Leak Detection in Liquid Bulk Storage Tanks

Leak Detection as a Function of Tank Surface Area and Height

Leak detection tasks are usually associated with relatively small Underground Storage Tanks (UST's), such as gasoline or diesel tanks in gas (petro) stations.

However, Aboveground Storage Tanks (AST's), such as petroleum marketing, pipeline, and refinery tank farms; Field Constructed Steel Underground Bulk Storage Tanks (FCSUBST's); and Cut-N-Cover tanks which are constructed and buried underground all require a leak detection solution to prevent ground water contamination, product loss, environmental fines and clean-up costs. Also the costs of emptying the tank, cleaning the tank, certifying it be gas free, detecting the leak point, physical tank repair, contractor & internal manpower, and tank use (out of service) all add to the disruption.

Currently, within the United States the EPA (Environmental Protection Agency), State, and local governments do not give clear guidance and standards for leak detection for larger tanks (AST'S, FCSUBST's, Cut-n-Cover tanks, etc.). Leaks from these types of larger tanks could be more devastating to the environment due to the potential larger volume of liquid product. Leak rates can also increase due to higher pressure, thus spreading over a greater area and ground depth.

The problem lies in the difficulty of the leak detection task for larger tanks. The regular requirements for small underground tanks are 0.1 gal/hour for tank tightness test and 0.2 gal/hour for leak detection test at minimum 95% probability of detection and maximum 5% probability of false alarms.

The regular time required by most leak detection systems is 48 hours, though claims of 24 hours for small tanks are not uncommon. Let's use the value of 0.2 gal/hour target leak detection threshold over 48 hours period to calculate the resulting level change in an Aboveground Storage Tank (vertical cylinder tank) (see Table 1 below):

Tank dia.	Leak rate	Time Period for Leak Detection	level change
ft	gal/h	hours	16th inch
25	0.2	48	0.50
50	0.2	48	0.13
75	0.2	48	0.06
100	0.2	48	0.03
125	0.2	48	0.02

Table 1

To understand the difficulty of the problem we need to consider not only the miniscule changes in level caused by small leaks in large tanks but also various influential factors, such as temperature change:

Every 1.2°F of average temperature uncertainty will introduce an uncertainty of 1/16th of an inch ***per every 10ft of height*** in any vertical cylindrical storage tank. That means for an average 30ft height tank 1.2°F of average temperature uncertainty will result in 3/16th of an inch of level uncertainty.

Compare this value with the level changes in Table 1 required for leak detection and the overwhelming influence of temperature factor becomes obvious.

Uncertainty of average temperature is one of the strongest, but not the only factor influencing leak detection in Aboveground Storage Tanks (AST's), Field Constructed Underground Bulk Storage Tanks (FCSUBST's) or Cut-N-Cover Tanks. Thus, even when 0.5 or 1.0 gallon per hour thresholds are deemed acceptable, reliable leak detection still remains an extremely difficult technical task

Mass based approach vs. Level based approach

There are two approaches to leak detection systems based on measurements of quantity change in tanks. These are level-based and mass-based approaches.

The level-based approach is widely used in small underground tanks such as service station tanks utilizing mostly magnetostrictive technology, where the position of float on a rigid guide is measured using a magnetostrictive method. The same probe usually incorporates temperature measurement to compensate for the temperature effect. This technology has been certified in small tanks with only few feet of height and relatively small surface areas of liquid.

In large storage tanks, where a flexible guide for a magnetostrictive probe has been used, the discussed temperature effect on liquid expansion, temperature effect on float buoyancy, and even minimum friction of float and the guide are enough to make this technology inapplicable.

Mass measurement methods do have a significant advantage over level measurement methods because mass, unlike level and volume, does not change when temperature changes. Mass measurement methods are based on a hydrostatic approach. Indeed, pressure is nothing other than the weight of liquid per each square inch of its surface.

A pressure sensor positioned near the bottom of the tank in a stable environment would read the same pressure at zero leak situation whether temperature of liquid changes by 1^{o}F, 10^{o}F or does not change at all. At the same time an accurate pressure sensor will read changes of pressure (mass) if there is a leak independently of temperature change or temperature induced level change. This is because pressure is proportional to both density and level. In an ideal cylindrical tank, level increases exactly the same way as density decreases per every degree of temperature rise and vice versa.

There is no alternative to mass-based leak detection in any large storage tank.

However, the traditional hydrostatic systems (HTGs) with gauge pressure transmitters mounted on the wall of the tank are not capable of providing a realistic solution for leak detection. The gauge pressure transmitters would be significantly affected by environmental influences such as wind or ambient pressure and temperature variations. They will also be affected by differences between the liquid and ambient temperatures. It would be very difficult to accurately detect mass trends in conditions where there is no synchronization between vapor and liquid pressure sensors. Furthermore, the influence of the dead zone below the standard bottom HTG sensor will not be compensated for either. Traditional HTG's also do not accurately compensate for tank shell expansion in above ground storage tanks.

Traditional HTG cannot be physically used for cut and cover or buried tanks, concrete wall tanks or underground storage facilities.

Thus, other approaches to hydrostatic systems for mass-based leak detection have to be considered:

Leak Detection as service vs. Permanent Leak Detection Solution

Some mass-based leak detection systems were developed as a service method, which means a crew of technicians would go to a tank site, install the equipment and monitor for a pre-determined time, usually 48 hours or more, to determine if there is an existing leak.

The sensors for such systems are usually enclosed within a probe inserted into the liquid in order to avoid the environmental influeces discussed above.

While this method can provide much better accuracy than the level-based methods, it only checks for leaks during the time when service is provided at the tank site. If the leak was present beforehand, then environmental damage has probably already occurred.

Most state agency regulations require annual static leak detection tests depending on a tank's age and construction. Service based leak detection involves installing and removing equipment to perform a (48 hour) static test and then the equipment is gone, making it expensive and impractical to detect a leak when it occurs.

There are some mass based systems with permanent installation in the tank. Some of them include the use of a special differential pressure sensor with pneumatic control, requiring taking the tank out of operation for installation purposes (emptying of the tank, cleaning of the tank, venting of the tank, loss of use, etc.).

This alone would be of significant cost for tank operators, especially in Aboveground Storage Tanks (AST's) and large underground tanks. The failure of a single sensor or the pneumatic control would also require taking the tank out of operation. Such systems may require special equipment, software and personnel to conduct the leak detection test.

None of the methods described are applicable for all tank shapes or conditions when temperature change or density stratification occurs during the leak detection test process. That is because compensation of level and density only work correctly in cylindrical tanks. Note: these systems do not have temperature sensors to compensate for tank shell expansion.

Mass based multi-sensor approach

A better solution is a multi-sensor mass based method using a multitude of accurate absolute pressure and temperature sensors installed within a slotted gaugewell (standpipe). An example would be Multi-function tank Gauge (MTG). The sensors should be positioned near the bottom of the tank, throughout the tank depths, and in vapor space. The sensors should be operated by a single processor capable of timing and synchronizing the measurements of the different pressure and temperature sensor modules.

Such a modernized hydrostatic mass-based approach would allow for the following:

1. Installation into above or below ground tank facility without emptying the tank
2. Statistical analysis, allowing the influence of any single pressure drift or failure to be minimized
3. Compensating the temperature influences on the pressure sensor performance
4. Usage of sensors with different span over tank depths for optimal sensitivity
5. Compensation of temperature influence for even slight irregularity of tank geometry and corrections for the temperature related tank shell expansion
6. Immunity from environmental factors by using absolute pressure transducers.

7. Synchronized measurements in vapor and liquid to exclude the influence of the vapor or ambient pressure noises.
8. Redundancy to allow exclusion of malfunctioned sensors from leak detection test analysis as opposed to aborting the tests and requiring immediage repair in case of single sensor-based systems.
9. The method can work as a fully automatic system but can also log historical data allowing analysis of the raw data and manual statistical evaluation of each situation or suspected leaks both current and backward in time.

Integration of the Leak Detection and the Tank Gauge

The multi-sensor mass-based leak detection approach can be utilized as both a Tank Gauge System and a continuous Leak Detection System. However, a correctly engineered configuration of the gauge is required when used for leak detection. Example: redundant bottom and vapor sensors should be used in a multi-function gauge to increase reliability of the leak detection. The total number of sensor modules must be chosen to provide enough redundancy and statistics depending on minimum leak detection threshold required and the static time necessary for each storage tank to run the leak detection test procedure.

Engineered approach

The task of leak detection for any large storage tank whether above or underground must always be considered through an engineered approach. Size, type and location of the tank will influence the minimum leak detection threshold and the required leak detection test duration, as well as the number of sensors and their location in a multi-sensor mass-based leak detection gauge. The height of the tank, the available access for the installation of the system through the tank roof, and any limitations for underground storage facility must be evaluated as well.

The multi-sensor mass-based probe is usually able to accommodate tank site limitations by means of its sectioned design and the fact that only a single penetration through the roof is required. The multi-sensor mass-based leak detection can be installed with or without a gaugewell based upon multiple factors, i.e., tank type (cone roof, floating roof, etc.), location within a tank in regards to other equipment (noise, etc.) or pipe entries (flow in or out).

For each individual tank, an engineered approach is required to determine the best suitable technology, the cost factors and the proper configuration within the chosen technology.

Conclusion

The only feasible approach to leak detection in AST's, FCSUBST's, and Cut-n-Cover tanks is the mass-based method.

While service-type and permanent-type mass-based leak detection methods may work for the same tank the frequency and overall cost should determine the choice whether the leak detection should be a permanent solution or a periodic service.

Multi-sensor mass-based system provide the most flexibility in configuration and the least dependence on individual sensors failures and influential factors.

A multi-sensor mass based leak detection system is the only one that can be configured as a Tank gauge and a leak detection solution (Static, Periodic, or Continual) with the same instrument.