, hydrant system control, independent high level alarm systems, Emergency Fuel Shut-Off (EFSO) and interfaces to leak detection systems are all possible with FuelsManager’s Tank Farm Automation.
11.1.2 Features

- SCADA functionality: Supervisory control coupled with data acquisition for any tank gauging application - Integration of pumps, valves and PLCs with a minimum of hardware
- Full API/ASTM compliant calculations assure accurate and real-time inventory data of your liquid hydrocarbon stock
- Windows compatibility and graphical user interface (GUI) give worldwide acceptance and ease of use
- Standard "tank" object for ease of configuration with standard templates for various tank types
- Comprehensive alarm/event/reporting capabilities - Daily alarm/event file logged to the hard disk
- Client/Server design - Industry standard design for SCADA/DCS applications
11.1.3 Measurement system

FuelsManager can calculate the following data:
- Reference density
- Total observed volume
- Gross observed volume
- Floating roof adjustment
- Net standard volume
- Mass
- Available volume / available mass
- Remaining volume / remaining mass
- Water volume
- Flow

FuelsManager compensates for variations in temperature using
- Volume correction factor (VCF)
- Compensation for tank shell temperature (CTSh)
11.1.4 FuelsManager licensing options

The FuelsManager software suite is available as a licensed product with various levels of functionality. Each edition is available pre-installed on a PC or as a software license only, available editions include Server, Professional and Standard.

The Inventory Management license (without PC)
- User and operator manual
- CD with files necessary to install Inventory Management and ViewRTU software
- Software protection key

The Inventory Management license preinstalled onto a PC
- PC with minimum required features for workstation or server editions
- User and operator manual
- CD with files necessary to install Inventory Management and ViewRTU software
- Software protection key
- Windows NT/2000 license

Server Edition
- Highest level of licensing
- Intended for large installations
- Customer purchase a single site license
- Allows multiple Inventory Management clients to access the data from a central data server
- No additional licences are required to connect Inventory Management workstations
- PC platforms will be selected to best fit your site application and location

With a server license, any PC running Inventory Management can access data from a central data server. A separate Inventory Management license key is not needed for each PC.

Professional Edition
- Intended for small to medium sized networks
- Customer need to be able to customize the operator interface and show data over a network
- Each Inventory Management workstation on the network has its own licensing key
- The Inventory Management Professional Edition can also act as a server and provide inventory data to other Inventory Management Professional Editions

Inventory Management Professional can serve data to other professional or standard Inventory Management editions.

Standard Edition
- Intended for standalone systems for up to 30 tanks
- Can be used as a client to a Professional or Server Edition
- Inventory Management Standard Edition supports predefined graphics and reports
  - Does not allow these standards to be modified
  - Custom graphics or reports cannot be created
- Cannot serve data to other Inventory Management stations
- Cannot be used with the optional Product Movement Package
- Does not support SCADA functionality
- No Input/Output points
12 Tank Gauging system as a subsystem of DCS (protocols, interfaces, drivers)

Endress+Hauser instruments and systems are designed to provide seamless interfaces to external systems using industry standard protocols. Tank farm automation systems can receive tank gauging data from either the RTU8130 directly or via the FuelsManager Inventory Management System. The following represents some of the standard interfaces available with the RTU8130 and FuelsManager:

- The RTU8130 offers a configurable Modbus master and slave interface for the transfer of raw data
- Fuelsmanager offers a configurable Modbus master and slave interface for the transfer of raw, calculated data and alarm information
- Fuelsmanager offers a configurable Allen Bradley Data Highway slave interface for the transfer of raw, calculated data and alarm information
- Fuelsmanager has both an OPC server and OPC client interface. OPC (OLE for Process Control) is quickly becoming the industry standard for intra-product communications in the process control industry for all tank, input and output points
- Fuelsmanager tank data can be accessed via an ODBC compliant database, either locally or remotely, via a LAN.
- Numerous other interfaces have been implemented in both the RTU8130 and Fuelsmanager to connect to other devices and systems via special or proprietary protocols.
12.1 Integration of HART and analogue Fieldgates (optional)

Tank gauging systems from Endress+Hauser offer the option of remote monitoring of instruments with analog (4...20mA) or HART communication:

- The Fieldgate FXA320, together with FuelsManager, enables remote monitoring of connected 4...20 mA sensors/actuators, either via telephone lines (analogue), Ethernet TCP/IP or mobile communications (GSM).
- The Fieldgate FXA520, together with FuelsManager, enables remote monitoring of connected HART® sensors/actuators, either via telephone lines (analogue), Ethernet TCP/IP or mobile communications (GSM).

Both Fieldgates can be integrated into FuelsManager via an OPC interface, where FuelsManager is the OPC Client and an OPC server connects to the Fieldgates.
13 Characteristics of Data Communication Protocols

Endress+Hauser’s Tank Side Monitor NRF 590, used in combination with radar, supports all of the following industry standard communication protocols allowing it to be integrated with existing instrumentation and connect to host computer systems without the need for additional hardware. These protocols allow for piece-by-piece replacement and upgrading of older technologies to modern radar solutions.

13.1 Sakura V1

V1 protocol provides a standard form of digital communication via a two-wire system. V1 was brought to the market by Sakura Endress and meets the demands of the Japanese market. The Tank Side Monitor implementation of the V1 slave protocol supports various old and new V1 protocols:
- V1 (new V1)
- MDP (old V1)
- BBB (old V1)
- MIC+232 (old V1)

13.2 EIA-485 (RS) Modbus

In Modbus, the flow of data between two devices uses a master/slave protocol. The NRF 590 acts as a Modbus slave and runs on the EIA-485 (RS) version of the MODBUS communications board. Modbus provides Varec MFT parameter mapping for easier setup in retrofit applications. It provides direct connection to PLC and DCS systems.

13.3 Whessoematic WM550

WM550 protocol provides a standard form of digital communication via dual current loops. WM550 was developed to facilitate communications to transmitters installed on mechanical float and tape gauges. It is a two-wire system and the only protocol with a redundant loop.

13.4 Enraf BPM

Enraf BiPhaseMark (BPM) protocol provides compatibility to Enraf systems by emulating the Enraf GPU-BPM protocol. The NRF 590 is fully compatible to ENRAF (802, 812), 811, 854 and 954 series servo gauges, 813 MGT (mechanical gauge transmitter), 872, 873 and 973 series Radar gauges, 874 AIM (Analogue Input Module) and the 875 VCU (Valve Command Unit).

13.5 Varec Mark/Space

Mark/Space protocol provides a standard form of digital communication via a voltage mode bus. Mark/Space was developed to facilitate communication to transmitters installed on mechanical float and tape gauges. It supports product level, temperature and discrete inputs.

13.6 L&J Tankway

L&J Tankway protocol provides a standard form of digital communication via a voltage mode bus. Tankway supports product level, temperature and discrete inputs.
13.7 GPE

GPE protocol provides a standard form of digital communication via a current loop. It is compatible with L&J and GPE mechanical float and tape and servo instrumentation.
14 Summary

There are various technologies available in order to perform the task of 'Tank Gauging' and key factors effecting how a technology is applied in a given measurement situation. These factors are not only related to the product to be measured, but also to the technology, environment and external and site specifics. Any tank gauging technology is only as good as the way in which it is integrated with other technologies in order to form a complete integrated tank gauging system.

Hybrid Tank Measurement Systems (HTMS) are recommended for all markets where products are bought and sold based on mass measurement. HTMS provides the best results with the highest possible accuracy - level measurement communicated down to the tank bottom, volume calculation out of the level data, spot or average temperature measurement, water-interface measurement and pressure measurement with one or two pressure transmitters. With HTMS, it is possible to produce a highly reliable, high performance and cost-effective tank gauging solution.

Endress+Hauser offers complete HTMS solutions including instrumentation and system components: high accuracy level instruments working on the Radar or Servo principle, spot or average temperature sensors with an optional integrated water interface unit, pressure sensors of various classes, tank side indicators with calculation functions, data interfaces and management software packages for inventory control or custody transfer applications.

A tight network of well-trained, service-minded product managers and sales representatives, together with local agents, gives Endress+Hauser a strong presence across global markets. Endress+Hauser offers service, spare parts and advice to help you achieve what is right for you.

The company owes its good reputation to industry know-how, and to the creativity and commitment of its employees. Endress+Hauser stands for financial strength and continuity, the broadest range in its industry, and long-term customer relationships.
15 Associated Documentation

Standards

Application Documentation
2. SO501B/00/en Tank Farms and Terminals: System and Gauging Solutions for inventory control and custody transfer applications
3. CP010V/00/en Inventory Measurement: Inventory control and custody transfer solutions for tank farms and terminals
4. SD003V/00/en Tank Gauging Systems: Inventory management software for refineries tank farms and terminals

System Documentation
5. Am002G03ae FuelsManager Administrator Manual, V4.3, E+H System & Gauging, Atlanta, USA, 2002
6. Um002G03ae FuelsManager Operator Guide, V4.3, E+H System & Gauging, Atlanta, USA
7. Um002G03ae FuelsManager Movement System V4.3, E+H System & Gauging, Atlanta, USA
8. TI007G03ae RTU 8130 Remote Terminal Unit: Intelligent communication interface and host gateway, Endress+Hauser Systems & Gauging, Atlanta, USA
9. RTU/8130 User Manual, V4.2, E+H System & Gauging, Atlanta, USA
10. Ba053G03ae RTU User manual with Model 8203 Dual RS-485 Comms – Rackbus, , E+H System & Gauging, Atlanta, USA

Instrument Documentation
11. TI006N08EN/05.03 NMS53x Proservo NMS52x series : Taking tank gauging to new limits, software V4.25, Sakura Endress
12. Ti008N08EN/02.02 Tank Side Monitor Promonitor NRF560, Sakura Endress
13. TI 042N/08/EN/06.03 Prothermo NMT539: Intrinsically safe multi-signal converter with precision average temperature and water bottom sensor for inventory control and custody transfer applications, Sakura Endress, Japan
14. Ba001N08EN/02.02 Proservo NMS53 Operating Manual, software version V4.25, Sakura Endress
15. Ba003N08EN/02.02 Promonitor NRF560 Operating Manual, Sakura Endress

Supporting Documentation
16. Uncertainties in Inventory Calculations in Tank Gauging, E+H Advisory Notes, Endress+Hauser, AdvNote015InventoryUncertaintiesInTG.pdf
17. Understanding Uncertainties in Hybrid Tank Gauging or HTMS E+H Advisory Notes, Endress+Hauser, AdvNote018HTMSUncertainties.pdf
18. ISO 15169 - Petroleum and liquid petroleum products - Determination of volume, density and mass of the contents of vertical cylindrical tanks by Hybrid Tank Measurement Systems
19. API MPMS Chapter 3 - section 6 -- Measurement of liquid hydrocarbons by hybrid tank measurement systems
20. ISO, Guide to the Expression of Uncertainty in Measurement (or any of the derived documents such as from OIML or NIST (TN297)