High Accuracy Level Measurement for Custody Transfer & Inventory Control by Proservo NMS8x & Micropilot NMR8x

White Paper

Endress+Hauser

People for Process Automation

Endress+Hauser
People for Process Automation

Hiroyuki Fukasawa
Product Manager Proservo, Tank Gauging, Inventory Management Solutions
Endress+Hauser Yamanashi Co., Ltd.

Philipp Walser
Product Manager Micropilot, Tank Gauging, Inventory Management Solutions
Endress+Hauser SE+Co. KG

Register

1 Abstract

Proservo NMS8x and Micropilot NMR8x are designed and used for high accuracy liquid level measurement in custody transfer and inventory control applications. This white paper describes why there are needs for two different measuring technologies for high accuracy liquid level measurement.

2 Measuring technology

2.1. Proservo NMS8x measuring technology

NMS8x is an intelligent tank gauge for measuring liquid levels with high precision. The system is based on the principle of gauging displacement illustrated in the Figure 1.
A small displacer is accurately positioned in a liquid medium using a stepping motor. The displacer is then suspended on a measuring wire which is wound onto a finely grooved wire drum. NMS8x counts the rotations of the wire drum and to calculate the traveling distance of the wire and obtain the liquid level change.
The drum is driven via coupling magnets that are completely separated by the drum housing. Outer magnets are connected to the wire drum, with inner magnets connected to the drive motor. As the inner magnets turn, their magnetic attraction causes the outer magnets to turn, as well, causing the entire drum assembly to turn. The weight of the displacer on the wire creates torque on the outer magnets generating change of magnetic flux. These changes generated in the drum assembly are detected by a unique electromagnetic transducer on the inner magnets. The transducer transmits the weigh signal to a CPU using a non-contact principle. The drive motor is actuated to keep the weigh signal constant at set value defined by the operating command.
When the displacer is lowered and touches a liquid, the weight of the displacer is reduced by liquid buoyancy force, which is measured by a temperature-compensated magnetic transducer. As a result, the torque in the magnetic coupling changes, and this is measured by six hall sensors. A signal indicating the weight of the displacer is sent to the motor control circuit. As the liquid levels rise and fall, the displacer position is adjusted by the drive motor. The rotation of the wire drum is continuously evaluated to determine the level value using a magnetic rotary encoder. In addition to gauging the level, NMS8x can measure the interfaces between up to three liquid phases, and the tank bottom, as well as spot and profile densities.

A Displacer position data
B Weight data
1 Encoder
2 Motor
3 Rotary transformer
4 Shafts
5 Gears
6 Wire drum
7 Measuring wire
8 Displacer

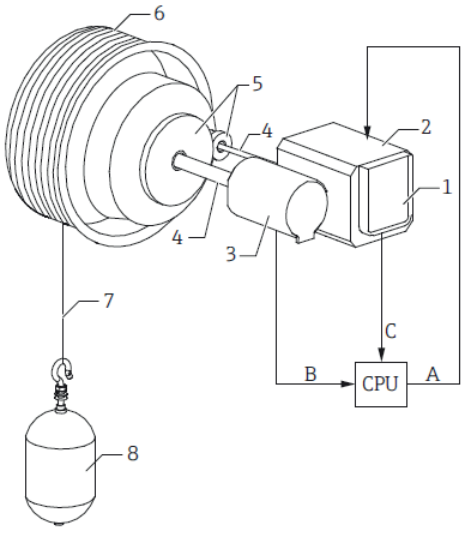


Figure 1: Proservo NMS8x Measuring Technology

2.2. Micropilot NMR8x measuring technology

Micropilot is a directional level radar, operating based on the “Frequency-Modulated Continuous Wave” principle (FMCW) illustrated in the Figure 2. The radar emits a precise crystal-oscillated, continuously varying frequency wave from the antenna. The wave is reflected off the product surface and received again by the radar system.

R Reference point of the measurement

D Distance between R and the product surface

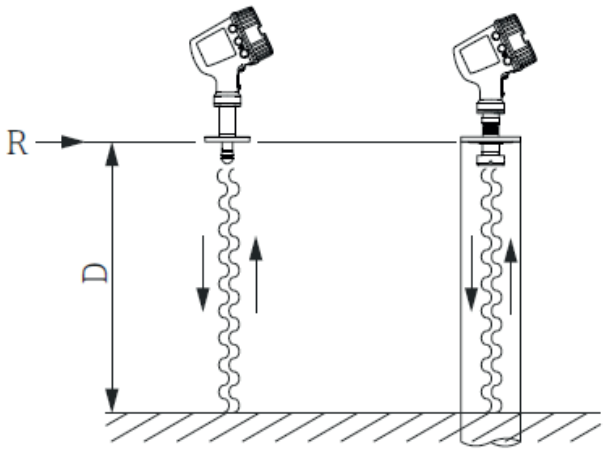


Figure 2: FMCW principle: Emission and reflection of the continuous wave

The frequency of this wave is precisely modulated in the form of a sawtooth signal between two limit frequencies f1 and f2 illustrated in the Figure 3.
Thus, at any given time the frequencies of the emitted and the received signal differ by
$\Delta f = k \Delta t$
where Δt is the transit time and k is the known slope of the frequency modulation.
Δt, on the other hand, is determined by the distance D between the reference point R and the product surface:
$D = (c \Delta t) / 2$
where c is the speed of propagation of the wave.
In summary, D can be calculated from the measured frequency shift Δf. D is then used to calculate the contents of the tank.

1 Emitted signal

2 Received signal

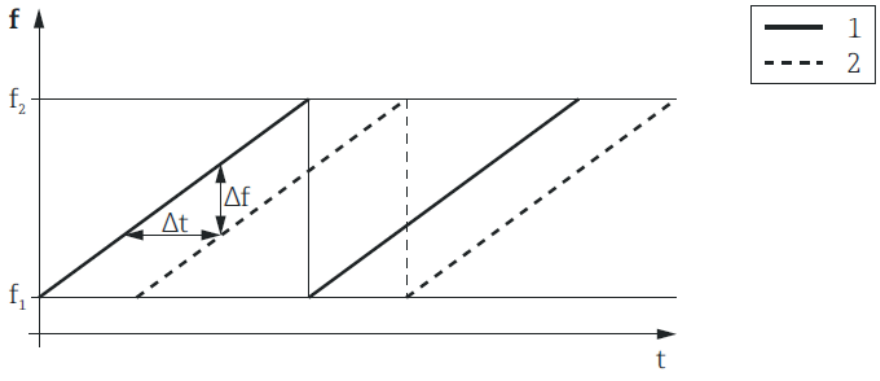


Figure 3: FMCW principle: Results of the frequency modulation

3 Industry requirements

Typical areas of applications include Oil & Gas, Chemicals & Petrochemicals, Power & Energy and alcohol. At these industries, measurement accuracy is the primary important to fulfill legal requirements and to maximize operational profits.

4 Custody transfer

Custody transfer refers to transactions involving the transfer of crude and/or refined petroleum products between two companies via tanks, barges, pipelines, rail tankers, trucks, and ships. At these transactions, accuracy is of great importance because of the following requirements.

- Measuring devices to fulfill legally stipulated accuracy by applied standards
- Accurate measurements to contribute fair trade for both sellers and buyers

The applied standards depend upon countries, but the universally common essence leads to two standards as its origin, namely OIML R85[1], API Chapter 3.1B[2] and ISO 4266[3]. Governments and officials reference these standards to establish their local regulations. OIML R85, API Chapter 3.1B and ISO 4266 require level measurement accuracy within ± 1 mm as the intrinsic accuracy prior to installation on-site, which have to be calibrated and verified at manufacturer's factory before shipment. After installation on-site, additional ± 3 mm is accepted to be used for custody transfer applications. As in the Table 1, the requirement for custody transfer applications is more rigorous than that for inventory control applications, which are not subject to transactions between two companies.

	Custody Transfer	Inventory Control
Factory calibration	± 1 mm (1/16 in)	± 3 mm (1/8 in)
Effect of installation on-site	± 3 mm (1/8 in)	n.a.
Verification on-site	± 4 mm (3/16 in)	± 25 mm (1 in)

Table 1: Accuracy Requirements for Level Measurements

Not to mention the inventory control requirement, Proservo NMS8x and Micropilot NMR8x satisfies the custody transfer requirement. They are approved for the design and performance by the pattern type approvals of international metrology institutes, e.g. NMi[4], PTB[5], LNE[6] for custody transfer applications. Furthermore, Endress+Hauser as the manufacture calibrate and verify Proservo NMS8x and Micropilot NMR8x measurement accuracy at the state of the art calibration facilities.

Proservo NMS8x are calibrated at the production center in Yamanashi, Japan as shown in the Figure 4 with the following features.

- Range: up to 40 m calibration
- Resolution: 1 µm or less by reference laser device
- Uncertainty: ± 0.02 mm approved by NMi

Figure 4: Calibration Facility in Yamanashi, Japan

Micropilot NMR8x are calibrated at the production center in Maulburg, Germany as shown in the Figure 5 with the following features.

- Range: up to 30 m calibration
- Resolution: 1 µm or less by reference laser device
- Uncertainty: ± 0.09 mmw for free space and ± 0.11 mm for stilling well approved by NMi

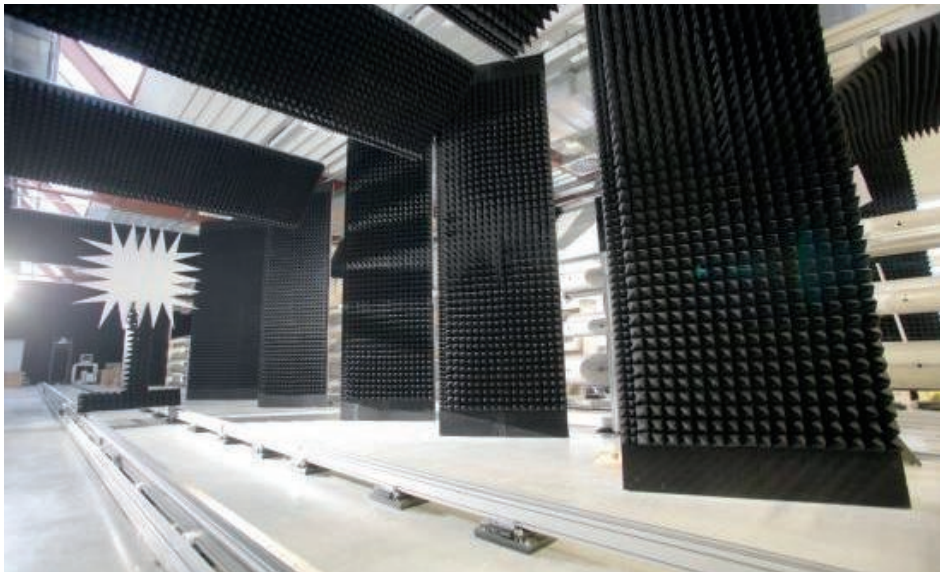
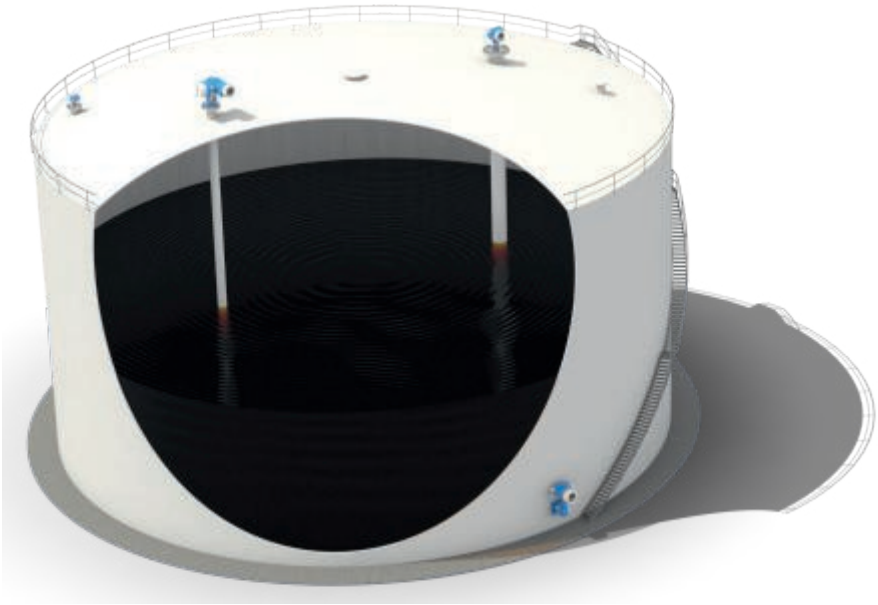


Figure 5: Calibration Facility in Maulburg, Germany

5 Inventory control

In the inventory control application, the accuracy requirement is not as rigorous as the custody transfer application. API Chapter 3.1B recommends that the accuracy should be within ± 3 mm, which can be achieved by level devices for process applications. However, the measurement uncertainty, directly influences the credibility of stock amount in a tank. With respect to the asset management to maximize operational profit, precise measurement is extremely important. Therefore, custody transfer devices are recommended and used for the inventory control application as well.
For example, a 50 m diameter bulk storage tank illustrated in the Figure 6, differences of accuracy have the huge impact in asset uncertainty as in the Table 2. In case that Proservo NMS8x used instead of inventory control device apart from installation errors, it is possible to save USD 902,451 per 1 year.



	Proservo NMS8x	Micropilot NMR8x	Custody Transfer	Inventory Control	Unit
Level accuracy	± 0.4	± 0.5	± 1.0	± 3.0	mm
Volume impact	0.8	1.0	2.0	5.9	m^3
Difference in Liter	785	982	1,963	5,890	l
Difference in Barrel	5	6	12	37	barrel
Asset impact per 1 operation (77 USD / barrel)	380	475	951	2,853	USD
Asset impact per 1 year (1 operation per day)	138,839	173,548	347,097	1,041,290	USD
Saving compared with inventory control	902,451	867,741	694,193	n.a.	USD

Table 2: Asset Impact by Level Measurement Accuracy

6 Freedom of Choice by Customer Needs

For accurate level measurements, the custody transfer approval bodies, NMi and PTB, recommended technology selections according to applications because of the following technical background.

- Black oil is better to be measured with the non-contact measurement by the radar technology. The non-contact measurement is not influenced by oil viscosity because the sensor does not touch it.
- White oil as clean products can be measured with both non-contact measurement by the radar technology and the direct contact measurement by the servo technology.
- Liquified gas is better to be measured with the direct contact measurement by the servo technology. The direct contact measurement is not influenced by low DK (Dielectric Constant), vapor phase and/ or BOG (Boil Off Gas) of the applications.

Since Endress+Hauser offer both of those two different measuring technologies, customers can choose the right measurement device depending on applications. The summary is illustrated in the Figure 7.

Non-contact measurement
by radar technology

Direct contact measurement
by servo technology

Black oil	**White oil**	**Liquified gas**
e.g.	e.g.	e.g.
Asphalt	Alcohol	Ammonia
Bitumen	Benzene	Butadiene
Palm oil	Diesel	Butane
Paraffin	Gasoline	LNG
Styrene	Kerosene	LPG
Sulphur	Light fuel oil	Propane

Figure 7: Recommended Application Selections

7 Additional measurement functionalities

7.1. Interface measurements

In addition to level measurement, Proservo NMS8x can measure the interfaces of up to three different liquid layers. The interfaces data are typically used for the following purposes.

- Drain water under the oil layer to prevent the tank corrosion and maximize the operational range
- Precise tank volume and/or mass calculations to subtract water.
- Monitor the emersion layer to optimize additive injections
- Keep proper amount of water layer at underground rock cavern storages

7.2. Density measurements

Proservo NMS8x has the added value functionality to measure density. Up to 50 points profile density measurement is available throughout a tank. The functionality is used for the following purposes.

- Product quality check
- Mass calculation depending on countries regulations
- LNG rollover prevention depending on required specifications

7.3. Temperature measurements

Proservo NMS8x and Micropilot NMR8x can display and transmit measured temperature data with Prothermo NMT539 or NMT532. Up to 16 points profile temperature and average calculation data can be used for the following purposes.

- Asset management and business optimization for volume and mass calculations
- Custody transfer conformity for temperature measurement, e.g. PTB
- Address the industry recommendation, API Chapter 7[7]
- Temperature critical product monitoring, e.g. LNG, asphalt, bitumen, crude oil, palm oil

8 Functional Safety

Overspill and dry run accidents are the worst thing which must be prevented. Proservo NMS8x and Micropilot NMR8x are approved for SIL (Safety Integrity Level) 2/3 complied with IEC 61508[8] to prevent those accidents. The approval is not for just a Proven-In-Use but for SIL-By-Design which means the quality is guaranteed from the development phase. Proservo NMS8x and Micropilot NMR8x can output both relays and 4-20 mA outputs as the following safety functions.

- Min. for dry run prevention
- Max. for overfill prevention according to API Recommendation Practice 2350[9]
- Range for continuous safety monitoring complied with NAMUR NE43[10]

Furthermore, the diverse technology installation is by far safer than just a dual installation of a single technology. That is because, one of two technologies should survive in case of one of them does not fit to an application. The combination of Proservo NMS8x and Micropilot NMR8x achieves the high Safety Integrity Level called SIL 3. These are the applicable level of safety.

- SIL 2 by single channel: Proservo NMS8x 1 unit or Micropilot NMR8x 1 unit
- SIL 3 by homogeneous redundancy: Proservo NMS8x 2 unit or Micropilot NMR8x 2 unit
- SIL 3 by diverse redundancy: Proservo NMS8x 1 unit and Micropilot NMR8x 1 unit

9 Condition monitoring

Proservo NMS8x and Micropilot NMR8x can be accessed from its display, CDI (Common Data Interface) with FieldCare (Endress+Hauser field device configuration and monitoring tool), system receivers and a host system to see measurement data and diagnostics. The information complied with NAMUR NE107[11] enables users to identify a significant change which is indicative of a fault. It helps users to take predictive actions against possible interruptions caused by tank operation or device failure.

10 Robust Design

Tank firms are often located in corrosive environment such as coastal areas. Aluminum housing surface may corrode or degrade due to the environment. Proservo NMS8x is available with not only process but also transmitter housings made of the material 316L shown in the Figure 8 and Micropilot NMR8x is following soon. The material 316L is the low carbon stainless steel and suitable to harsh installations. Also, it is preferred to alcohol applications such as breweries because of hygiene by rust prevention.

Figure 8: Proservo NMS8x all 316L housing

11 System compatibility and flexibility

Proservo NMS8x and Micropilot NMR8x can communicate with existing systems via various protocols, e.g. Modbus RS485, HART, V1. Especially, the redundancy communication capability helps users to upgrade or migrate the existing systems step by step without operation stop. Also, wireless communication is available with HART or Modbus adapter to save cabling and construction cost. Endress+Hauser also offers the system receivers Tankvision NXA82x and NXA8x to integrate measured data from field devices as the interface to the host system such as PLC and DCS, and visualization, volume and mass calculations are available by HMI (Human Machine Interface) and/or Web browser.

12 Conclusion

Proservo NMS8x and Micropilot NMR8x are the high accuracy level measurement devices used for both custody transfer and inventory control applications. Due to two different measuring technologies, users can choose the right measurement device depending on applications. Also, with the added value functionalities from safety functions to communication capabilities, users can operate tanks safely and profitably while envisioning the future system expansion plan.

References

[1]**OIML R85**
Automatic level gauges for measuring the level of liquid in stationary storage tanks
Part 1: Metrological and technical requirements
Part 2: Metrological control and tests

[2]**API Chapter 3.1B**
Standard Practice for Level Measurement of Liquid Hydrocarbons in Stationary Tanks by Automatic Tank Gauging

[3]**ISO 4266**
Petroleum and liquid petroleum products -- Measurement of level and temperature in storage tanks by automatic methods

[4]**NMi**
Netherlands Measurement Institute

[5]**PTB**
Physikalisch-Technische Bundesanstalt (National Metrology Institute of Germany)

[6]**LNE**
Laboratoire national de métrologie et d'essais (National Metrology and Testing Laboratory of France)

[7]**API Chapter 7**
Manual of Petroleum Measurement Standards
Chapter 7-Temperature Determination

[8]**IEC 61508**
Functional safety standard for electrical/electronic/programmable electronic safety-related systems

[9]**API Recommendation Practice 2350**
Overfill Protection for Storage Tanks in Petroleum Facilities

[10]**NAMUR NE43**
Standardization of the Signal Level for the Failure Information of Digital Transmitters

[11]**NAMUR NE107**
Self-Monitoring and Diagnosis of Field Devices

Contact

Endress+Hauser SE+Co. KG
Hauptstraße 1
79689 Maulburg
Germany

Tel +49 7622 28 0
Fax +49 7622 28 1438
info@pcm.endress.com
www.pcm.endress.com

WP01094F/00/EN/01.18

Endress+Hauser

People for Process Automation