

An Engineering Assessment of Volumetric Methods of Leak Detection in Aboveground Storage Tanks

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Executive Summary

Introduction

Though volumetric methods of leak detection have been used successfully to reliably detect small leaks in underground storage tanks, their performance in large aboveground storage tanks (ASTs) is unknown. This document provides the results of an engineering assessment of volumetric methods for detecting small leaks in large ASTs.¹ To assess the environment under which a volumetric leak detection test might be conducted on an AST, a series of experiments were done on a 114-foot-diameter AST containing a heavy naphtha petroleum product and located at the Mobil Oil Refinery in Beaumont, Texas. Data concerning normally occurring volume changes that are not associated with a leak were provided by (1) precision level measurement systems and (2) horizontal and vertical arrays of thermistors placed in two locations: inside the tank, immersed in the product, and outside the tank along its external wall.

Background

The American Petroleum Institute (API) has completed two phases of a leak detection project for ASTs. The purpose of Phase I was to assess different leak detection technologies to determine which had the greatest potential for field application. Because acoustic and volumetric methods were found to have significant operational and performance advantages, they were the ones chosen for testing under Phase II of the project.

The purpose of Phase II was to perform an engineering evaluation of acoustic and volumetric methods for detecting small leaks in large ASTs. The principal objectives of Phase II were:

- to determine, in the case of acoustic methods, the nature of the leak signal and the ambient noise in an AST;
- to determine, in the case of volumetric methods, the sources and magnitude of ambient noise associated with measurements in an AST;
- to perform field experiments on a large, full-scale AST; and
- to recommend ways to improve existing AST leak detection methods.

Conclusion

The analytical and experimental results of this project suggest that differential-pressure-measurement methods (i.e., mass measurement methods), which are a type of volumetric method, can be used to detect small leaks in ASTs. Such methods can achieve a high level of performance because they are not affected by thermally induced volume changes in a tank with vertical walls. However, other sources of ambient noise, such as thermal expansion of the tank wall and evaporation and condensation of the product in the tank, do affect performance and must be compensated for separately.

¹ The results of the acoustic study are provided in a separate API document entitled *An Engineering Assessment of Acoustic Methods of Leak Detection in Aboveground Storage Tanks*, by Eric G. Eckert and Joseph W. Maresca, Jr.

Summary of Results

The analytical and experimental results of this project suggest that the performance of a volumetric test in detecting small leaks is limited by the magnitude of the uncompensated volume error and by the duration of the test. Because of the diurnal character of the volume fluctuations, tests that are less than 24 hours long may yield erroneous results. The data suggest that a test may have to be 48 to 72 hours long to reduce the effects of uncompensated volume fluctuations.

The field test data, collected at two different product levels over two three-day periods, indicate that volume changes of several hundred gallons per hour occur in response to ambient temperature changes. During both test periods, volume changes of as much as 1000 gallons were observed over a 24-hour period. Because of these large changes, it is necessary to compensate for the effects of temperature fluctuations occurring in both the product and the tank shell, and for the effects of evaporative product losses, if volume measurements are to be useful in detecting leaks. Analysis of the test data indicates that a small number of temperature sensors mounted on the external circumference of the tank can readily compensate for thermally induced changes in the volume of the tank shell.

The largest sources of uncompensated volume changes were horizontal product temperature gradients and evaporative losses. The data suggest that the size of these volume changes was approximately 10 gallons per hour, with as much as 80% of this value being due to non-uniformity of the product temperature field. The effect of these changes (the "thermal error") can be minimized by using a differential-pressure-measurement system to monitor changes in the level of product in the tank. With this approach, a volumetric test should be able to detect leak rates as low as 1 gallon per hour, if evaporative losses can be minimized and if tests longer than 24 hours can be tolerated.

1 Introduction

This report summarizes Phase II of a research program conducted by the American Petroleum Institute (API) to evaluate the performance of technologies that can be used to detect leaks in the floors of aboveground storage tanks. During Phase I, an analytical assessment of the performance four leak detection technologies was investigated [1, 2]. The four technologies included: (1) passive-acoustic sensing systems, (2) volumetric systems, especially differential-pressure (or "mass") measurement systems, (3) advanced inventory reconciliation methods, and (4) tracer methods. During Phase II, field tests were conducted on an aboveground storage tank to make an engineering assessment of the performance of two of these technologies, volumetric detection systems and passive-acoustic sensing systems. This report describes the engineering assessment of the volumetric systems that were examined; the engineering assessment of acoustic systems is described in a separate report [3].

The specific objectives of the Phase II research in the area of volumetric measurements were to:

- assess the current state of AST leak detection technology
- characterize the sources of ambient noise associated with volumetric measurements in an AST
- perform field experiments on a full-scale AST
- recommend ways to improve existing AST detection systems

The field tests were conducted at the Mobil Oil Refinery in Beaumont, Texas, on a 50,000-bbl, 114-ft-diameter AST containing a heavy naphtha petroleum product. The experiments focused on the ambient noise field and how it affects accurate detection of the volume changes due to a leak.

2 Background

Volumetric systems are the most commonly used method of detecting leaks in *underground* storage tanks (USTs) [4-6]. These systems typically measure the change in the level of product in the tank; they compensate for the thermal expansion or contraction of the product by measuring changes in the temperature of that product. Their method of compensating for other sources of background noise is to wait for the volume changes to become negligibly small. Volumetric leak detection systems that compensate directly for the thermally induced volume changes in the product would seem to be directly applicable to the detection of leaks in ASTs. Differential-pressure-measurement systems (mass-measurement systems) are an example of this type of volumetric system. Because the cross-sectional area of the product surface is a constant regardless of the level of product, mass measurement systems compensate directly for thermally induced changes in the volume of product; they are, however, subject to other sources of uncompensated noise.

As with USTs, the nature of the leak signal in an AST is well known. Unlike USTs, however, the signal in an AST is not affected by the level of the groundwater, and, because the leak is in the floor of the tank, the pressure head above that leak is known. The primary focus of the field tests was to quantify the magnitude of the volume changes associated with important sources of system and ambient noise.

3 Summary of Results

In order to assess the environment under which a volumetric leak detection test on an AST might be conducted, a series of experiments were done on a single 50,000-bbl tank containing heavy naphtha. Instrumentation deployed in the tank provided information concerning level changes in the product as well as temperature changes in both the product and tank wall. The test data, collected at two different product levels over two separate three-day periods, indicate that volume changes of several hundred gallons per hour occur in response to ambient temperature changes. During both test periods, volume changes of as much as 1000 gal were not uncommon over a 24-h period. Because of these large changes, compensation schemes are required if one is to be able to account for the effects of temperature fluctuations occurring in both the product and the tank shell, and for the effects of evaporative product losses.

When a single array of product temperature sensors was used, compensation of the measured volume changes for these thermal effects resulted in a net loss of product from the tank during both test periods. A large fraction of this loss can be explained by the existence of horizontal temperature gradients in the product and by evaporative loss. Differences in the estimate of the product thermal volume obtained from two vertical thermistor arrays were found to range from less than 100 gal to as much as 400 gal for different test periods. In addition to these product volume changes, the thermal expansion of the tank shell was found to approach several hundred gallons over a 24-h period, and could be accurately estimated by as few as six temperature sensors placed around the tank circumference.

The product surface was found to experience periodic fluctuations having magnitudes approaching 100 gal. These volume changes, coupled with the thermally induced volume changes, are large compared to the range of volume rates of interest. This active product surface thus permits the use of less precise sensors for the primary volume measurement. The accurate estimate of the rate of change of volume can then be obtained by sufficiently averaging through a volume time series to reduce the uncertainty in the rate to acceptable levels. As a result, a range of mass measurements, i.e., those made by pressure sensors, should be suitable for use in a leak test.

The ability of a volumetric test to detect small leaks is limited by the test duration and the magnitude of the uncompensated volume error. The current data indicate that a test duration between 48 and 72 h is required in order for the effects of uncompensated diurnal volume fluctuations to be reduced. Shorter test durations (less than 24 h) would yield erroneous results because of the diurnal character of the volume fluctuations.

The largest sources of uncompensated volume were found to be evaporative losses and the non-uniform thermal expansion of the product. The data suggest that the magnitude of these effects was roughly 10 gal/h, with as much as 80% of this value being due to inadequate spatial coverage of the product temperature field. Since a mass measurement system is not affected by horizontal temperature gradients, and intrinsically compensates for thermally induced product volume changes, a volumetric test should be able to detect leak rates as small as 1 gal/h if the effects of evaporation can be minimized and if tests longer than 24 h can be tolerated.

4 Report Organization

The work performed as part of the Phase II program is summarized in a technical paper prepared for publication in the engineering and scientific literature [7]. This paper, a copy of which is presented in Appendix A of this report, describes the results of the experiments conducted with a volumetric leak detection system during April and May 1991. Two three-day field tests were conducted on a 114-ft-diameter AST, and two levels of product (10 and 17 ft) were used during these tests. The paper describes the volume changes associated with each source of noise at each level of product.

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