Associazione Italiana Strumentisti

ISA Italy Section

GdS - Misure Fiscali

Milan, October, 25 2018

Auditorium TECNIMONT

Tank Gauging System Overview &
Tank Gauging Solution: Fiscal Metering in a Tank Farm

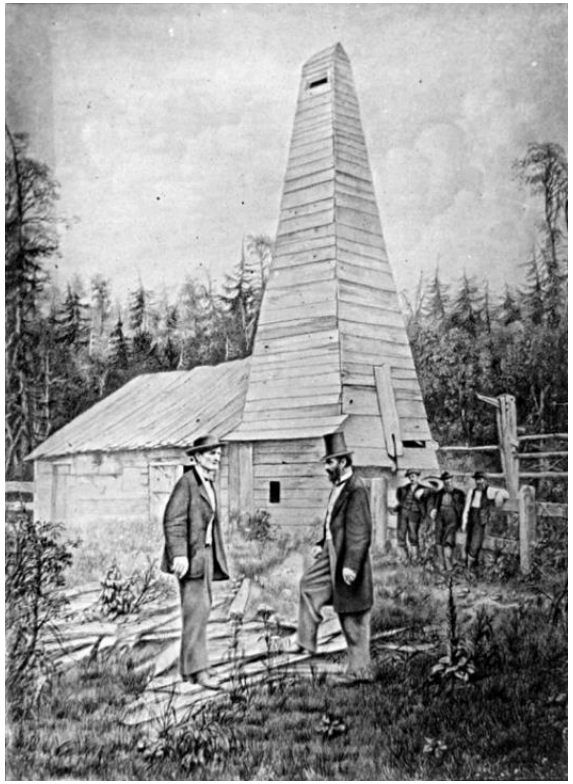
EMERSON

Endress+Hauser
People for Process Automation

Paolo Gaiti-Luca Romani

The Birth Of An Industry

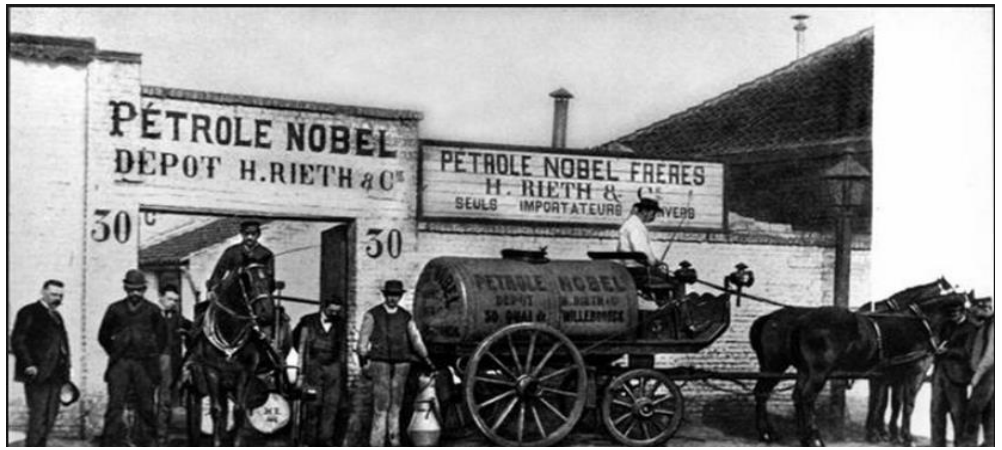
- Titusville, Pennsylvania 1859
- Colonel Drake drills the first commercial oil well
- But where to store all the oil?



The Birth Of An Industry

- **Storage tanks in Rijeka, Croatia in 1883**

- The 18th century saw a boom in the oil industry. The United States dominated the industry with its leading company, Standard Oil.
- Branobel lead by Ludvig Nobel challenged American domination and opened the first refinery in Baku. By sea, in 1877, he ordered the construction of the first oil tanker. And in 1878, it began its service to Branobel and had the capability to haul 750 tons of oil.



The Need for Storage Remains Today

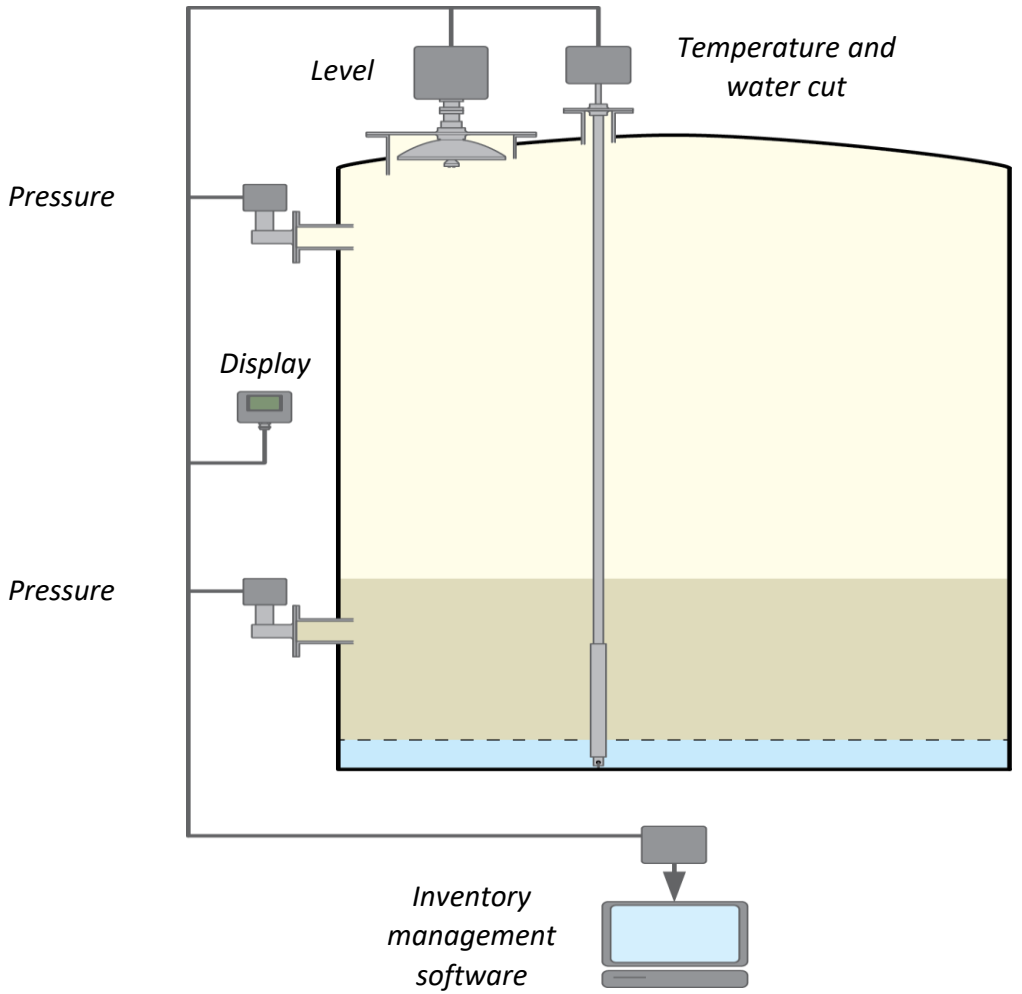
- **Globally:**
  - ~1000 tank terminals
  - ~700 refineries
  - 40,000+ airports
  - Tanks and caverns for strategic petroleum reserve
  - Many many smaller tanks for intermediate storage, reloading, buffering, etc.

What Is Tank Gauging?

- Tank Gauging = **static quantity measurement of liquid products in bulk storage tanks**
- Output is **volume** and **mass**
- **Automatic Tank Gauging (ATG)** collects measurements with automated instruments and sends the data back to control room

What Does A Tank Gauging System Measure?

- **Measured** data:
  - Level
  - Temperature (multi-spot average)
  - Bottom water level
  - Pressure
- ...is used to **calculate**:
  - Gross volume
  - Net volume (temperature compensated volume according to API standards)
  - Density
  - Mass
- Requires an **integrated system with many instruments** to collect all the measurements
- Requires **software** to automatically calculate volume, density and mass



Where Is Tank Gauging Used?

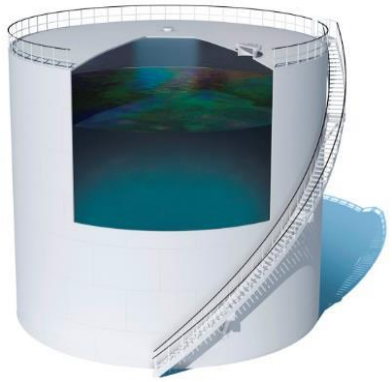
- Refineries
- Storage terminals
- Fuel depots
- Pipelines
- Airports
- LNG plants
- Petrochemical industry
- Chemical storage
- Etc.…

Anywhere with large storage tanks for liquid products!

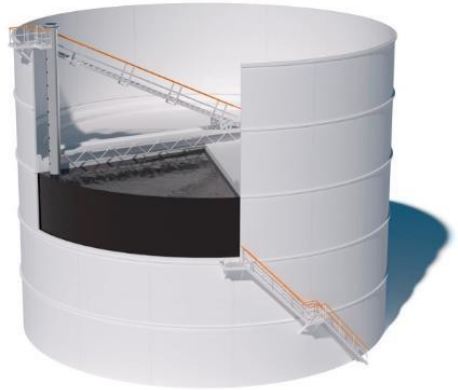
Tank Types

Atmospheric

Fixed roof tank



Floating roof tank



Pressurized

Bullet tank

Sphere tank

Fixed Roof Tank

- Flat or cone roof
  - No internal floating roof
- Bottom: flat, coned or sloping
- Sump on side or centered

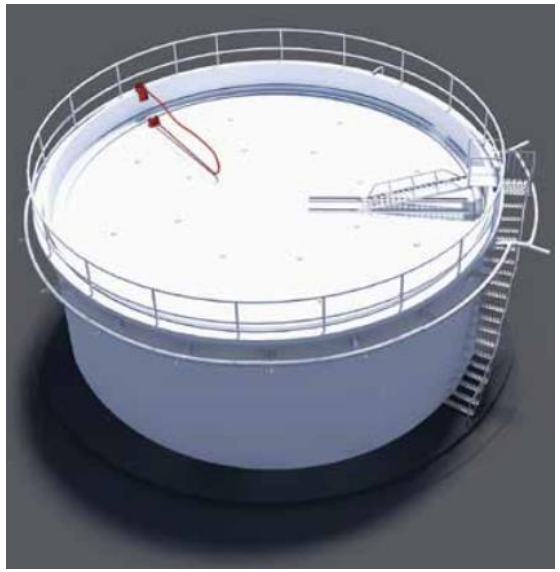
Cone roof tank

36” sump

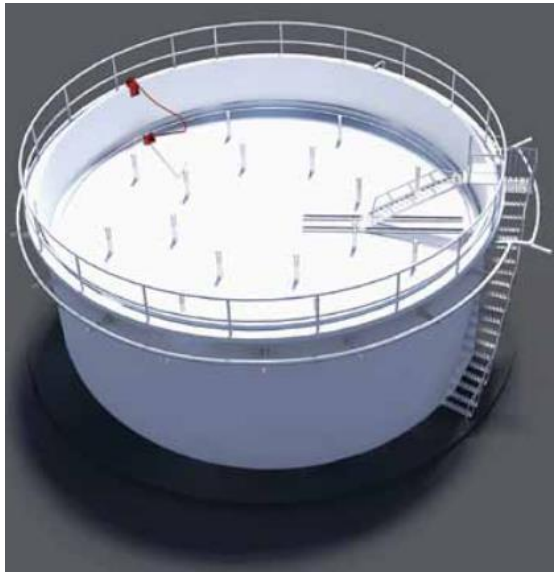
Multi-spot temperature water probe

Floating Roof Tank

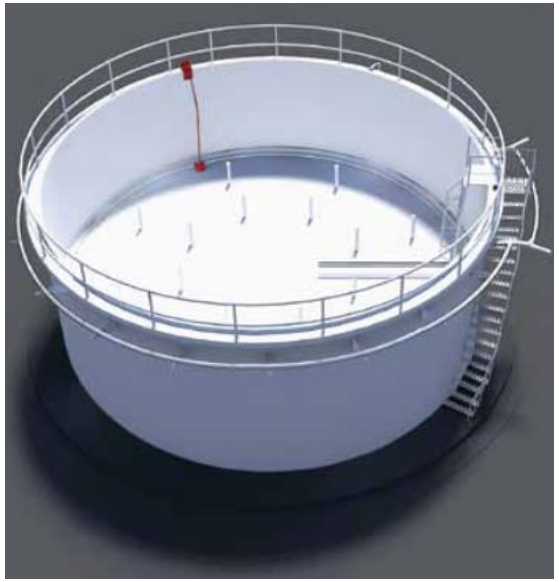
- Roof floats on top of the liquid and moves up and down with the liquid level
- No vapor space – reduces breathing losses
- Typically used for crude oil, gasoline, diesel, jet fuel, etc.



Full



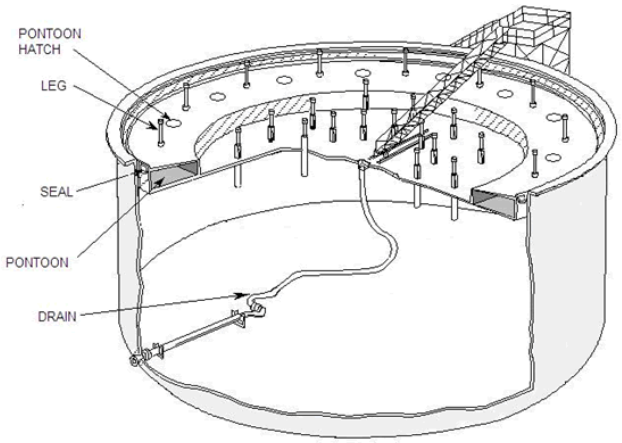
Half full



Empty

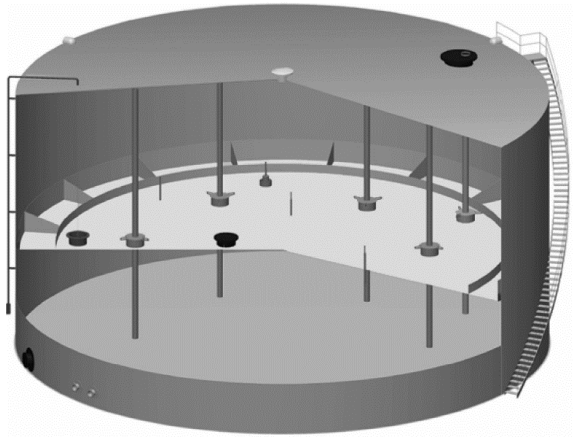
Floating Roof Tank Types

• External



- Exposed to wind, rain, snow etc.

• Internal (cone)



- Protected from weather conditions
- “Sealed” tank – not open to outside atmosphere
- Requires more equipment – breather valves, EPR valves, etc.

• Internal (dome)

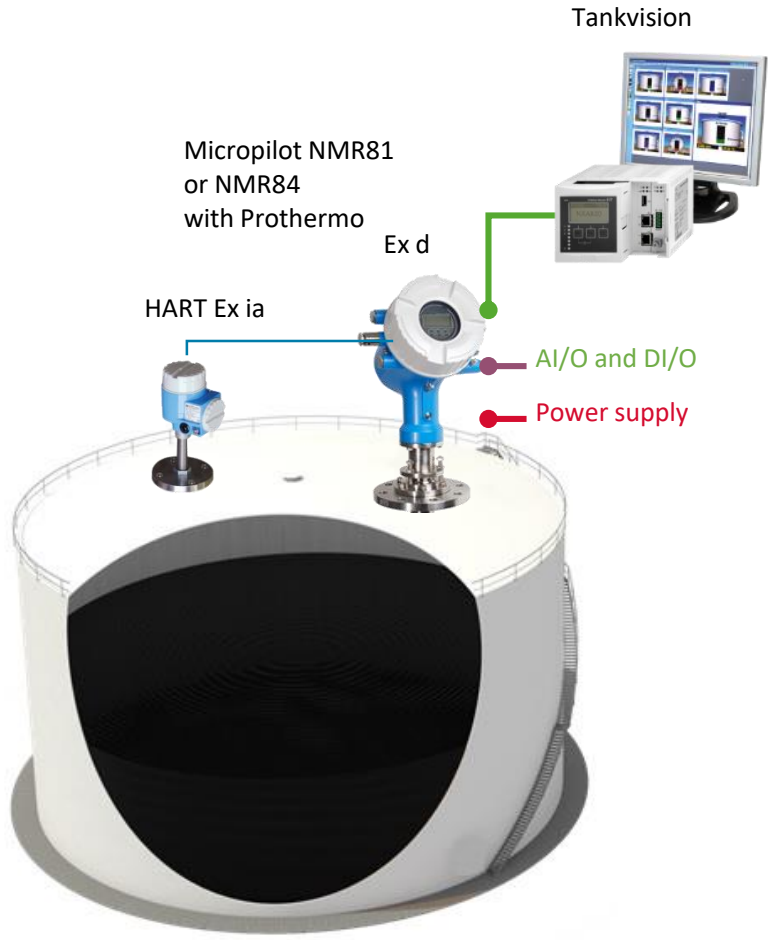
- Self-supporting aluminum dome
- Can be made as retrofit on existing external floating roof tank

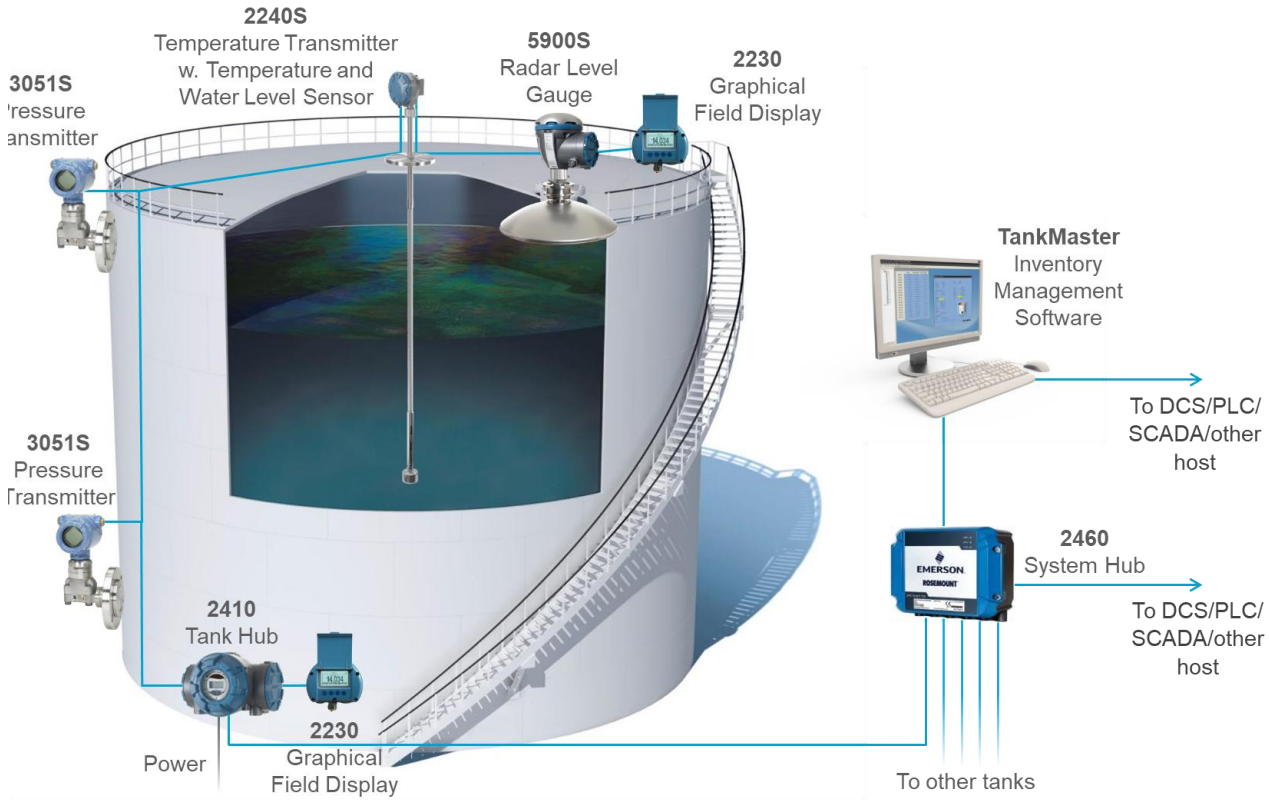
Pressurized Tanks

- Bullet

- Sphere

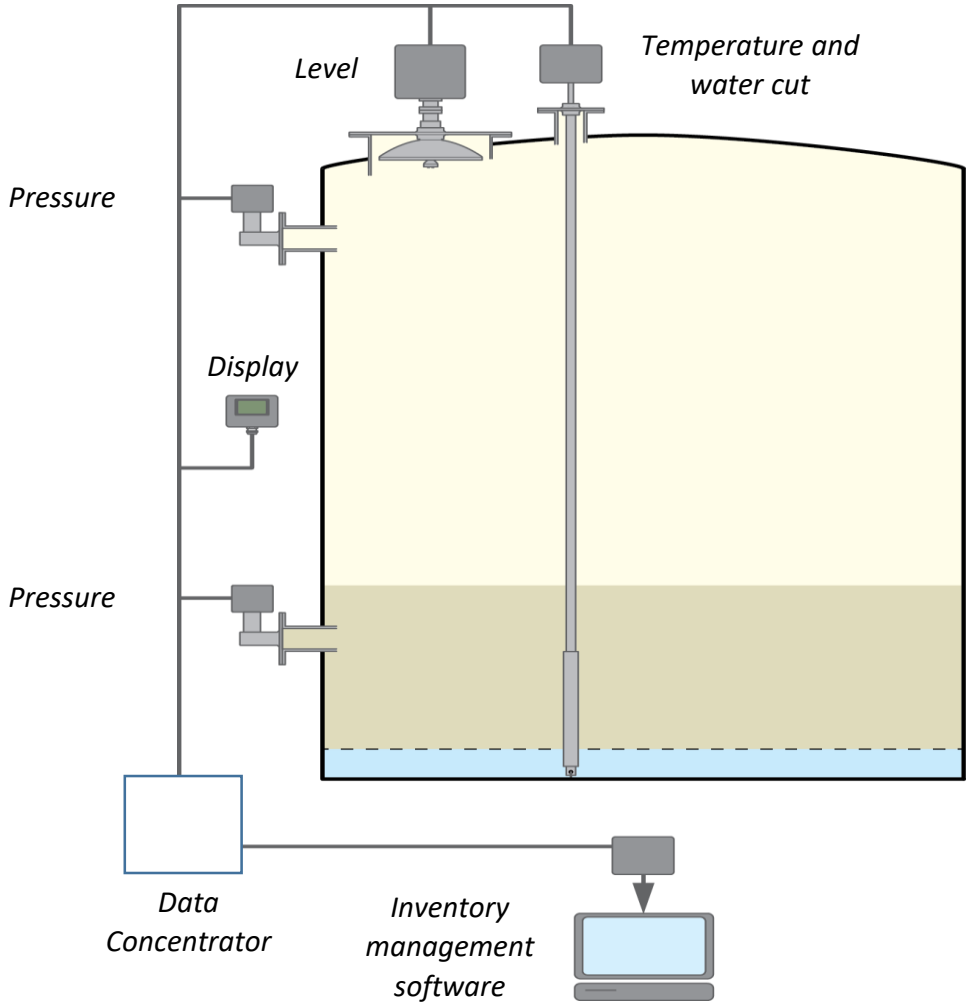
Instrument Overview





Core Tank Gauging Devices

1. Float, Radar or Servo Gauge
2. Temperature Multipoint & Water cut
3. Pressure Vapor
4. Pressure Liquid
5. Data concentrator
6. Inventory SW

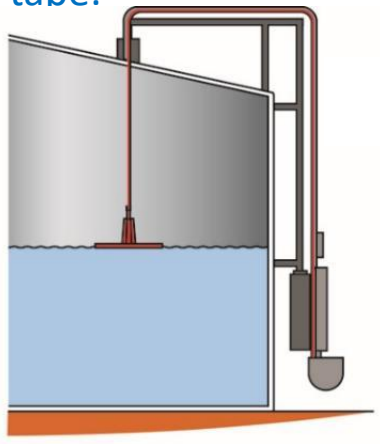


Most Common Tank Gauging Technologies

• Float and tape

A large float, suspended by a perforated steel tape, is kept taught by a constant torque spring motor.

Liquid level is measured by mechanically tracking the position of the tape.

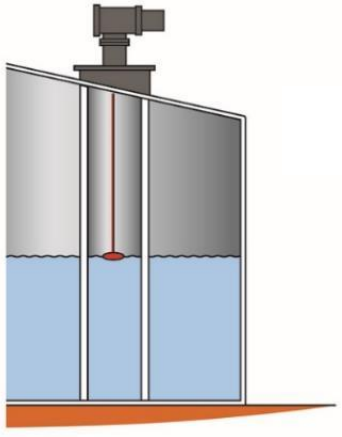


1940s

• Servo

A displacer, suspended by a wire, is raised and lowered by an electrical servo motor.

A weighing system continuously measures the weight of the displacer to determine liquid level.

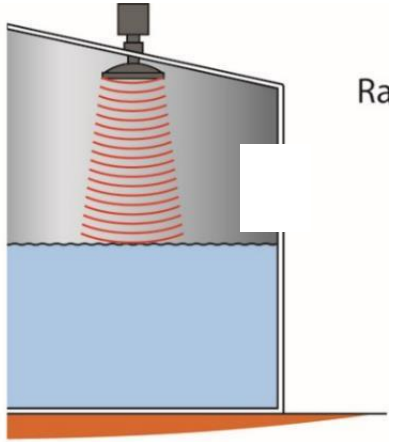


1960s

• Radar

The radar gauge uses microwaves for measuring the liquid surface level.

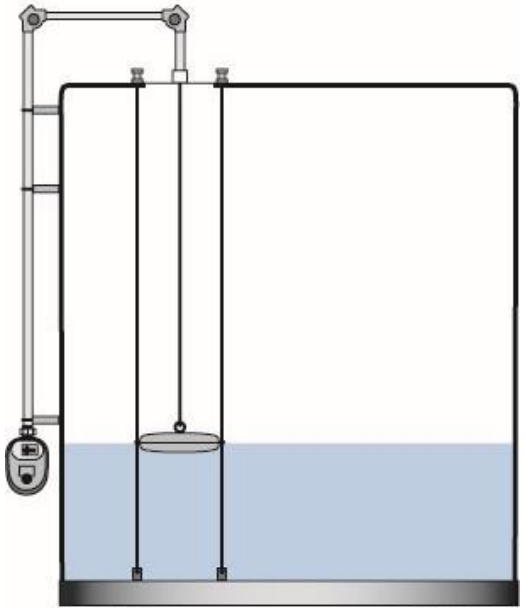
Radar gauges are electronic devices without moving parts and do not come into contact with the liquid.

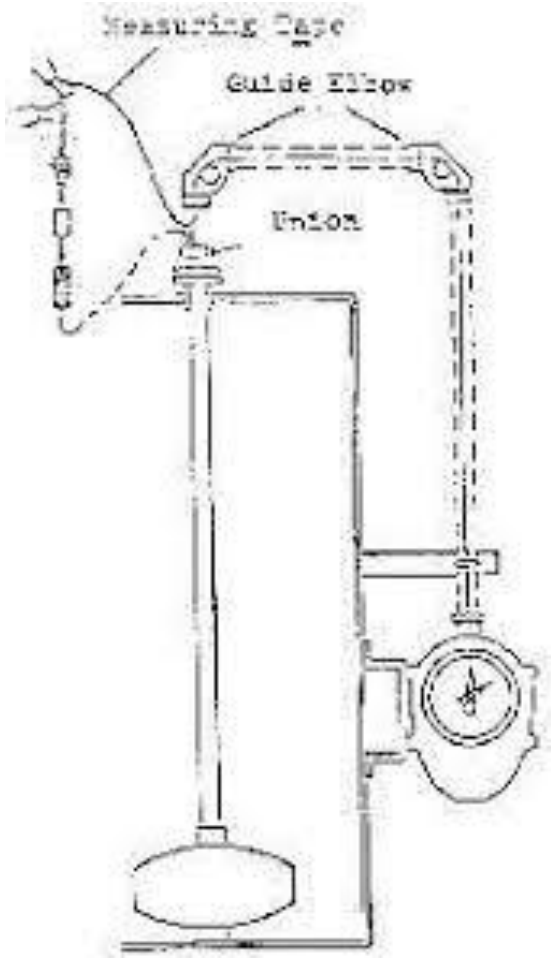


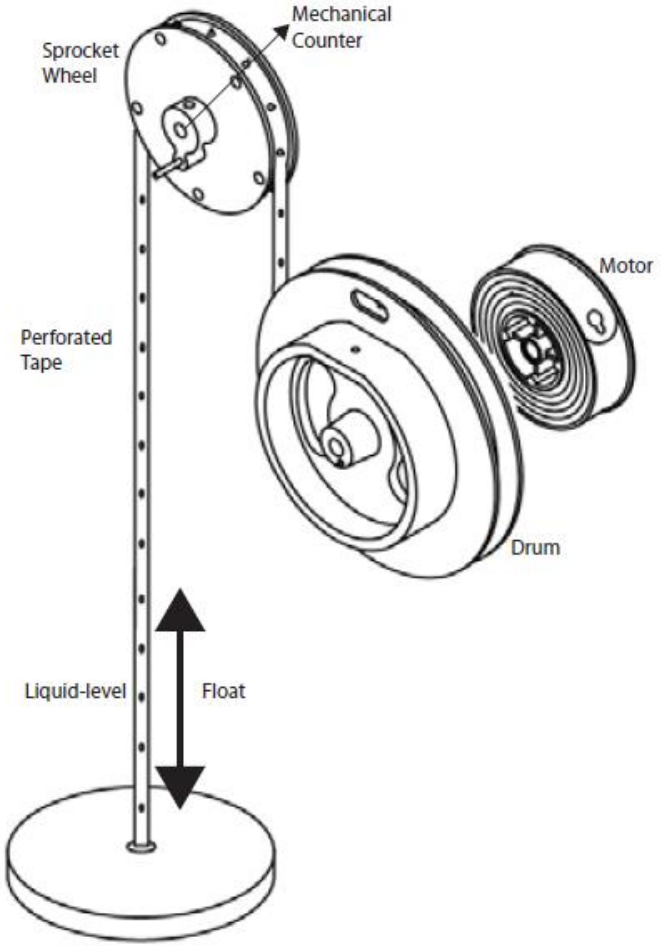
1980s

Float And Tape Technology

- First Automatic Tank Gauge (1940s)
- Large stainless steel float
- Float hangs by a metal tape
- Kept taught by spring motor
- Tape drives mechanical counter

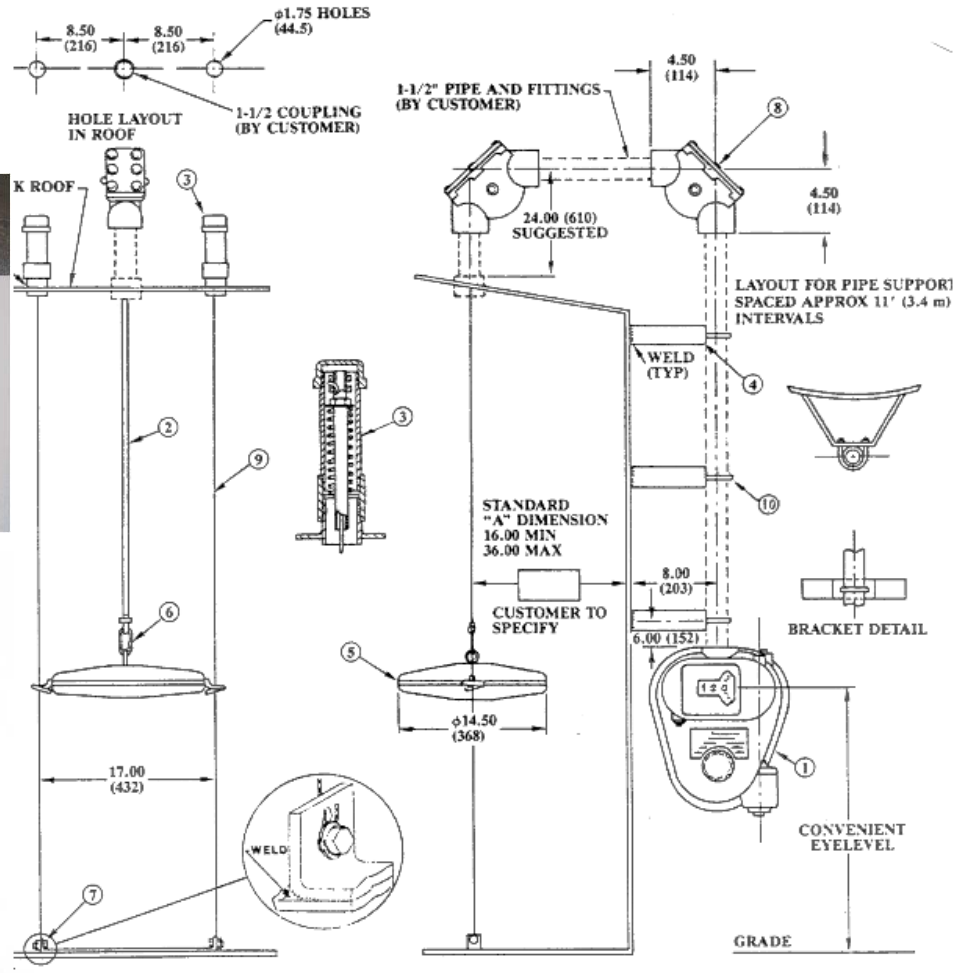






“Simple” Mechanical Device

- Float follows level due to tension in spring motor
- Tape drives mechanical counter with local readout
- Remote indication possible via electronic transmitter
- Guide wires inside tank
- Does not require power
- Accuracy ~10-25 mm (0.5”-1”)
- Many moving parts
- Maintenance
- No error indications or diagnostics
  - Float or tape gets stuck
  - Guide wires loose, kinked, or broken
- Unreliable and error-prone
- **Still** often used



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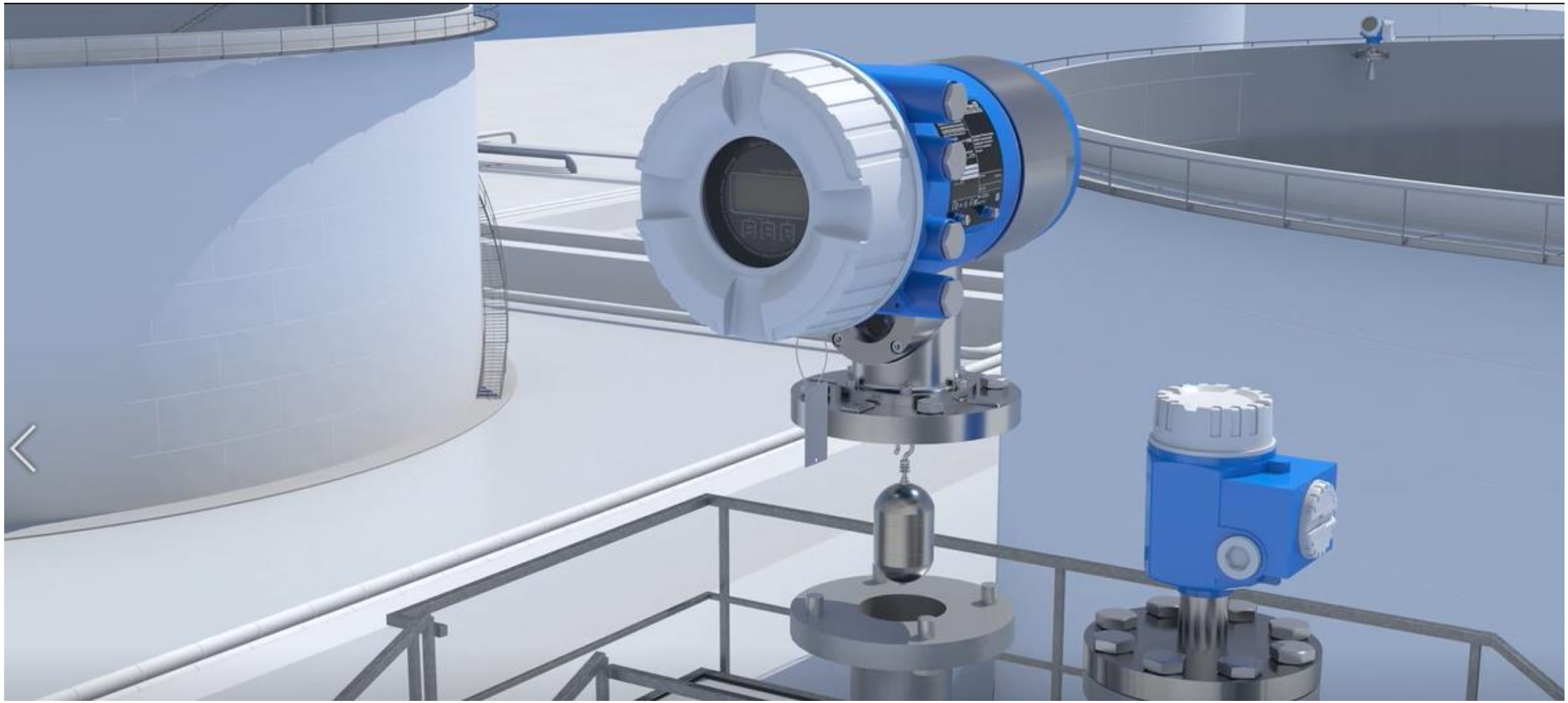
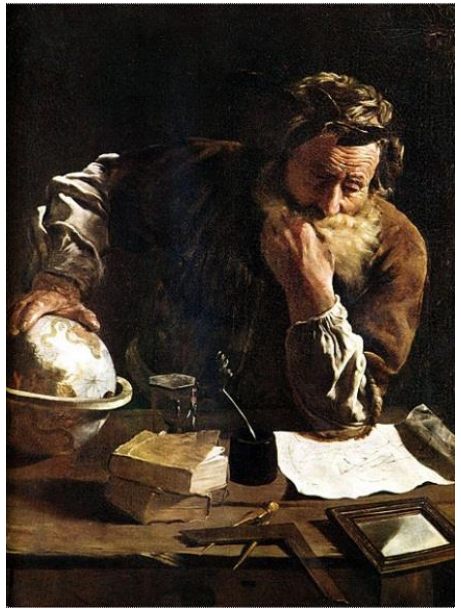
Servo displacer gauges

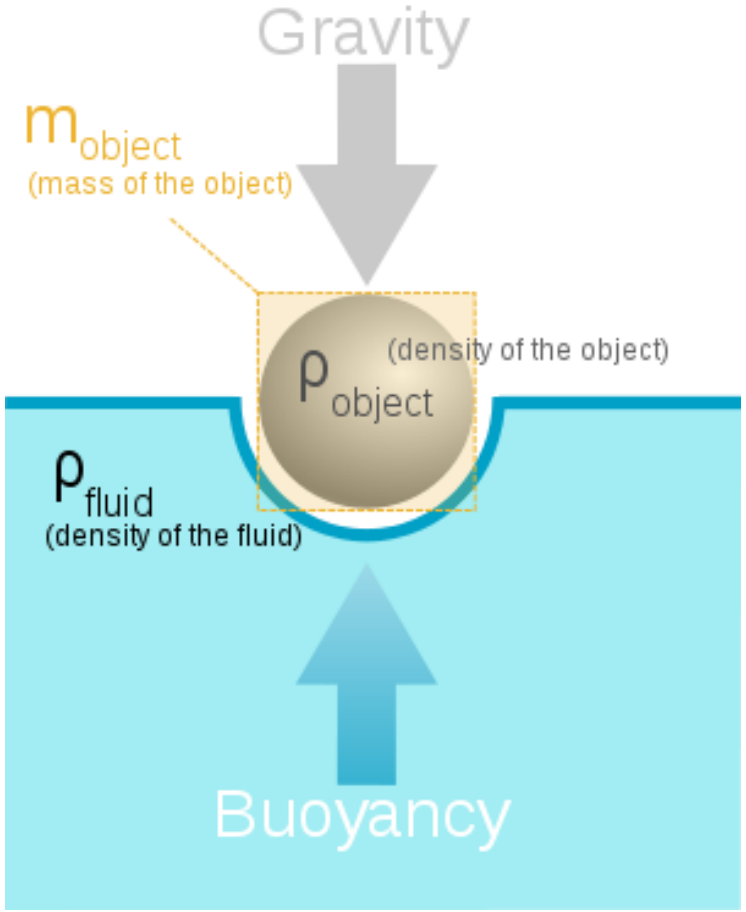


The physical principle

- In physics, buoyancy is a force exerted by a liquid, gas or other fluid, that opposes an object's weight
- Buoyancy = weight of displaced fluid.

Any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object.
Archimedes of Syracuse



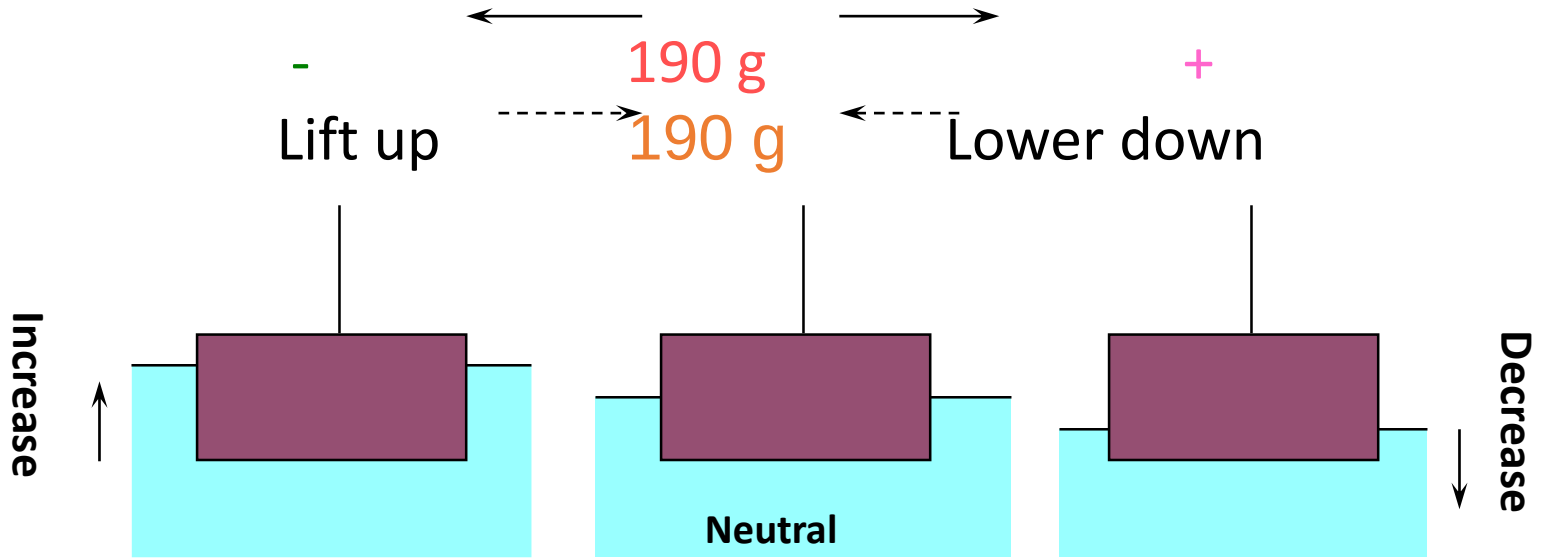


The forces at work in buoyancy

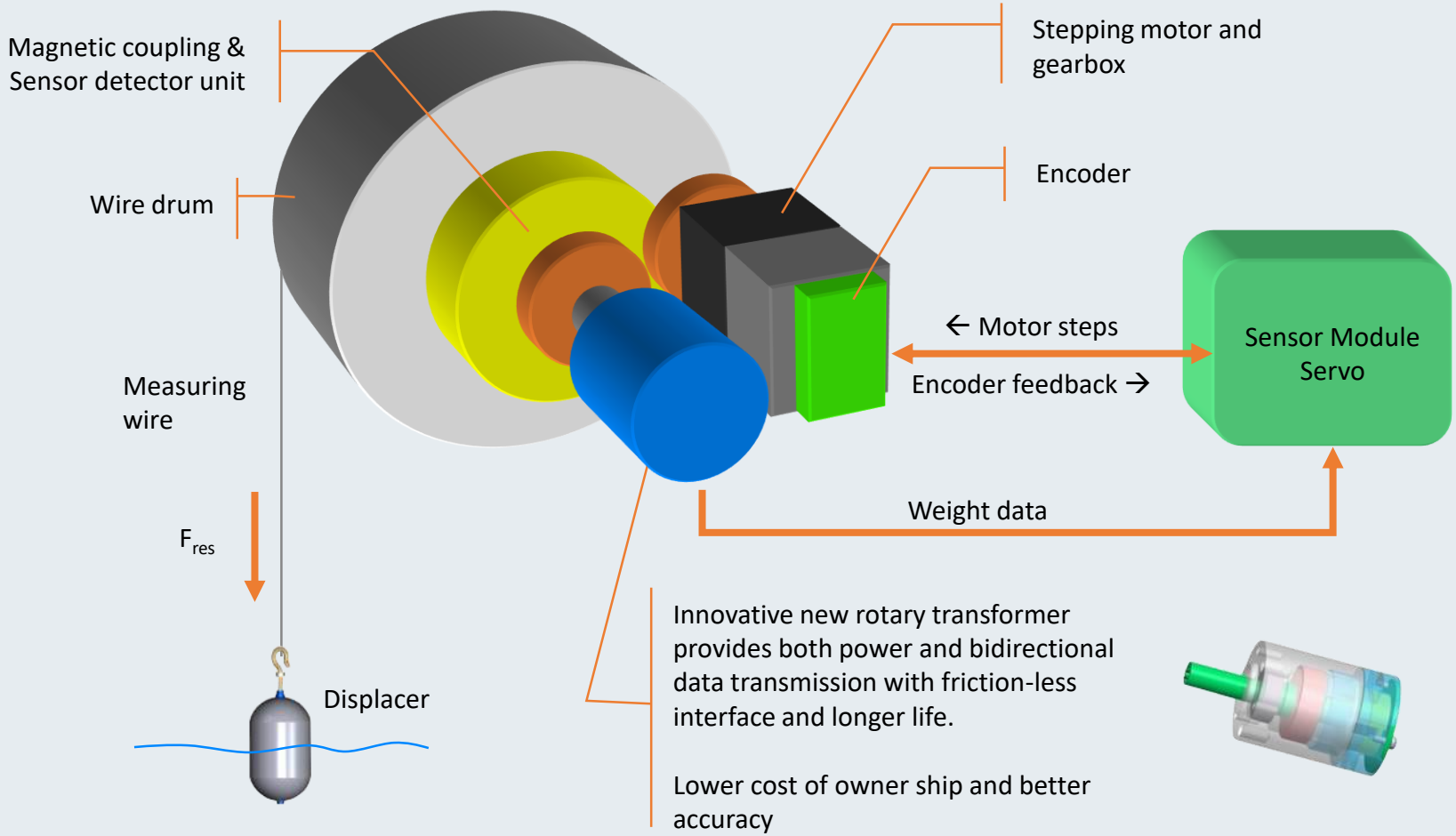
Working Principle: Buoyancy

- Work depends on the Archimedes Principle

- Typical values for Proservo:
  Measuring wire tension maintained at about 190 g

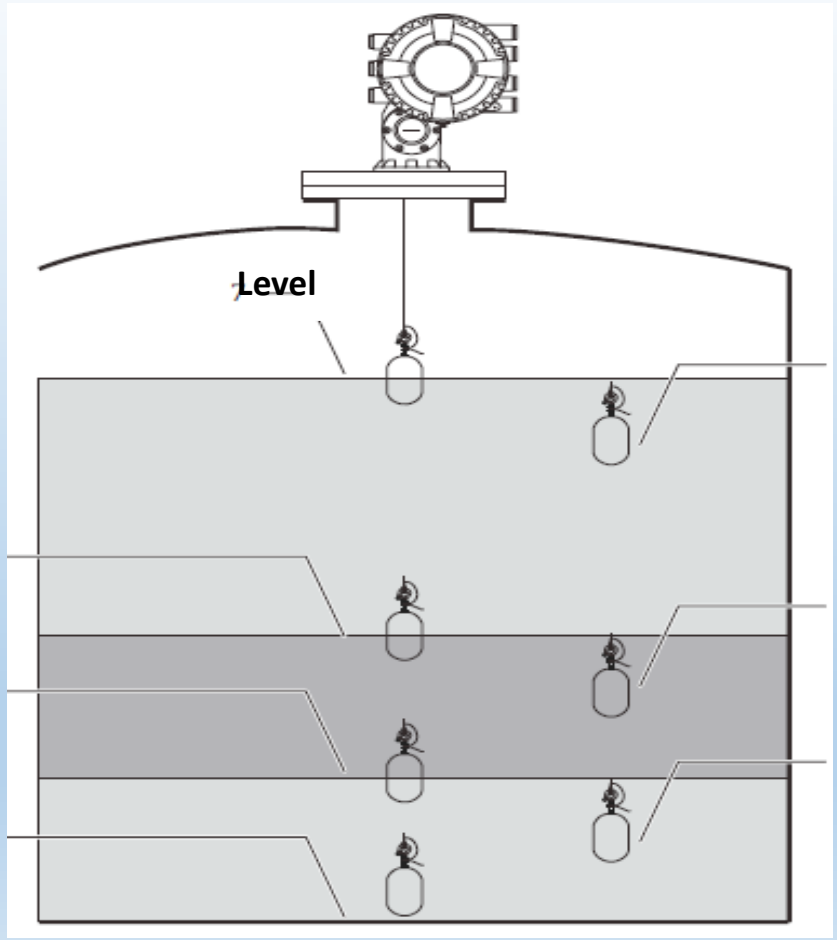


Physical principle



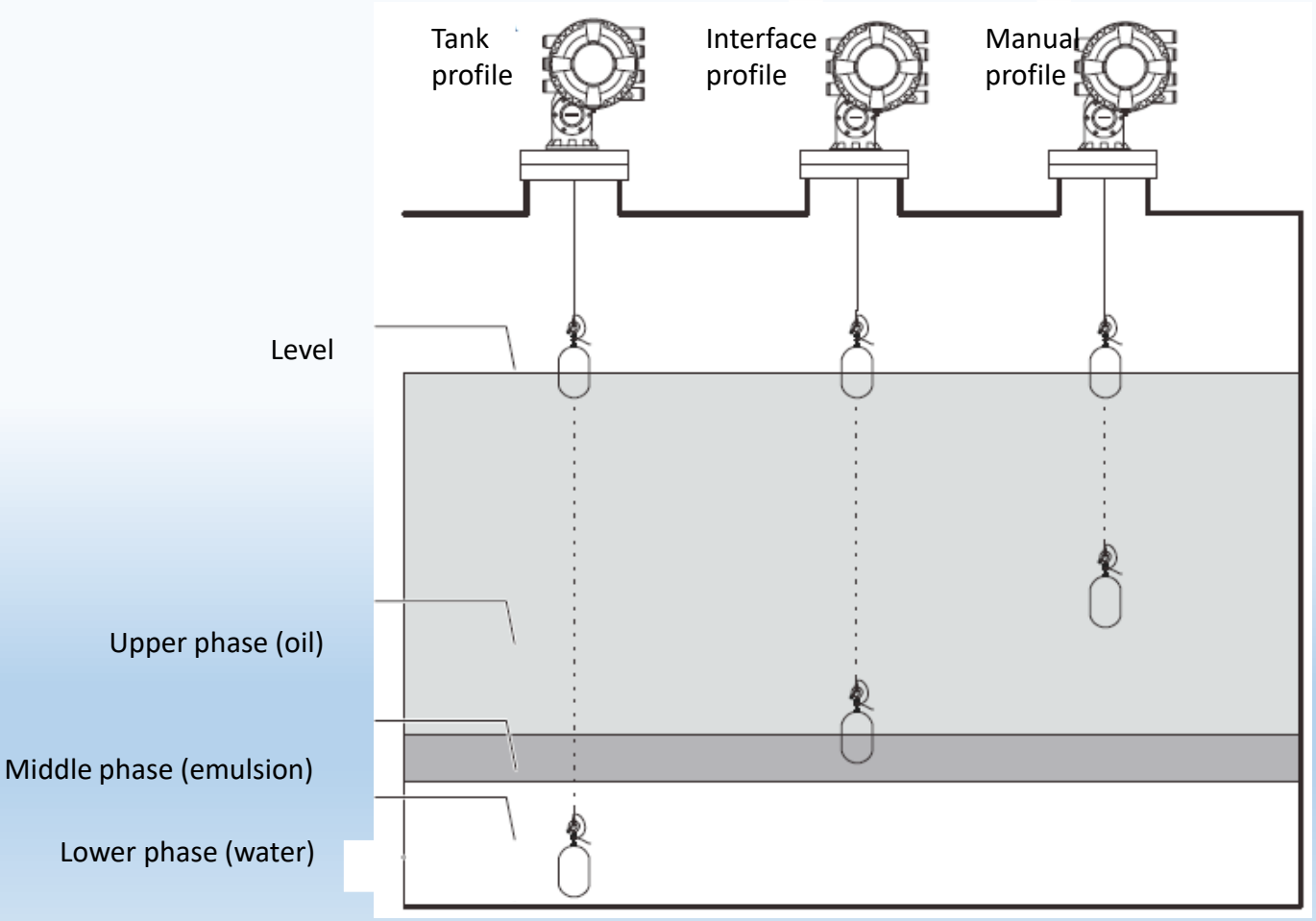
Multiple measurement by single device

- **Level**
- **Interface**
  - Upper interface
  - Lower interface
- **Density**
  - Upper density
  - Middle density
  - Lower density
- **Tank bottom**



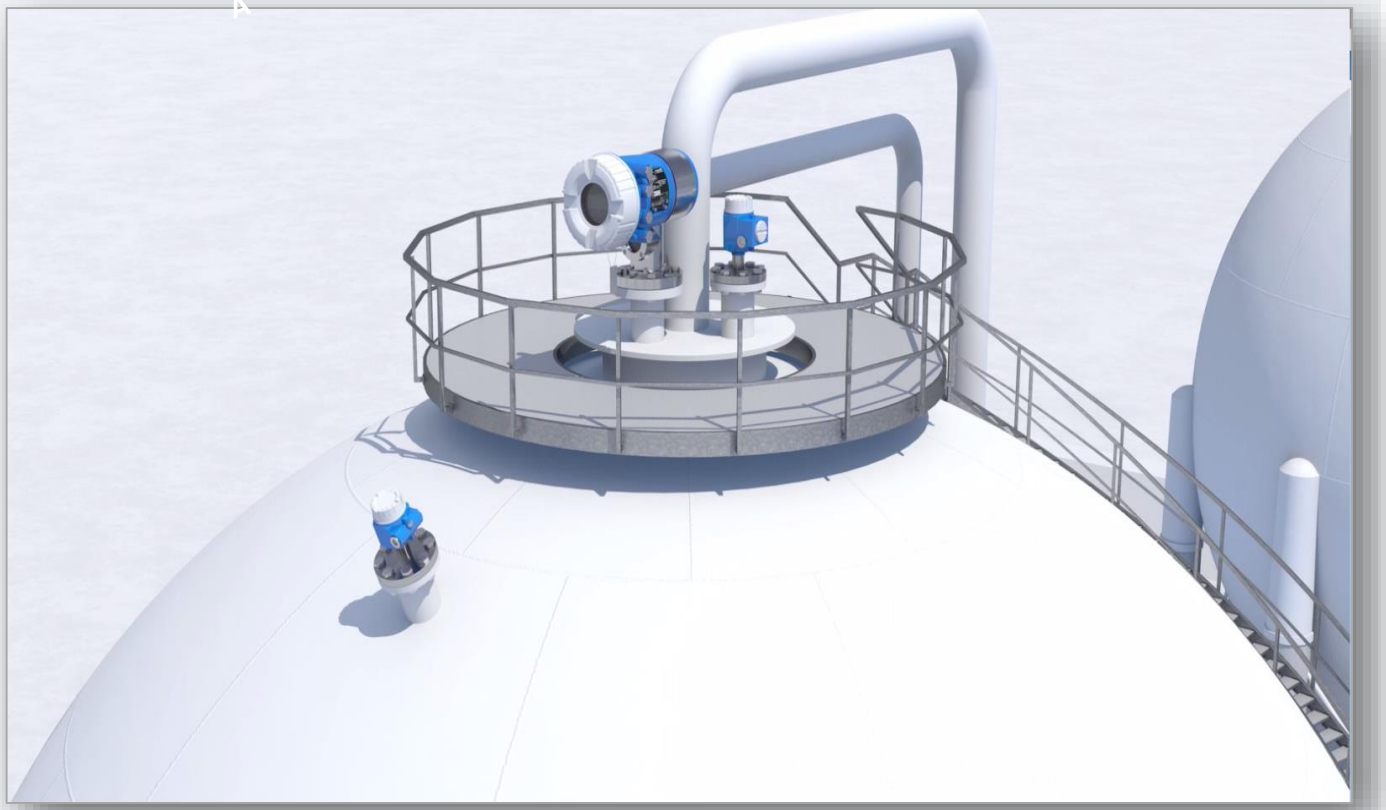
Multiple measurement by single device

- **Density profile up to 50 points**
  - Tank profile
  - Interface profile
  - Manual profile



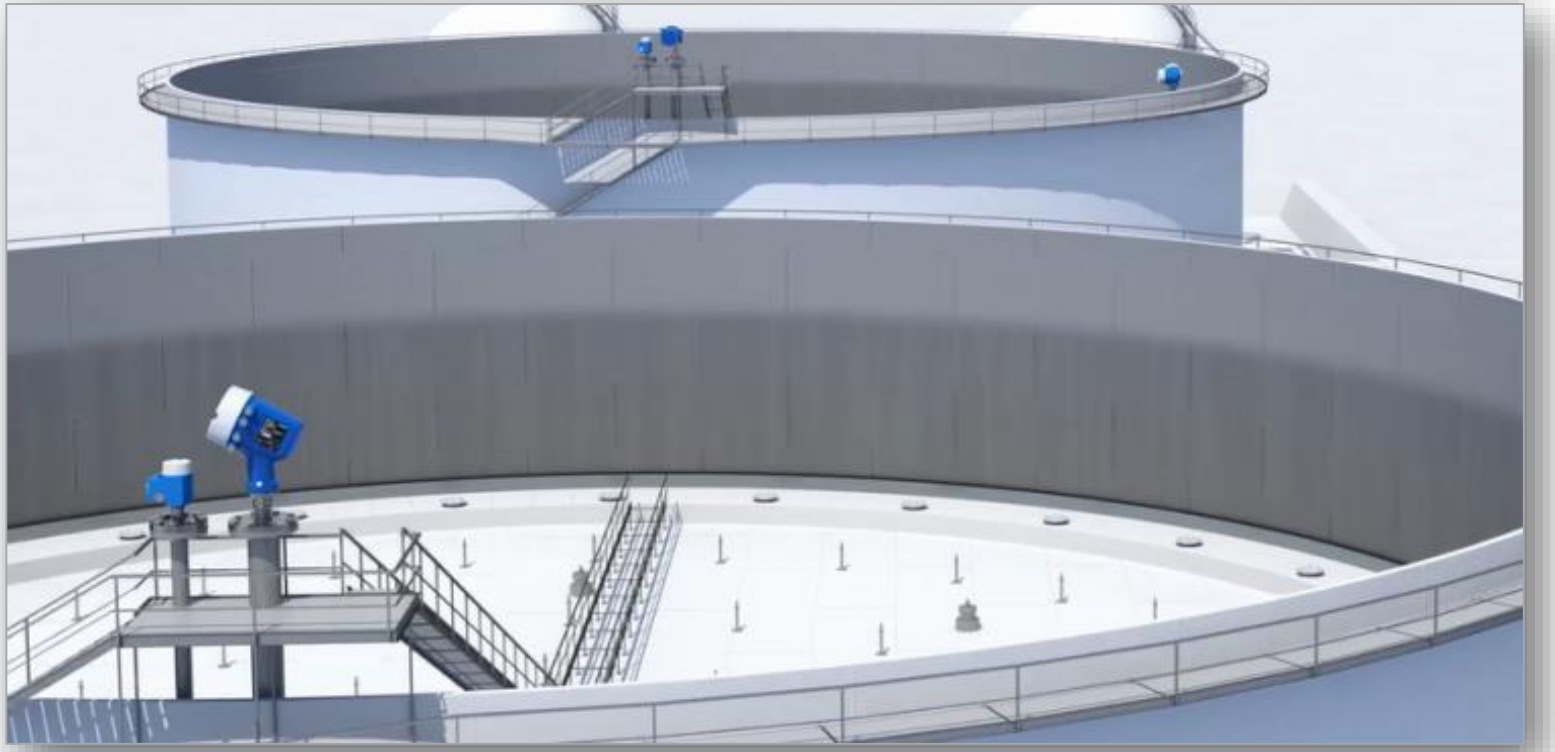
Typical servo installations: spheres LPG/LNG - Ammonia

- No issues with stilling wells
- P up to 25 bar,
- T 200…+200° C
- No gas pressure compensation needed.
- Measuring range up to 47m.
- Atex Ex d(ia)
- W&M certificates up to 40m.



Typical servo installations: floating roofs, stilling wells

- No issues with stilling wells
- P up to 6 bar,
- Measuring range up to 47m.
- Atex Ex d(ia)
- W&M certificates up to 36 m.



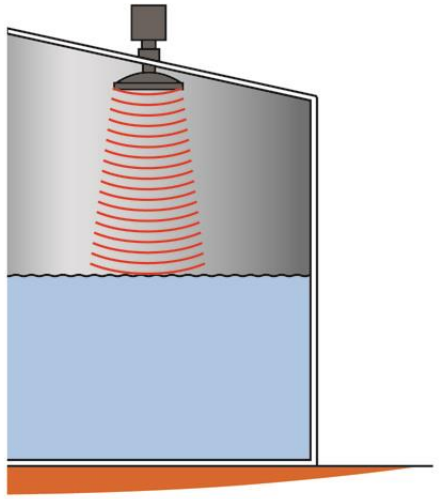
Pros and cons Servo gauges

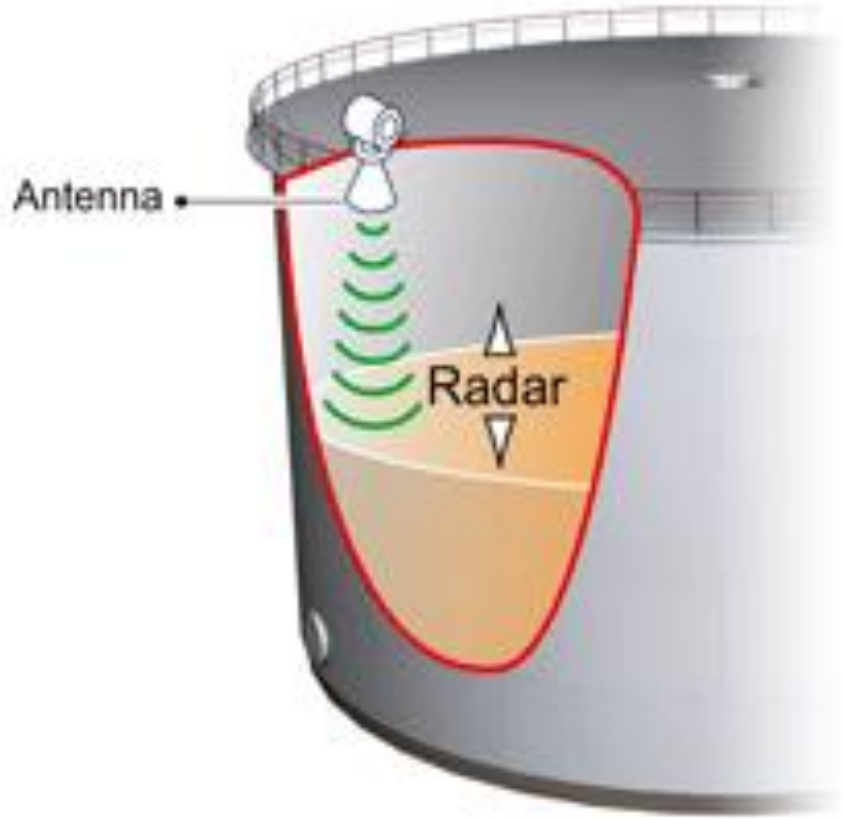
• Highest accuracy • Multiparameter measurements • Not influenced by stilling wells • Not influenced by gas phase • Easier calibration • Easier achievement of requested accuracy • Ideal with liquid gasses LPG, LNG	• Mechanical movements • Wear and tear • Maintenance needed • Not suitable with highly viscous fluids • No free space installation -> stilling well • Displacer weight subject to build-up • Slightly higher price than radars

Radar tank Gauging

Radar Tank Gauging

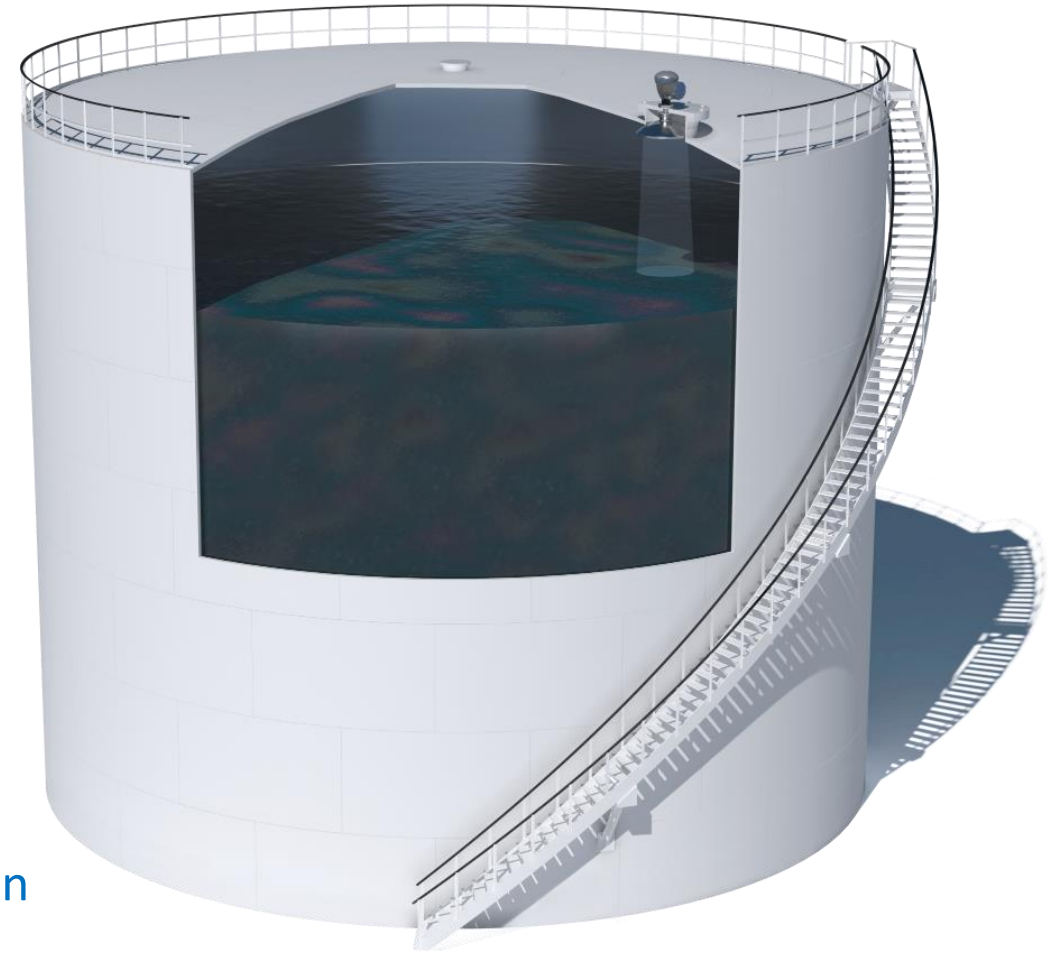
- Third generation ATG
- First developed for ocean tankers in the 70s
- Introduced to land tanks in 1980s
- Invented, developed and pioneered by SAAB in 1977
- Now is the most popular in ATG application





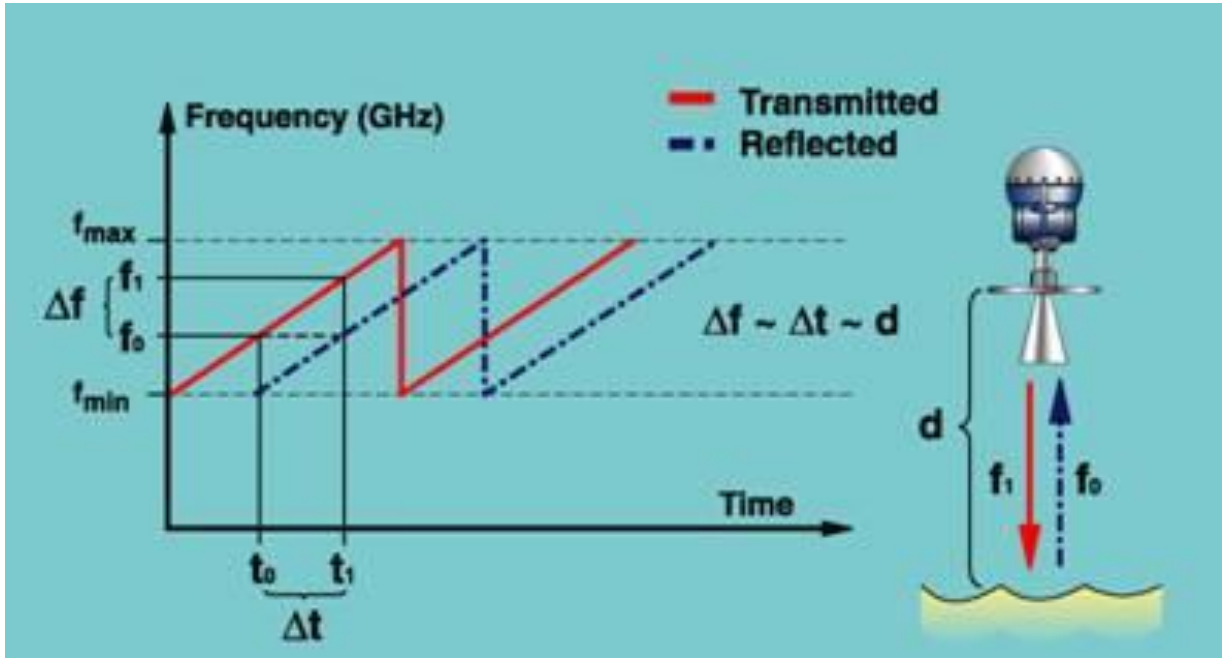
Radar: Fully Electronic Measurement

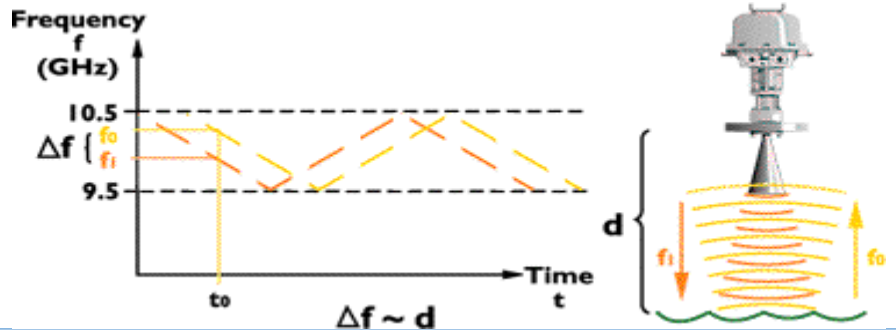
- Measures distance to liquid surface with microwaves
- Three main technologies on the market:
  - High Frequency radar 80GHz (FMCW)
  - Medium Frequency 26GHz (Pulse)
  - Low Frequency 10GHz (FMCW)
- Transmitter head
  - Contains all electronics
  - Mounted outside the tank
  - No contact parts with fluid
- Antenna
  - Emits and receives microwaves
  - Mounted inside the tank
  - The antenna selection depends on the installation condition



Radar Tank Gauging FMCW

- Measures difference in frequency between transmitted and reflected signals
- To differentiate between the two signals, the transmitted signal constantly changes frequency
- The frequency difference between returned and transmitted signal is proportional to distance
- Not a time of flight technique like pulse and impossible to create mis-registration errors

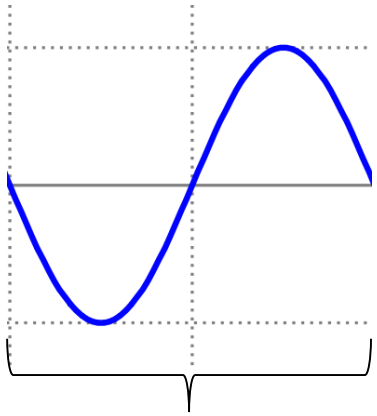




Radar Physics

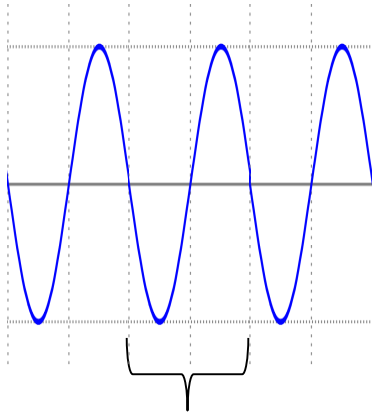
- The fundamental physical difference between different frequencies is the wavelength
- Frequency (f) is inversely proportional to wavelength (λ) (higher frequency = shorter wavelength)
- Wavelength has direct effect on a number of important properties of the radar signal
  - Sensitivity to disturbances
  - Measurement robustness in difficult conditions
  - Antenna size and beam angle

10 GHz



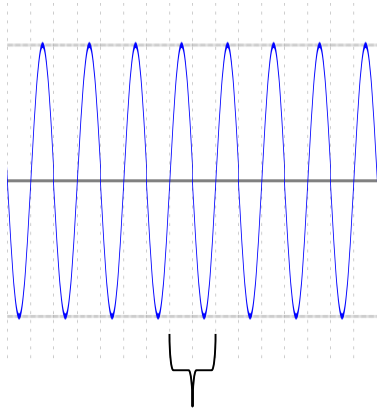
Wavelength λ = 3 cm

26 GHz

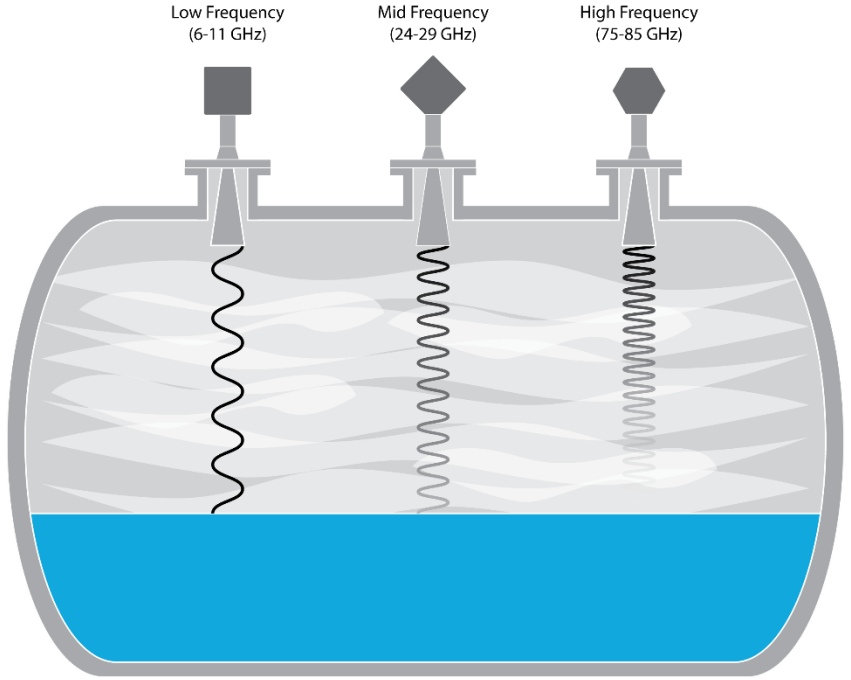


Wavelength λ = 1 cm

80 GHz

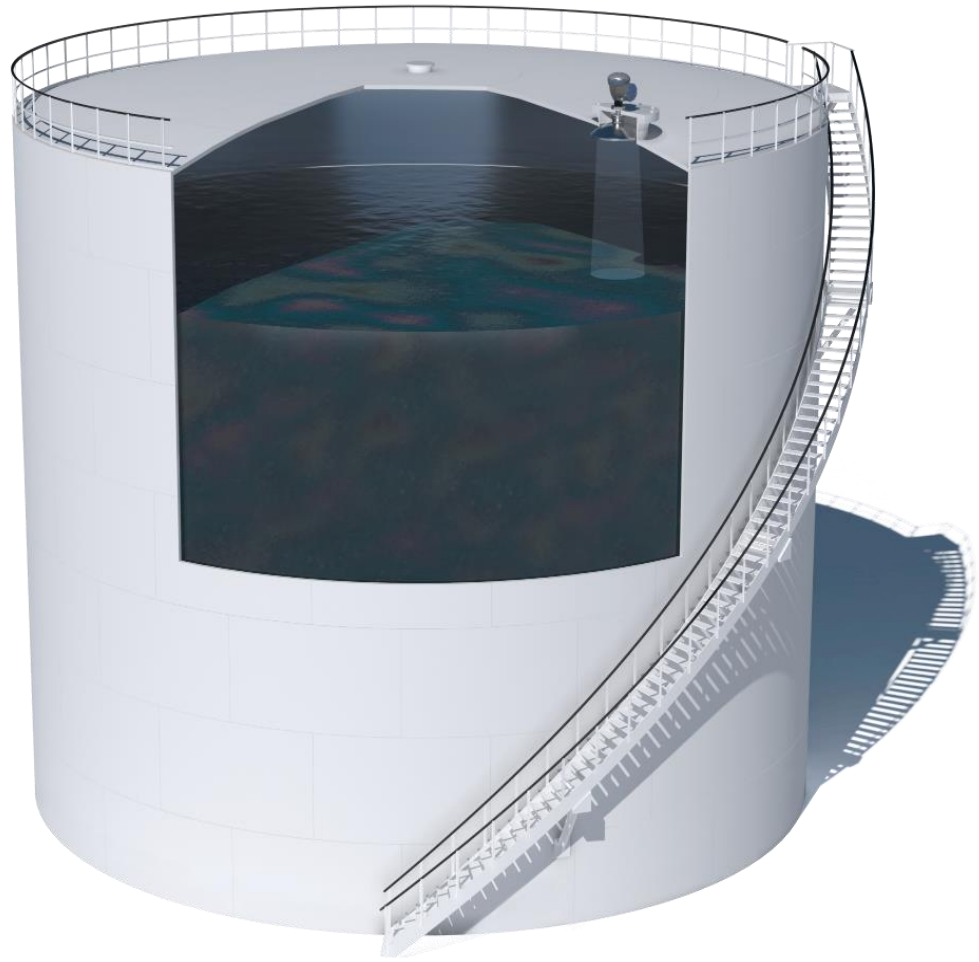


Wavelength λ = 0,38 cm



Modern And Trouble-Free

- Non-contact measurement
- No moving parts
- Virtually maintenance-free
- Long MTBF (>100 years)
- Long product life (>30 years)



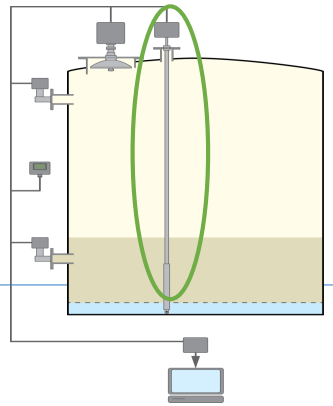
Temperature Measurement

Temperature Transmitter

- Multipoint temperature sensor
- ±0.05° C conversion accuracy

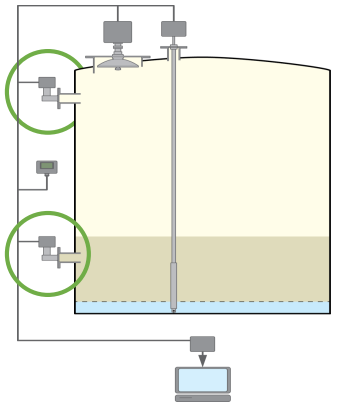
Multiple Spot Temperature Sensor

- Flexible hose with temperature spots encased inside
- Measures temperature at multiple points in the tank
- Up to 16 temperature measurement points
- 3- or 4-wire RTD spot elements /Termocouples or CU90
- With integrated bottom water level capacitive sensor
- For cryogenic liquids down to -170° C (566 version)
- 1/6 DIN Class B, 1/10 DIN Class B, and DIN Class A (566 version) accuracy classed offered



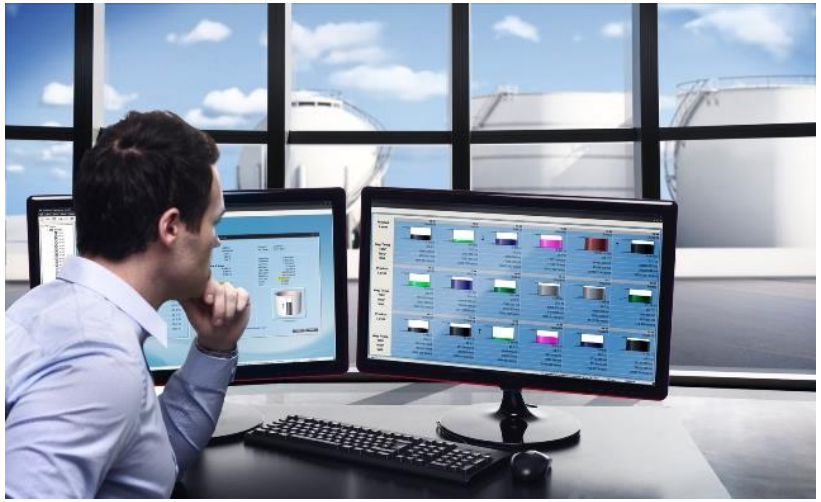
Pressure Transmitter

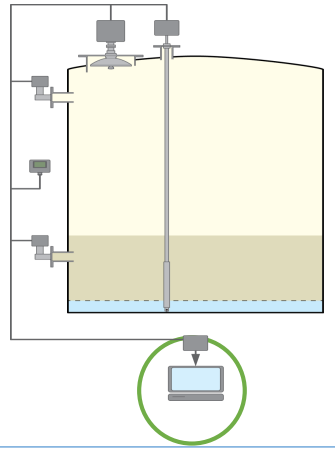
- Used in general for density
- High accuracy
- Application Hydrostatic Pressure or Vapor Space pressure
- Used for online Density Measurement



Inventory Software

- Complete inventory management software
- Collects all tank gauging data such as level, temperature, water interface, etc.
- Calculates volume and mass
- Displays it in easy to use operator interface
- Includes advanced functions for better terminal reliability, efficiency and safety
  - Alarms
  - Reports
  - Batch handling
  - Custody transfer approvals
  - And much more...
- Integrates into all major DCS/SCADA/host systems
- Web version for external access
- Developed according to API standard

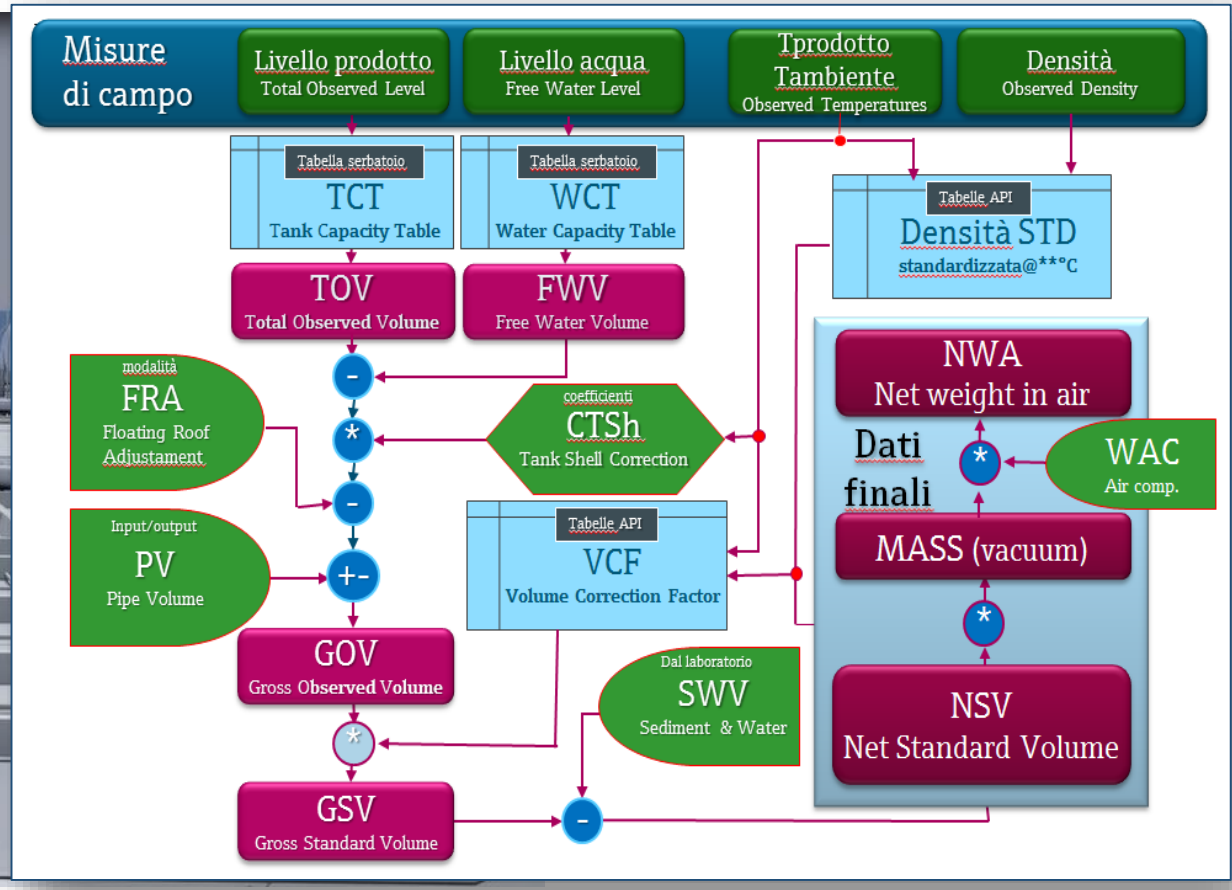




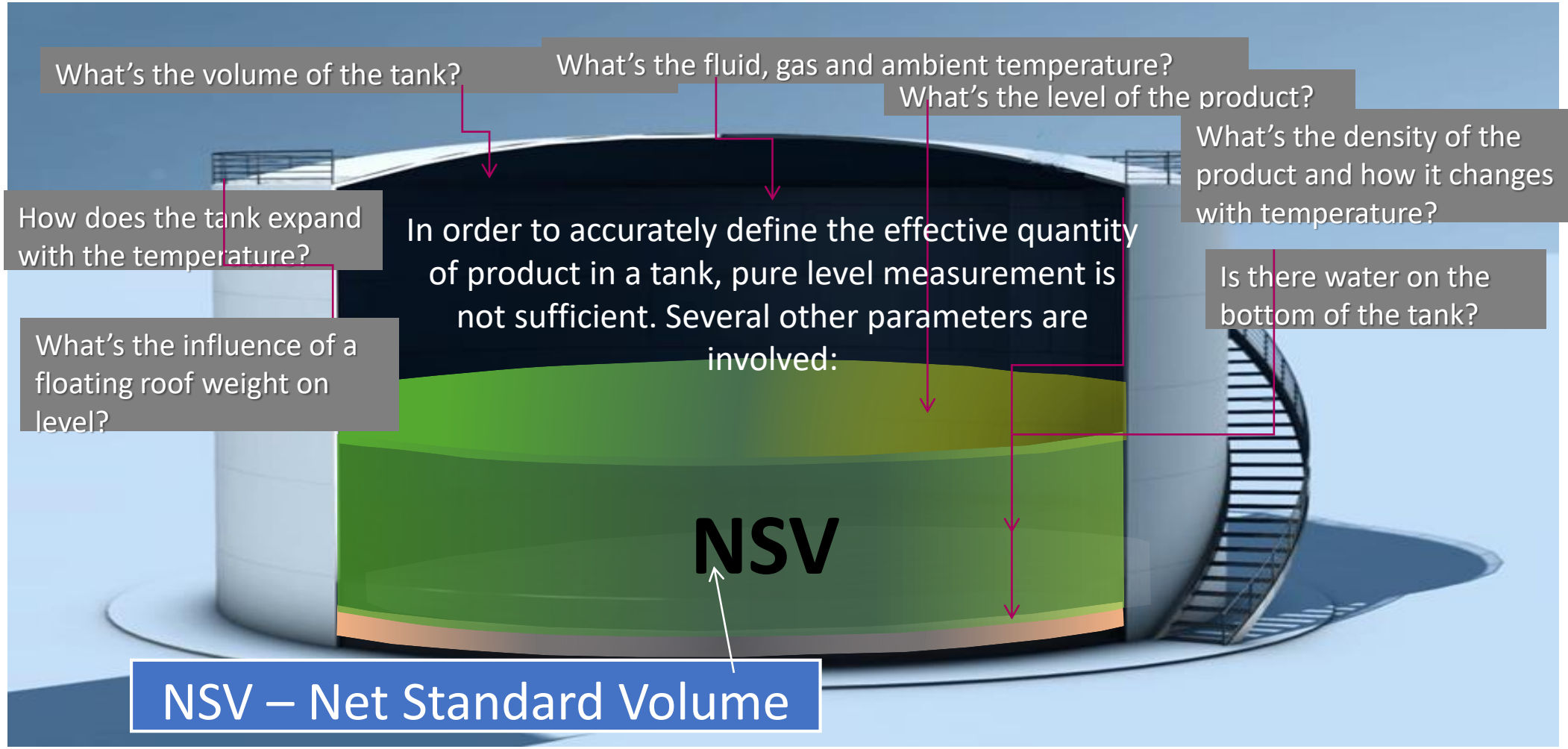
Tank Gauging – Main Use Cases

- Oil movement and operations
- Inventory control
- Overfill prevention
- Custody transfer
- Tank monitoring
- Mass balance & loss control
- Leak detection

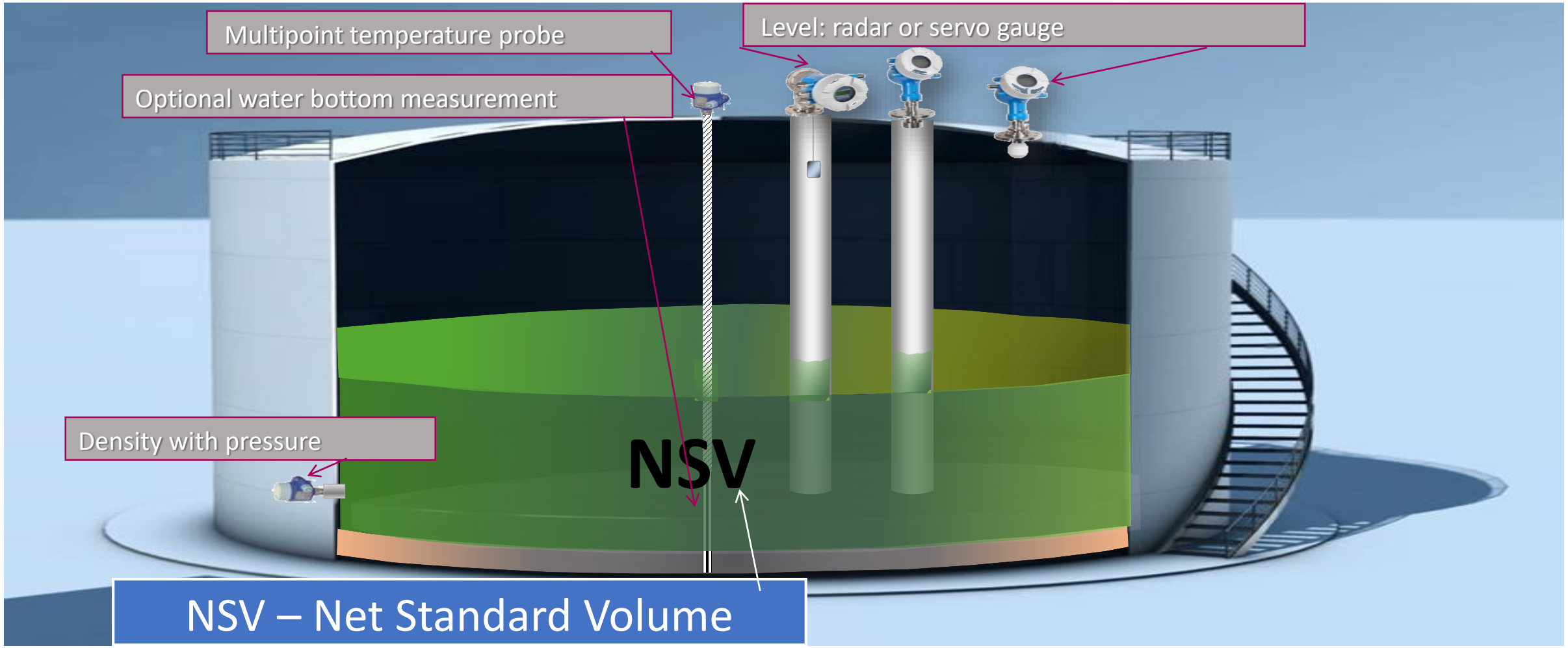
Measured and calculated values



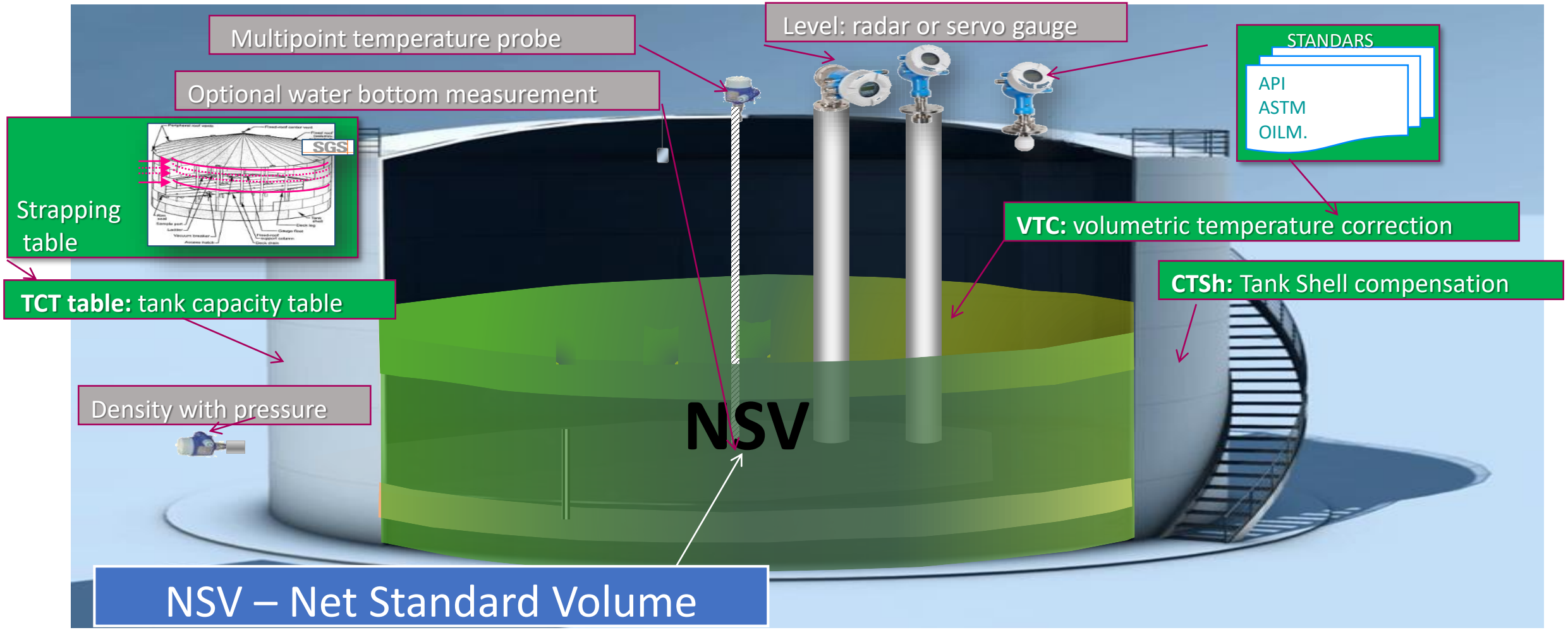
Requested result and parameters involved



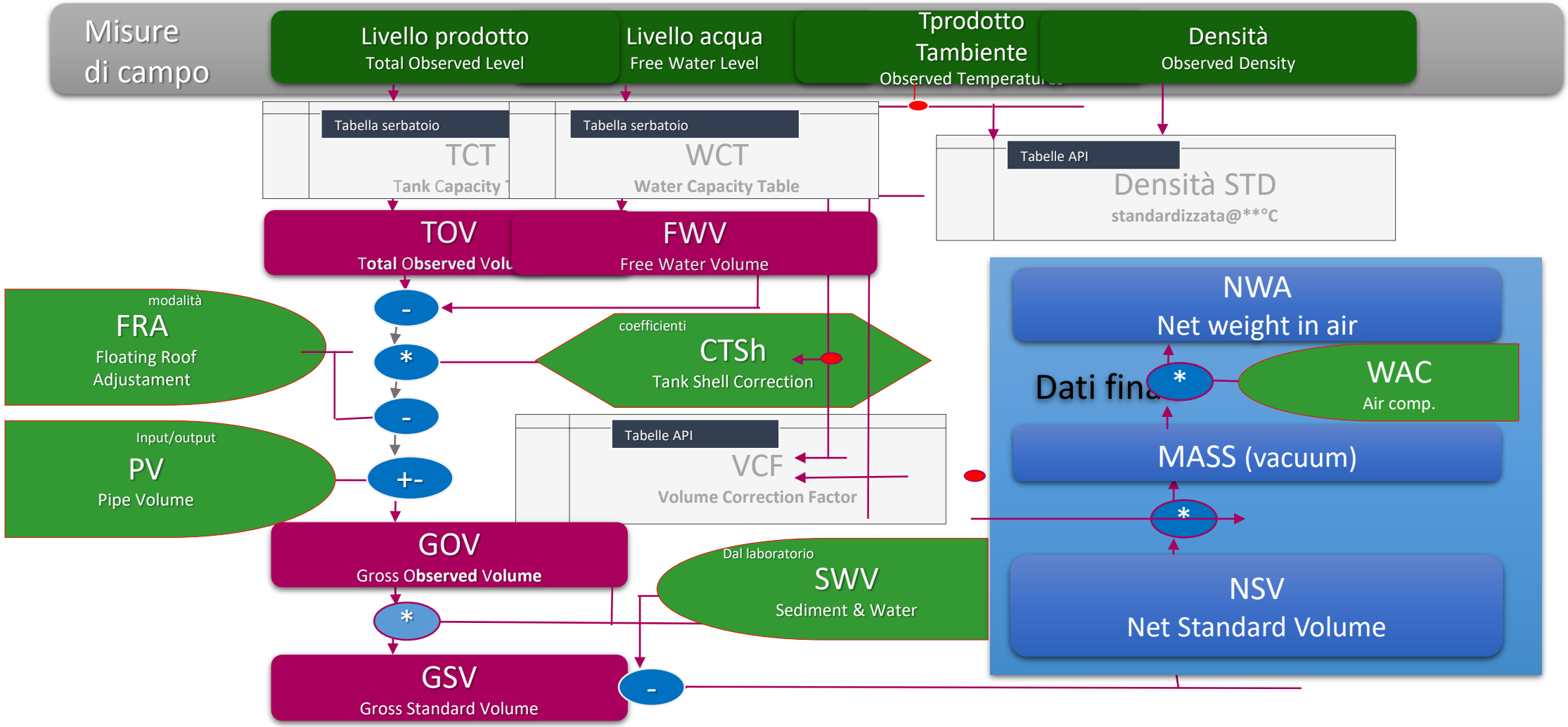
Some parameters are directly measured…



.. Others will be added as tables or coefficients



TGS performs data concentration, calculations, visualization and data transfer



In what case a certified accuracy is needed?

- **In commercial transactions between two entities (Custody Transfer)**

  The accounting of the transferred product may be performed on line by using a flowmeter or in the tanks by accurate measurement of the volume/mass variations during the filling. In order to be mutually accepted, the measuring system must fulfil the accuracy and calculation standards defined by international sector Institutes and Bodies (OIML, API, ISO, etc.); the compliance of instruments to such standards is certified by national metrological institutes (PTB, NMI, etc.).

- **When dealing with products subject to taxation (duties)**

  For a simple and automated handling of the duties.

  Note: acceptance of the measuring system is usually subject to the advice of relevant local authorities (eg. MISE, Agenzia delle Dogane)

OIML R85 and API accuracy

Inventory Control	Custody Transfer
Measurement of the content in a plant	For trading products or tax payment evaluation
API **recommendations** for level (under reference) +/- 3mm In application +/- 25mm	OIML/ API **recommendations** For level (under reference) +/- 1mm In application +/- 4mm
No approval	OIML rules and local approvals e.g. PTB, NMi, GOST,..

OIML R85 and API accuracy

- API Chapter 3.3: the accuracy of +/- 1 mm only refers to calibration prior to installation, i.e. in the factory or testing laboratory under controlled conditions.
- API 3.3 section 3.3: the error caused by installation and operating conditions on the ATGs used in custody transfer service should not exceed +/- 3mm, provided the operating conditions are within the limits specified by the ATG manufacturer
- API 3.1 B section 4.3.4: the overall accuracy (includes both the intrinsic accuracy of the ATG, and those effects caused by installation and operating conditions) of an ATG in custody transfer service should be within +/- 4mm.
- API 3.1 A section 3.1 A.9.1.1: manual gauging shall require 3 consecutive readings to be within a range of +/- 3 mm

Main institutes and organizations

OIML Organization Intenational de Métrologie Légale

- The **International Organization of Legal Metrology** (French: *Organisation Internationale de Métrologie Légale* - **OIML**), is an intergovernmental organization, created in 1955 and based in Paris, to promote the global harmonization of the legal metrology procedures that underpin and facilitate international trade. Such harmonization ensures that certification of measuring devices in one country is compatible with certification in another, thereby facilitating trade in the measuring devices and in products that rely on the measuring devices.

- Its prescriptions define the methods of measurement both static (level) and dynamic (flow) in the transfer of products between third parties (custody transfer).

The principal prescription related to Tank Gauging are:

- **R71**: General requirements. Réservoirs de stockage fixes - Prescriptions générales.
- **R85**: Automatic Level Gauges for Measuring the. Level of Liquid in Stationary Storage Tanks
- **R117** Dynamic measuring systems for liquids other than water
- **R125**: Measuring systems for the mass of liquids in tanks

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6.2.2 The maximum permissible errors, positive and negative, under rated operating conditions to be applied for the relevant indications are specified in Table 2.

Description	MPE
Prior to installation	1 mm
After installation	4 mm

Table 2 Maximum permissible errors (MPE)

API American Petroleum Institute

- Since 1924, the American Petroleum Institute has been a cornerstone in establishing and maintaining **standards** for the worldwide oil and natural gas industry

- The API Standards and Prescriptions cover the problems of transferring products between third parties (custody transfer) and those of storage management (inventory control)

The principal prescriptions related to Tank Gauging are:

- **Chapter 3:** Measure of level
- **Chapter7:** measure of Temperature
- **Chapters 11& 12:** Volume Calculation.

API Chapter 3.1B

3.1B.4.3.2 Calibration Prior to Installation (Factory Calibration)

The reading of an ATG to be used for custody transfer application should agree with a certified measurement instrument within ±1 mm or ($\pm^{1}/_{16}$ inch) over the entire range of the ATG. The certified measurement instrument should be traceable to the national standards and should be provided with a calibration correction table. The uncertainty of the reference should not exceed 0.5 mm or ($^{1}/_{32}$ inch), with the calibration correction applied.

The reading of an ATG to be used for inventory application should agree with a certified measurement instrument within ±3 mm ($\pm^{1}/_{8}$ inch) over the entire range of the ATG. The certified measurement instrument should be traceable to the national standards and should be provided with a calibration correction table.

3.1B.4.3.3 Error Caused by Installation and Operating Conditions

The total error of an ATG in custody transfer service should not be affected by more than ±3 mm ($\pm^{1}/_{8}$ inch) due to installation, to variation of operating conditions (refer to Section 3.1B.4.3.5) or variation of physical and electrical properties of the liquid and/or vapor, provided that these conditions are within the limits specified.

3.1B.4.3.4 Overall Accuracy of the Installed ATG

The overall accuracy of the installed ATG includes both the intrinsic accuracy of the ATG, as verified by factory calibration, and those effects caused by installation and operating conditions. The overall accuracy of an ATG in custody transfer service should be within ±4 mm ($\pm^{3}/_{16}$ inch). The overall accuracy of an ATG in Inventory control service should be within ±25 mm (±1 inch).

ISO: International Standardization Organization

- The International Organization for Standardization (**ISO**) is an international **standard**-setting body composed of representatives from various national **standards** organizations. Founded on 23 February 1947, the organization promotes worldwide proprietary, industrial and commercial **standards, ISO** take care also to the armonizzation of the local rule and norms

The principal prescriptions in the ISO Standard 4266 related to Tank Gauging are:

- **Part 1**: Measurement of level in atmospheric tanks
- **Part 3**: Gives guidance on the accuracy, installation, commissioning, calibration and verification of automatic level gauges
- **Part 4**: Measurement of the temperature in atmospheric tanks
- **Part 6**: Measurement of the temperature in pressure tanks

ISO 4266

7.3.3.3 Initial verification tolerance for fiscal/custody transfer application

The purpose of the fiscal/custody transfer verification is to ensure that the ALG, as installed, can sense and indicate level over its measuring range as accurately as properly performed reference manual tank level measurement.

If the test difference is not greater than 4 mm at all any of the test levels, the ALG should be considered to be suitable for fiscal and/or custody transfer applications. If the test difference exceeds 4 mm at any of the test levels, check for the stability of the manual gauging reference point and possible problem of the ALG installation.


Questions?
Thanks!
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335