DETECTING LEAKS IN LARGER TANKS

Alexander Bukhman, Gauging Systems Inc., USA, compares leak detection methods for aboveground storage tanks.

eak detection tasks are usually associated with relatively small underground storage tanks (USTs), such as gasoline or diesel tanks in gas (petrol) stations.

However, aboveground storage tanks (ASTs), such as petroleum marketing, pipeline, and refinery tank farms; field constructed underground bulk storage tanks (FCUBSTs); and cut-and-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.

Clear guidance and standards for leak detection in larger tanks are currently not provided by the US Environmental Protection Agency (EPA), as well as state and local governments. However, leaks from larger tanks could be devastating to the environment due to the larger volume of liquid product. Leak rates can also increase due to higher pressure, thus spreading over a greater area and ground depth.

The task of leak detection is difficult for larger tanks. The regular requirements for small underground tanks are 0.1 gal./hr for tank tightness tests and 0.2 gal./hr for leak detection tests at a minimum of

Table 1. Level change vs tank dia. for given leak rate

Tank dia. (ft)	Leak rate (gal./hr)	Time period for leak detection (hrs)	Level change (16^{th} in.)
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

95% probability of detection and maximum of 5% probability of false alarms.

The time required by most leak detection systems is 48 hrs, though claims of 24 hrs for small tanks are not uncommon. In Table 1, 0.2 gal./hr is used as a target leak detection threshold over a 48 hr period to calculate the resulting level change in an aboveground storage tank (vertical cylinder tank).

To understand the difficulty of the problem, it is important to not only consider the small 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 $1/16^{th}$ of an inch per every 10 ft of height in any vertical cylindrical storage tank. This means for an average tank that is 30 ft high, 1.2°F of average temperature uncertainty will result in $3/16^{th}$ of an inch of level uncertainty. Compare this value with the level changes required for leak detection in Table 1 and the overwhelming influence of temperature factor becomes obvious.

While uncertainty of average temperature is one of the strongest factors influencing leak detection in ASTs, FCUBSTs and cut-and-cover tanks, it is not the only factor. Thus, even when 0.5 or 1 gal./hr 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: level-based and mass-based.

The level-based approach is widely used in small underground tanks, such as service station tanks utilising 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.

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

Mass measurement methods have a significant advantage over level measurement methods because unlike level and volume, mass does not change when temperature changes. Mass measurement methods are based on a hydrostatic approach.

A pressure sensor positioned near the bottom of the tank in a stable environment would read the same pressure during a 'zero leak' situation, whether the temperature of the liquid changes by 1°F, 10°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 independent 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 in 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 large storage tanks.

Traditional hydrostatic tank gauge (HTG) systems, with gauge pressure transmitters mounted on the wall of the tank, are affected by differences between the liquid and ambient temperatures. It would be difficult to accurately detect mass trends in conditions where there is no synchronisation between vapour and liquid pressure sensors. Furthermore, the influence of the dead zone below the standard bottom HTG sensor will not be compensated for. Traditional HTGs do not accurately compensate for tank shell expansion in ASTs.

Traditional HTGs 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 period of time, usually 48 hrs 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 influences discussed previously.

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

Most states' regulations require annual, quarterly or even monthly 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 hr) static test, which is expensive and impractical to detect a leak when it occurs.

There are some mass-based systems that are permanently installed in the tank. Some of these systems include the use of a special differential pressure sensor with pneumatic control, requiring the tank to be taken 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 for ASTs and large underground tanks. The failure of a single sensor or the pneumatic control would also require the tank to be taken 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 possible 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. It is important to note that these systems do not have temperature sensors to compensate for tank shell expansion.

Mass-based multi-sensor approach

An alternative 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 a multi-function tank gauge (MTG). The sensors should be positioned near the bottom of the tank, throughout the tank depths, and in the vapour space. The sensors should be operated by a single processor, capable of timing and synchronising the measurements of the different pressure and temperature sensor modules.

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

- Installation into an above or below ground tank facility without emptying the tank.
- Statistical analysis, allowing the influence of any single pressure drift or failure to be minimised.
- Compensation of temperature influences on the pressure sensor performance.
- The use of sensors with different span over tank depths for optimal sensitivity.
- Compensation of temperature influence for even slight irregularity of tank geometry and corrections for the temperature related tank shell expansion.
- Immunity from environmental factors by using absolute pressure transducers.
- Synchronised measurements in vapour and liquid to exclude the influence of the vapour or ambient pressure noises.
- Redundancy to allow exclusion of malfunctioned sensors from leak detection test analysis as opposed to aborting the tests and requiring immediate repair in case of single sensor-based systems.
- 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.

Integration of leak detection and the tank gauge

The multi-sensor mass-based leak detection approach can be utilised 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. For example, redundant bottom and vapour sensors should be used in a multi-function gauge to increase the reliability of the leak detection. The total number of sensor modules must be chosen to provide enough redundancy and statistics depending on the minimum leak detection threshold required and the static time available and 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. The 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 of the underground storage facility must also be evaluated.

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.

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

Conclusion

The mass-based method is the most feasible approach to leak detection for ASTs, FCUBSTs, and cut-and-cover tanks.

While service-type and permanent-type mass-based leak detection methods may work for the same tank, it is important to determine whether the choice of leak detection should be a permanent solution or a periodic service.

A multi-sensor mass-based system provides the most flexibility in configuration and the least dependence on individual sensor failures and influential factors. This type of leak detection system can be configured as a tank gauge and a leak detection solution with the same instrument.