New Generation of Multi-Sensor Hydrostatic Gauges - Analysis

Introduction

New generation of Hydrostatic Gauges appeared on the Market of Tank Gauges in the late 1990-es Since then these systems have been installed in numerous applications domestically and around the globe. This article provides analysis of this relatively new technology and comparison with other more traditional gauging methods and the API standards.

Multi-Sensor Hydrostatic Gauges Build

While exploiting the classic principles of Hydrostatic Tank Gauges (HTG) physics the Multi-Sensor Hydrostatic Gauges have a very different build as compared with the traditional HTG. The traditional HTG detailed in API 16.2 in its maximum configuration is comprised of 3 pressure transmitters – two located on the tank walls and one on the roof. Such structure affects cost of installation and causes multiple methodic uncertainties in the measurements. Multiple hot taps might be required for installation of a traditional HTG. There are issues with accurate measurement of sensor positions, uneven temperature distribution over pressure transmitter body, environment effects such as wind affecting the reference port of each of the pressure transmitters in the traditional HTG-s

Alternatively, the Multi-Sensor Hydrostatic Gauges is installed as a single pipe-like structure with embedded sensor modules. The installation uses a single flange on the tank roof. One can imagine it as several traditional HTG gauges installed inside the tank and stacked on top of each other. Thus, none of the negative effects influencing the traditional HTG apply to the Multi-Sensor Hydrostatic Gauges, while the functionality of the Multi-Sensor Hydrostatic Gauges significantly exceeds that of the traditional HTG.

A significant add-up to the to the traditional HTG – each sensor in the new structure is also equipped with a high accuracy RTD – providing multiple temperature measurements.

In fact, the functionality of the Multi-Sensor Hydrostatic Gauges meets the requirements of API standards for traditional ATG-s and HTG-s. The analysis of the functionality of the Multi-Sensor Hydrostatic Gauges as compared to the requirements of API 3.1B, API 3.6, API 7.4 and API 18.2 are given below

Temperature

API MPMS Chapter 7.4 paragraphs 6.2.2 through 6.4 stipulate that the temperature accuracy is verified (using various methods) to 0.5C - thus setting requirements for the installed accuracy. Since their appearance in late 90s the Multi-Sensor Hydrostatic gauges have been using Platinum Class A or better RTD-s.

The class A RTD standard uncertainty table is given below for the convenience of the reader of this article. This table shows that Class A RTD's provides accuracy of +/- 0.3C in the range of -70 to +70C (-94F to +158F) which covers most of the applications.

ACTUAL **RTD ACCURACY +/- °C PT100 Ω ALPHA 0.003850 to DIN 43760 IEC751 DIN EN 60 751**

B GRADE	A GRADE		BAND 3 (1/3 DIN)	BAND 5 (1/10 DIN)
-200 °C	1.30 °C	0.55 °C	0.39 °C	0.38 °C
-150 °C	1.05 °C	0.45 °C	0.23 °C	0.21 °C
-100 °C	0.80 °C	0.35 °C	0.15 °C	0.12 °C
-90 °C	0.75 °C	0.33 °C	0.14 °C	0.10 °C
-80 °C	0.70 °C	0.31 °C	0.13 °C	0.09 °C
-70 °C	0.65 °C	0.29 °C	0.12 °C	0.08 °C
-60 °C	0.60 °C	0.27 °C	0.11 °C	0.07 °C
-50 °C	0.55 °C	0.25 °C	0.10 °C	0.06 °C
-40 °C	0.50 °C	0.23 °C	0.10 °C	0.06 °C
-30 °C	0.45 °C	0.21 °C	0.09 °C	0.05 °C
-20 °C	0.40 °C	0.19 °C	0.09 °C	0.04 °C
-10 °C	0.37 °C	0.17 °C	0.08 °C	0.03 °C
0 °C	0.30 °C	0.15 °C	0.08 °C	0.03 °C
10 °C	0.35 °C	0.17 °C	0.09 °C	0.04 °C
20 °C	0.40 °C	0.19 °C	0.10 °C	0.04 °C
30 °C	0.45 °C	0.21 °C	0.11 °C	0.05 °C
40 °C	0.50 °C	0.23 °C	0.12 °C	0.06 °C
50 °C	0.55 °C	0.25 °C	0.13 °C	0.07 °C
60 °C	0.60 °C	0.27 °C	0.14 °C	0.08 °C
70 °C	0.65 °C	0.29 °C	0.16 °C	0.09 °C
80 °C	0.70 °C	0.31 °C	0.17 °C	0.10 °C
90 °C	0.75 °C	0.33 °C	0.18 °C	0.11 °C
100 °C	0.80 °C	0.35 °C	0.19 °C	0.12 °C
110 °C	0.85 °C	0.37 °C	0.20 °C	0.13 °C
120 °C	0.90 °C	0.39 °C	0.21 °C	0.14 °C
130 °C	0.95 °C	0.41 °C	0.22 °C	0.15 °C
140 °C	1.00 °C	0.43 °C	0.24 °C	0.15 °C
150 °C	1.05 °C	0.45 °C	0.25 °C	0.16 °C
160 °C	1.10 °C	0.47 °C	0.26 °C	0.17 °C

170 °C	1.15 °C	0.49 °C	0.27 °C	0.18 °C
180 °C	1.20 °C	0.51 °C	0.29 °C	0.19 °C
190 °C	1.25 °C	0.53 °C	0.30 °C	0.21 °C
200 °C	1.30 °C	0.55 °C	0.31 °C	0.22 °C

It is important to note that the Multi-Sensor Hydrostatic Gauges use full 4-wire schematics for each of the spot RTD-s which (unlike with many other traditional systems). The 4-wire schematic completely compensates for any influence of wire.

The API 7.4 also sets the transmitter accuracy to 0.15C. The modern Multi-Sensor Hydrostatic Gauges use very high resolution digital electronics with transmitter accuracy significantly exceeding the above Standard requirement. Normally the 0.05C accuracy is stated merely because the higher accuracy value is difficult and impractical to verify.

As a special order, higher accuracy RTD-s such as 1/3, 1/10DIN could be included with the gauges for even higher temperature accuracy, but in practice this is rarely necessary. The reason is that the cost increase by using extra precision spot RTD-s may not pay off in real world as an average temperature accuracy improvement due to both vertical and horizontal temperature stratification in tanks, strong non-linearity of temperature profile, temperature inertia, inaccuracy of temperature correction coefficients for products and tank shell etc. The temperature accuracy does not affect mass calculations in Multi-Sensor Hydrostatic Gauges, which are more immune to temperature influences as compared to traditional HTG and by far more so compared to traditional ATG including Hybrid ATG.

Level

Level only and temperature only are not yet the quantity parameters but are the components for a volume calculations in traditional ATG approach.

Level requirements are described in API MPMS Chapter 3.1b and in more comprehensive API MPMS Chapter 3.6 as well as in ISO 4266-1 2002 (E). All those standards state the same overall system accuracy.

Quoting from API MPMS Chapter 3.1 B:

"*3.1B.4.3.4 Overall Accuracy of the Installed ATG*

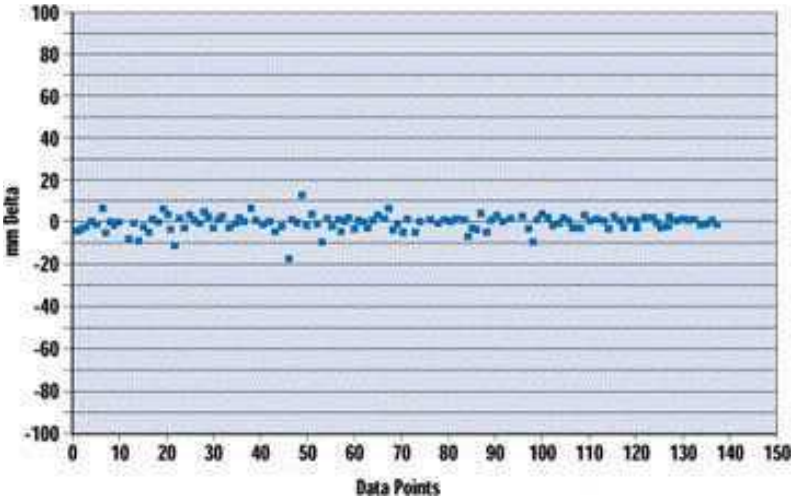
The overall accuracy of the installed ATG includes both the intrinsic accuracy of the ATG, as verified by factory calibration, and those effects caused by installation and operating conditions. The overall accuracy of an ATG in custody transfer service should be within ±4 mm (~ 3/16 inch). The overall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

Multi-Sensor Hydrostatic Gauges discussed here are true INNAGE based gauges thus API 3.1b paragraphs 4.3.5 through 6.2 and 7.3 should apply.

It is important to mention that many manufacturers' statements of 1 or even a half millimeter level accuracy are misleading, because they mention neither application conditions nor installed accuracy, thus confusing the instrumental and installed specifications. The tank operators are not interested how the gauges will perform under control laboratory conditions. The tank operators are only interested in installed verifiable accuracy of their gauges in the actual working conditions of their tanks. Verification means comparison to a known reference. The only reference available on a tank is the manual tape, which should be kept in proper conditions and itself periodically calibrated/certified. Using this tape a good gauger can achieve measurements with 1-2 mm deviations. It is a known rule in metrology that reference must be 3-5 times more accurate than the claimed specification of the instrument for which this reference is used as a calibration or verification tool.

An independent field study made by ARAMCO Saudi Arabia that included multiple radars and servo gauges including custody transfer gauges by leading manufacturer. The study was conducted over a few months. The best accuracy achievable for radar was +/-5mm with so called "unexplainable" spikes to +/-15mm. The same was true for Servo. The Radar and Servo were maintained by the manufacturers' technicians during the test. This is a real world best performance for those gauges

Manual vs. Custody Radar



"The custody transfer-quality radar gauge readings were generally within 5 mm of the manual dips, with a few unexplained outliers to ±15 mm.".

The Multi-Sensor Hydrostatic Gauges meet the level performance required by the API standards and exceed performance disclosed in the above study of the traditional methods.

It should be mentioned however that the level performance would depend on the number of the sensor modules included with such Multi-Sensor Hydrostatic Gauge, maximum fill height and possibly other application conditions. The Multi-Sensor Hydrostatic Gauges allow to choose a suitable combination of level performance and cost for a given task.

It is important to mention that Multi-Sensor Hydrostatic Gauges provide Mass independent of Level and can also provide Volume from Mass calculations that are not dependent on Level accuracy, leaving level information as purely operational parameter rather than parameter of inventory control or custody transfer

Density

From our overview the Multi-Sensor Hydrostatic Gauge is the only type of system available in the market that can provide high accuracy MULTILAYER and AVERAGE density at the same time and in combination with other measurements (Level, multi-spot and average temperature, mass, volume etc.). Specifications usually state a typical value of 1.5 kg/cub meter, but the actual accuracy depends of whether we speak about layer or average density. Average density accuracy for a full tank would often be as good as 0.5kg/cub. Meter. The density measurement specification depends on the number of sensors, distance between the sensors and actual level of liquid in the tank.

The level of liquid in the tank affects any hydrostatic measurement of density including the one used in a hybrid ATG. However, no hybrid ATG can provide multiple density layers or density distribution in a tank. The latter is a unique feature of the Multi-Sensor Hydrostatic gauges.

When analyzing density (and mass) accuracy one must be careful with the manufacturers' specifications. The Hybrid ATG manufacturers usually provide formulas to calculate pressure and consequently density accuracy. Those formulas do not always provide a full understanding of the real accuracy. There are additional uncertainties such as, for example, an uncertainty of the actuation point (the diaphragm is mounted vertically not in parallel with the tank floor), environmental effects of the reference pressure port (for gauge type transducers any wind blowing across the tank, moisture, tank bulging – will all be sources of additional errors), etc. An additional strong influence on externally mounted transducer would be the difference between product and surrounding air temperatures. This is another illustration of how unrelated the stated instrumental accuracy can be when applied to a real tank installation.

A significant advantage of Multi-Sensor Hydrostatic gauge: All above additional errors do not apply to their design due to the use of absolute transducers with diaphragms mounted parallel to tank floor and with no influence of differential temperature between the product and surrounding air.

As far as requirements of the existing standards – the density is mentioned in API MPMS Chapter 3.6 paragraph 9.4.1d. The requirements set as 0.5% of the reading for custody transfer accuracy and 1% of the readings for inventory control accuracy. Multi-Sensor Hydrostatic gauge exceeds those requirements both for layer and average density.

Mass and Volume

Along with measurements of operational parameters such as level and temperature and quality parameters such as density and water content (described below), Mass and Volume are the most important quantity values of the tank gauging process. Nobody buys product in level units, people are interested in quantity, which could be expressed either in mass or in volume units or both.

The API MPMS Chapter 3.6 and 16.2 provide the formulas to estimate accuracy of mass and volume by hybrid and hydrostatic methods. Multi-Sensor Hydrostatic gauge meets both of those standards and exceeds the custody transfer specifications in most cases. The specifications of sensors employed by the Multi-Sensor Hydrostatic gauge is typically within +/-0.02% of the calibrated span and this is within ALL RANGE OF CONDITIONS – meaning no hidden additional errors. The Multi-Sensor Hydrostatic gauge design and operation algorithm allows for periodic sensors self-zeroing thus maintaining high accuracy without additional maintenance of recalibrating the pressure transmitters as in case of side mounted devices used in HTG and Hybrid ATG-s.

Note: Level based systems are usually based on a Radar or Servo Level instrument, Temperature averaging instrument, Water detector, TWO (2) or sometimes THREE (3) pressure transmitters, with multiple wiring and tank penetrations to approach chapters 3.6 or 16.2 requirements. Multi-Sensor Hydrostatic gauge does it all in one probe from one flange on top of the tank, which leads to elimination of multiple methodic uncertainties of combining data from different locations of the same tank.

The accuracy of the strapping table is in most cases the defining factor for total mass and/or volume accuracy. Multi-Sensor Hydrostatic gauge can store up to 1000 points of strapping table.

Another influential factor to assure correct Gross Standard Volume calculations (does not influence mass or TOV) is the product API table. Modern Multi-Sensor Hydrostatic gauges support API product tables and has provisions for the generic product VCF calculations as well.

The Volume can be uniquely calculated by Multi-Sensor Hydrostatic gauge either through standard Level-Temperature-Strapping table or as Mass divided by Density.

Water Content

Water content is an extremely important parameter for both quality and quantity of the stored and transferred product. New API 18.2 standard requires water measurements in Lease storage tanks.

The Multi-Sensor Hydrostatic gauge can calculate water content in crude including free and emulsified water. This represents a unique feature for any Tank Gauge because traditional Hybrid ATG-s can only calculate water in a limited space near the tank bottom, while traditional HTG-s are unable to calculate any water content in storage tanks.

Conclusion and Summary

Multi-Sensor Hydrostatic gauge meets ALL API standards' requirements for custody transfer and inventory control. Those include parameter measurement standards such as API 3.1b and API 7.4 and more comprehensive Volumetric and Mass standard, such as API 3.6, 16.2 and 18.2

In addition, Multi-Sensor Hydrostatic gauge uniquely provides the whole range of additional benefits such as:

- Leak detection capability with static tank due to direct mass sensitivity
- Vapor pressure monitoring to prevent roof rupture and provide hydrocarbon emission raw data
- Density profiling for mixing and blending
- Emulsions and entrained water in suspension for tank settling control and quality control
- All measurements at the same location with no horizontal stratification influence
- Self calibration and extremely low maintenance with single installation point and no moving parts.

Modern Multi-Sensor Hydrostatic gauge do not require any additional instrumentation of RTU and capable of calculating and transmitting all measurements' result from the single field instrument.