White Paper **Product: 3000 MTG** **Date: March 2001**

Mass Measurements - Methods, Technologies and Advantages

The reason for using mass measurements for inventory control is simple: Mass is the only objective parameter for quantity accounting. Mass does not depend on temperature or other environmental factors and it does not require complicated conversions. Mass is the only parameter naturally suitable for leak detection.

It seems natural to weigh goods we buy at the grocery store. Why don't we do the same with the expensive chemical or petroleum products? The answer is simple: There are traditional, accurate, and, what is most important, easily verifiable and easily calibrated scales available at every grocery store. Those scales evolved from simple balances to electronic devices, but they retained the principle of easy calibration. Unfortunately, there was no historical method or tradition for measuring mass in liquid storage tanks, and only very recently has the technology advanced to produce practical solutions.

Traditionally only volumetric methods were available for measuring liquids both in storage tanks and in flow. In storage tanks, that was achieved by manually gauging tanks with a tape. For flow, rotational meters – turbine and positive displacement – were used for volumetric readings. Volume, however is dependent on temperature. Therefore, a conversion is necessary to calculate so-called standard volume. This standard is, by the way, different in America and Europe, being referred to 60F and 15C respectively. Such a conversion requires very accurate true average temperature measurement.

One degree (1º) Fahrenheit of temperature stratification uncertainty in a 40-foot tank is equal to about 3/8 of an inch level error. Additional error comes from the approximate value of the temperature expansion coefficients. This is especially true for stratified products such as crude oil, where different fractions expand differently with temperature changes.

Besides these methodical errors, there are instrumental errors with any level instrument. These er-

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rors or uncertainties may vary depending on the level gauge type and specifics of the application, but they all have one thing in common – adding to the error of the final net volume result.

The above reasons pushed engineers to strive for reliable mass measurement solutions. Such a solution should still be able to provide reasonable level accuracy, be verifiable and compatible with existing control systems.

The first serious attempt at Mass measurements in above ground storage tanks evolved from simple DP cells' applications into HTG technology in early eighties. HTG incorporates simple and straightforward physics to calculate mass, density and level of liquid product in a storage tank. It normally uses three pressure transmitters – the first installed at the bottom of the tank, the second about 10-12 feet above and the third at the tank roof for vapor pressure compensation. One spot RTD is normally used for temperature measurement.

However, the limitations of the design led in many cases to the disappointment of tank operators and sometimes even to the loss of confidence in the very idea of mass measurements. HTG disadvantages start with expensive and troublesome installation with four penetrations through the tank shell and the necessity either to use hot tapping procedures or to take tank out of service. HTG relied on the density measurement in the lower layer of the tank for level calculations. However the density result was not very accurate due to insufficient accuracy of the measurement of the distance between the sensors taken in field after installation. The actuation points of the vertically positioned diaphragms are not precisely known. In addition, the tank bulging effect increases this error. That led to very significant errors.

The difference between product and environment temperatures causes temperature variations within the pressure sensor body, distorting the temperature compensation based on characterization of pressure sensing devices, affecting mass, density and level results.

Additional factors, such as wind blowing at the tank, also contribute to more errors. Serious measurement and maintenance problems are caused by pressure sensor drift, requiring periodic in field pressure sensor calibration.

HTG did not meet the expectations of users, but did raise interest in measurement of the density of the product that provides important qualitative data for tank operators. That impacted traditional technologies, which started to incorporate different methods of adding density and mass measurement to their level and volume capabilities.

Servo methods tried to present a density and mass solution by sending its displacer on long excursions to the tank bottom. By weighing the displacer in different layers of the product, the servo method advocates claim to have density stratification and mass as achievable parameters. However, simple analysis of "weighing" accuracy, or more precisely accuracy of measurement of the tension in the displacer wire, show that no density measurement is possible with an accuracy of better than 5-10 kg per cubic meter. That means 0.6 to 1.2% of mass accuracy – definitely insufficient for inventory control purposes. Also, such displacer travel may take tens of minutes, leaving the primary servo parameter – level – unattended. Also, dirt and residue accumulating on the wire will find its way to the precision servo drum, defeating the manufacturer's protection and adversely affecting the servo gauge performance.

More successful attempts to increase the capability of traditional level devices were to add accurate pressure transmitters to existing systems – Hybrid systems. That, however, increased the price of the system and still does not solve the problem of pressure transmitter drift and associated calibration.

Another approach to mass measurement has been made with multiple bubbler devices submerged from the top of the tank. These devices use a source of inert gas, such as nitrogen, force it through the product and measure the hydrostatic pressures at several levels. Theoretically, this provides multiple densities and more accurate level measurements. Such systems incorporate many pneumatic lines leading to the tank and accurate pressure transducers that are switched between these lines to acquire pressure data at several levels. This has some advantages over HTG, but such systems still have inherent problems:

The quality of pneumatic lines must be assured and maintained, otherwise measurement errors occur.

The positioning of pressure sensing points is not as accurate as one would desire due to system construction and the bubbling method itself.

The bubbler method is problematic for viscous products, where bubbles have trouble making their way to the surface aerating the product itself.

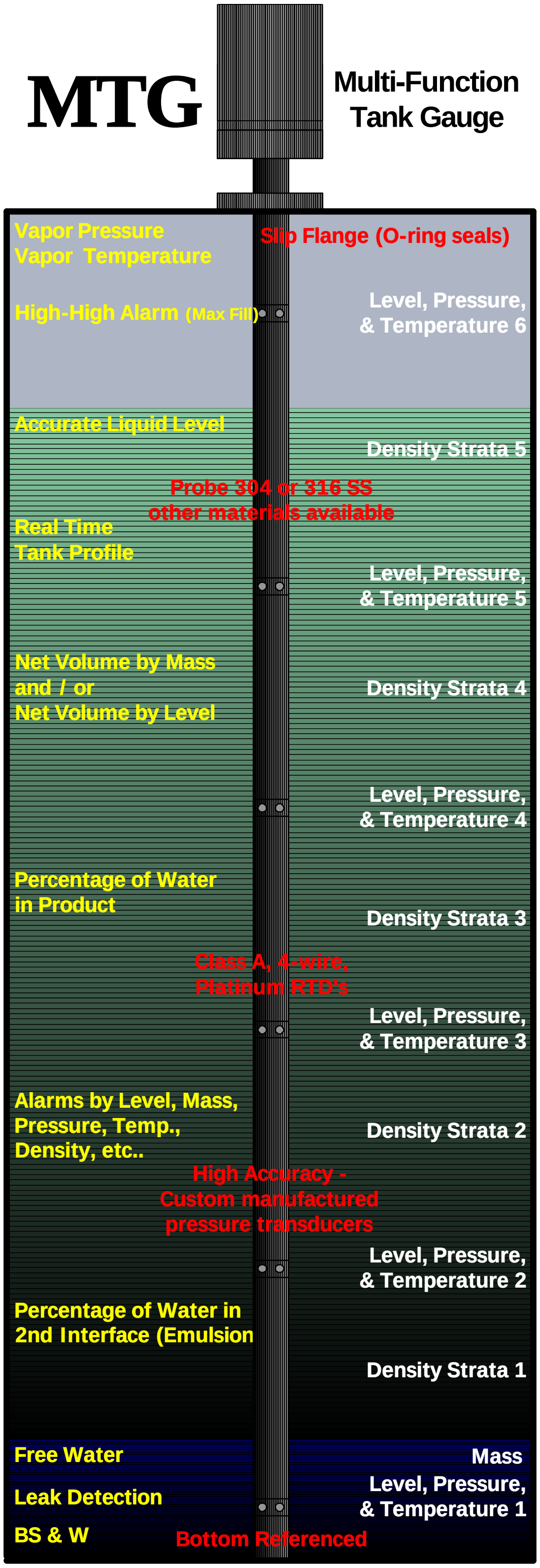
The newest development in mass measurement technology emerged about 3-4 years ago. This technology incorporates a multi-sensor rigid probe, which rests on the bottom of the tanks and protrudes through its roof by means of sliding sealing flange. Thus, this probe is bottom referenced with roof movements not affecting the measurements (eliminating errors common to all the referenced level devices).

This gauge incorporates several highly precise pressure and temperature sensors. The pressure sensors are installed with the diaphragms parallel to the liquid surface, making the actuation points precisely known. The probe itself is made of CNC machined sections and parts and is unaffected by tank bulging. This allows for very accurate multi-layer density measurements, highly accurate mass and level measurement

Multi-point accurate pressure, temperature and density measurements lead to numerous applications, such as tank profiling, blending controls, emulsion and water interfaces, measurements of percentage of water in product at any given level and more. Algorithms incorporated with the gauge software allow automatic self-calibration of the probe by using redundant measurements and product movement in the tank, making the system maintenance free.

The probe has a smooth pipe-like profile and allows installation in tanks with cone, external and internal floating roofs.

Should you expect more than just level, temperature, and free water from a tank gauge?



The MTG " Multi-function Tank Gauge" is a multi-sensor device that provides not only continuous level, but real-time profiling of the tanks content; Level, Mass, Multiple spot temperature points, Multiple density strata, Free water, Percentage of water in product, 2nd Interface (Emulsion in crude oil), Percentage of water in 2nd Interface (Emulsion), Vapor pressure, Vapor Temperature, Leak detection, Etc. Level accuracy meets or exceeds API Chapter 3.1 and Mass accuracy exceeds API Chapter 16 for inventory and custody transfer accuracy.

The MTG provides a variety of economic benefits ranging from electrical savings by the monitoring of density and temperature stratification, thus knowing when to heat or when to mix. The monitoring of Vapor Pressure, thus providing hydrocarbon emission, vapor blanketing leakage, or providing a third high-high level alarm. Vapor Pressure monitoring also protects the physical tank from damage due to over pressure or under pressure.

In tank blending by density. In settling tanks, the knowledge of the free water in the tank, but also suspended water in product. The MTG provides all necessary data to calculate Net Volume (Mass or level, temperature, water, and density) without waiting for laboratory analysis. Leak detection, etc.

The MTG is **bottom referenced** and can be installed in service. It doesn't require a stand pipe / stilling well or calibration pins to maintain accuracy, using only one tank opening. MTG operates on 24 Vdc or less (optional solar / battery). It is self calibrating and self diagnostic, and has **NO MOVING PARTS**.