A CASE STUDY OF A LARGE SCALE PRECISION TANK TESTING PROGRAM

Diane H. Heck

Tetra Tech Richardson
Newark, Delaware

Abstract

In September of 1986, a precision tank testing program was started to bring a major Maryland utility into compliance with the State of Maryland Oil Spill Control regulations regarding underground storage tanks. This program involved the testing of over 240 tanks ranging in size from 300 gallons to 1,500 gallons located throughout the entire state of Maryland.

Analyses of the testing results revealed that 40% of the systems tested leaked. Piping leaks caused 82% of the testing failures and tank leaks caused the remaining 18%. Tank systems located in urban areas experienced a 50% testing failure rate, while tank systems located in rural areas experienced only a 25% failure rate. Leaks in tank systems in urban areas appear to be the result of structural loading and corrosion, affects absent in rural areas. The age, capacity, and usage of the tank systems did not have a role in causing leaks either in the piping or the tank.

Background

Maryland is one of the few states with regulations which require precision tank testing. The deadline for testing tank systems 15 years and older was January 1987. The client had almost 250 tanks requiring testing. The testing program did not begin until September 1986. The primary goal of the program was to complete the testing of the tank systems in the short time available. Locating the position of the leak, in the piping, the tank, or in both areas was the secondary goal.

Maryland is made up of five geographic regions: the Eastern Shore, the Washington, D.C. area, the Annapolis/Southern Maryland area, and the Baltimore area. The Eastern Shore and the Annapolis/Southern Maryland area are characterized by interbedded sands, gravels and clays of the

Coastal Plain. The topography is gently rolling. The area is characterized by agricultural uses, tourist resorts, and small towns. The Washington, D.C. and Baltimore areas are composed of both crystalline rocks of the Piedmont Plateau and sedimentary deposits of the Coastal Plain. The Piedmont Plateau region is hilly, while the Coastal Plain region is flat. Both areas are highly populated urban centers. Western Maryland lies in the Appalachian Physiographic Province and is characterized by mountainous terrain. The area is rural, but a few medium-size cities are present.

The client's facilities required underground storage tanks for a variety of purposes. The tanks stored petroleum for automotive, power supply, and heating usage. The tanks ranged in size from 300 to 15,000 gallons and contained almost every type of petroleum product. Most of the tanks tested were steel. The following is a description of the tanks and their usage:

- Emergency Generator Tanks

  Typically 550 - 4,000 gallon capacity. Contents included diesel fuel or kerosene (K-1). Normally received fuel only once or twice a year.

- Heating Oil Tanks

  Capacity ranged from 1,000 - 6,000 gallons. Contain #2 fuel oil. Filled regularly in winter, not used during the summer.

- Waste Oil Tanks

  Usually small in size, 550 - 1,00 gallons. However, a few waste oil tanks were former gasoline tanks and, therefore, were as large as 4,000 gallons. Some had never been pumped out.

- Gasoline Tanks

  The largest of the tanks tested, 4,000 - 15,000 gallon capacities. Contents isolated to gasoline. Filled on a regular basis.

Most of these tanks are between 15 to 25 years old. Minimal maintenance and upkeep had been performed on them. Typically this maintenance was limited to the removal of excessive amounts of water in tanks and the normal disposal of waste oil in tanks. Extensive repairs were only initiated for extremely obvious problem situations.

Testing Methods

The Petro Tite Tank Testing System and the Horner EZY-Chek Leak Detector were utilized to perform the precision tank system testing. These methods meet NFPA 329 leak detection criteria and correct for the following variables:

- o water table
- o vapor pockets
- o tank end deflection

Both of these testing systems are temperature compensated hydrostatic pressure tests. Each requires that the tank and associated piping be overfilled with product; however, the Petro Tite system is able to test a tank system immediately after filling, while the EZY-Chek method can perform a test only after the product in the tank has stabilized (typically 8 to 12 hours). Actual testing time ranges from 2 to 8 hours for the Petro-Tite method and 1-1/2 to 4 hours for the EZY-Chek leak detector.

All testing systems have their limitations, but the combined utilization of these two methods allowed for the testing of almost all piping configurations with the least amount of modifications. Also, the EZY-Chek method is able to differentiate between the tank and associated piping without extensive excavaction.

Geographic Distribution

The tanks requiring testing were located throughout the entire state of Maryland. Many of the tanks were clustered in the metropolitan areas surrounding Baltimore and Washington, D.C. The remainder of the facilities were located in the sparsely populated regions of the Eastern Shore, Annapolis/Southern Maryland and Western Maryland. Distances between two tanks to be tested on any given day could be as much as 75 miles. Consequently, increased travel time decreased project progress. In addition, while urban areas were well documented on maps, towns in rural regions were merely indicated by a dot.

Analysis of Results

Number and Type of Failures

The precision testing program of the 243 unerground storage tank systems experienced a 40% failure rate. Eighty-two percent (82%) of these failures were due to piping leaks, while 18% were due to tank failures. Figure 1 describes the number of tests and reasons for failures in each of the five geographic provinces.

- o Eastern Shore

Nine of the 53 tank systems tested on the Eastern Shore failed. Eight failures were caused by piping leaks and one by a tank leak.

- o Annapolis/Southern Maryland

In the Annapolis/Southern Maryland area, twenty-six tank

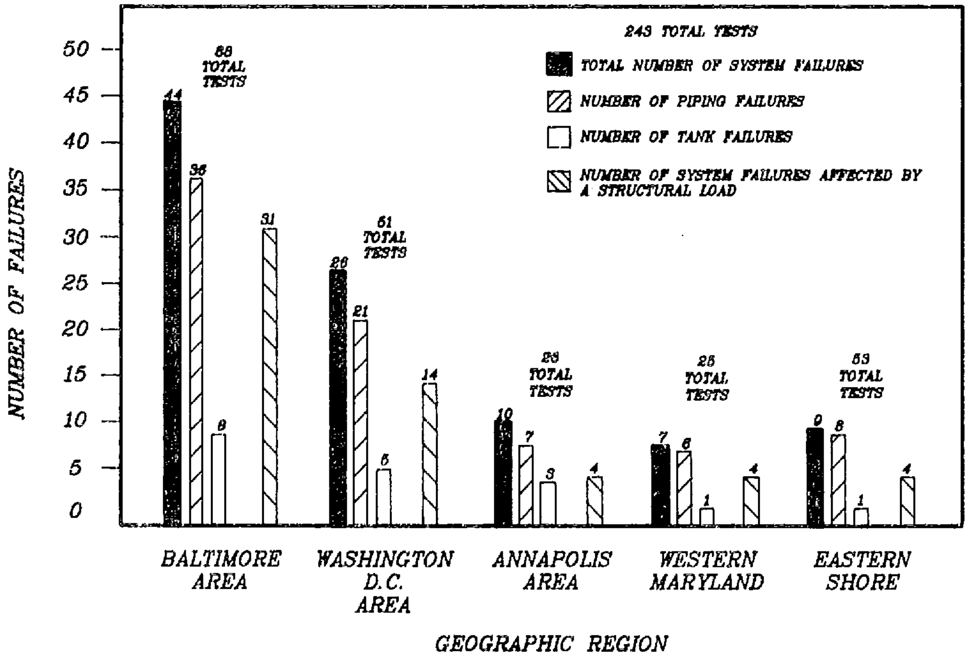


FIGURE 1

systems were tested and ten of them failed. Piping leaks caused seven failures while three failures were caused by tank leaks.

o Western Maryland

Twenty-five tank systems were tested in Western Maryland. All of the systems which failed were caused by piping leaks.

o Washington, D. C.

In the Washington, D.C. area, twenty-six of the 51 systems tested resulted in failures. Twenty-one failures were due to piping leaks and five to tank leaks.

o Baltimore

Eighty-eight tank systems were tested in the Baltimore area. Forty-four systems failed in this area. Thirty-six failures were due to piping leaks and eight to tank leaks.

Causes of Leaks

Piping leaks were a result of the following:

- o Corroded Fittings
  - Areas where threads were exposed experienced greater corrosion than surrounding piping.
  - Fittings of dissimilar material underwent accelerated corrosion.

- o Corroded Piping
  - Piping was pitted in localized regions or across the entire surface.
  - Sometimes corrosion was isolated to one piping; and at other times, affected all piping.

- o Loose piping & Fittings
  - Fittings installed "hand tight".
  - Piping, primarily fill pipes and vent pipes, which were dislodged due to vehicles hitting them.

- o Abandoned Piping
  - Piping no longer in use which was never properly plugged or capped.

Tank failures, where detected, were the result of:

- o Top of tank leaks
  - Bolts on manways were corroded, allowing seams/covers to loosen.
  - Screws and bolts fastening gauges to tanks corroded more repaidly.
  - Cracks radiating out from vent and/or fill pipes due to vehicles hitting piping above ground.
  - Separated seams.

- o Bottom of tank leaks
  - Pinholes in lower 1/3 of tanks.

Piping and fittings located at the tank top were the primary reasons that tank systems failed precision testing. Most leaked due to their corroded condition. Under normal operating conditions, these areas would contain petroleum product only intermittently. However, these leaks were exposed when the systems were overfilled with product.

Age

The criteria for performing precision tests on tank systems in the State of Maryland is 15 years old. Results of this testing program

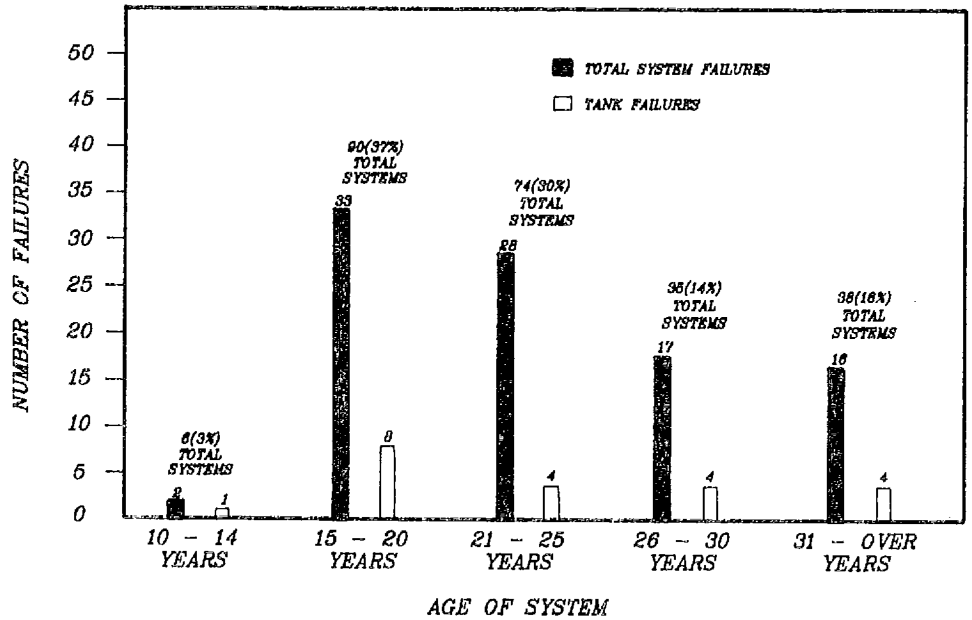


FIGURE 2

indicate that even though the percentage of failures increased with age, even young systems experienced a significant failure rate. Figure 2 depicts the total number of tank systems tested in each of five age groups: 10-14 years old, 15-20 years old, 21-25 years old, 26-30 years old, 31 years and older; and the percentage of systems in each age group. Although only six systems in the 10-14 year old age group were tested, they suffered a significant failure rate. As the age increases, the percentage of failures also increases until at the 26-30 year age group, the rate approaches 50 percent. The percentage drops only slightly at 31 years and older.

Of course, the longer a tank system remains buried, the greater the potential for a leak to occur. But these leaks are caused by other factors affecting the tank rather than strictly the age itself. Therefore, using age alone as a criteria for precision testing underground storage tank systems will not detect all the leaks that are occurring.

Tank Capacity

Proposed Federal underground storage tank regulations, at this time, exempt tank systems with capacities less than 1,100 gallons from conforming with testing requirements. However, analysis of testing results of the 243 tank systems revealed that the number of tank leaks was the same for capacities less than 2,000 gallons as for capacities greater than 2,000 gallons. This result holds true regardless of the region in which the systems were located. Therefore, any arguments for tanks with greater capacities having a higher probability for leakage cannot be validated by the testing results.

Tank Contents

Tanks containing heating oil for on-site consumptive use are exempt under the proposed Federal Underground Storage Tank Regulations. However, the State of Maryland Underground Storage Tank regulations do require the testing of these tanks. Sixty-one heating oil tank systems were tested. Thirty-nine of these systems failed testing resulting in a 64% failure rate. Seven failures were due to tank leaks and thirty-two failures were due to piping leaks. According to these results, systems containing heating oil for on-site consumptive use are no different than any other underground storage tank and do experience a significant percentage of failures.

Failure rates for other types of tank system contents tested are the following:

Contents	Number of Systems Tested	Number of Failures	Failure Rate (%)
Diesel	95	20	21%
K-1	52	26	50%
Gas	19	5	26%
Waste Oil	16	2	13%

Baltimore County Area

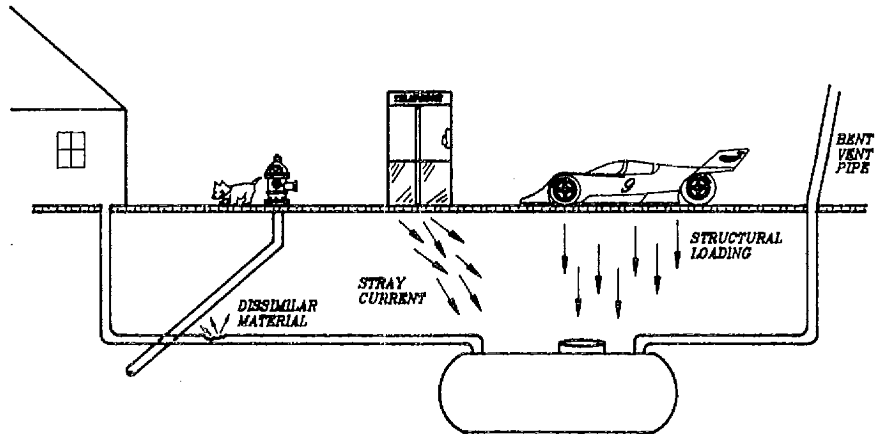
The majority of the failures encountered occurred in the Baltimore County area. This region did contain the highest density of facilities; however, a close examination of the characteristics affecting each failed tank system revealed that many influences caused leaks. These bad influences were concentrated in the Baltimore County area and included:

- Urbanization
- Geologic Environment

Either of these adverse influences may have been enough on their own to cause tank system failures in the other areas of Maryland. In the Baltimore region, these factors combined to create an unsuitable environment for unprotected steel tanks.

Urbanization

By far, the major influences compromising tank integrity were those characteristic of urban areas. These influences, which are summarized in Figure 3, are noticeably absent from most of the rural locations found in Western Maryland, the Eastern Shore, and the Annapolis/Southern Maryland area. The tank system failure rate was 50% in urban areas and only 25% in rural areas.



EFFECTS OF URBANIZATION
ON
UNDERGROUND STORAGE TANKS
FIGURE 3

An adverse environment for an unprotected steel tank is created in an urban setting by the following factors:

- o structural loading
- o dissimilar metals
- o stray currents

Structural Loading

Many tank systems in the Baltimore region were subjected to structural loading by being situated under driveways, parking lots, loading docks and sidewalks. Tank tops, standardly buried 2-1/2 to 3-1/2 feet below grade, and associated piping, typically 1 to 2 feet below grade were subjected to immense stress as cars and trucks passed over top of them. Other tanks were affected by their proximity to building foundations. In some instances, buildings had been expanded out over existing tanks. In one such case, a lunch room floor had to be torn up to gain direct access to test a tank. Tank systems existing in these conditions were not only influenced by the stresses associated with buildings, but also were probably disturbed during construction. Almost every tank which was subjected to some sort of load resulted in a precision test failure. In fact, 60% of al failures appear to be the result of structural loading. Piping, not designed to bear such loads, was usually the culprit.

At one location, the test was disturbed each time the tester approached to take a reading. Due to the tanks position, the tester had to stand on top of it to view the chart reorder. As he did this, the liquid level rose in the standpipe, indicating that even the seemingly insignificant weight of the tester applied a measurable load on the tank. Tests performed on tanks located next to driveways were affected in the same way when cars passed by.

Tank systems tested in the rural regions of Maryland lacked these stressful loading factors. Most were situated in grassy environs 15 - 20 feet from the buildings and driveways.

Dissimilar Metals

Galvanic corrosion was discovered in tank systems tested where dissimilar metals were in contact with one another. The dissimilar metals have differing potentials and generate currents which cause corrosion where the current leaves the metal possessing more the negative potential.

When tank tops and lines were exposed to investigate precision testing failures, several tank systems displayed the effects of galvanic corrosion. Dissimilar metals between lines and tanks, such as brass fittings connecting lines to tanks, acted as the cathode while the lines and tanks acted as the anode and corroded. Even steel piping bearing slightly different metalurgical properties than the associated steel tanks generated galvanic corrosion. In some cases, the potential differences between bare threads and the surface of the same pipe were great enough to cause the threads to corrode.

The influences of dissimilar metals became apparent at one location where a water supply pipe passed directly above an underground heating oil storage tank supply line. The supply line was badly scored with pinholes in the area where the two pipes contacted one another. Similar cases of galvanic corrosion produced by dissimilar metals occurred at other locations in the Baltimore County area.

Stray Currents

In urban settings, direct current pulses through the soil from numerous of sources. Potential sources include grounded equipment or wires, power supplies and electrified railways. These stray currents travel through the soil, flow through the tank system, then travel back to the source. Electrolytic corrosion occurs at the point where the current leaves the tank system. Stray currents can cause severe damage to storage systems in a very short time. (U.S. EPA 1986)

Observation of the areas neighboring tank systems in urbanized areas disclosed the fact that all of them were potentially being affected by at least one source of stray currents. An example occurred at one facility in the Washington, D.C. area. Large batteries inside the building were grounded outside the building approximately 20 feet from the piping for two storage tanks. Both tank systems' precision tests indicated piping leakage. Excavation revealed severely corroded piping and leaking bungs on the tank top. This facility is the same one mentioned as having corrosion problems associated with dissimilar metals. The pitting which occurred may have been accelerated by the stray currents existing in the area.

The frequency of tank system failures was by far the greatest in urban, especially big city, regions where the influences of structural loading, dissimilar metals, and stray currents are experienced. Although the Baltimore area, the most highly ubanized portion of Maryland, did h have the largest number of failures, the other typically rural regions also experienced system leaks caused by these influences. An example occurred in a relatively small city in Western Maryland where a tank system was buried beneath a sidewalk and between a busy street and a building. The precision testing had to be performed at night so that the tank would not be influenced by vehicles passing by on the street. Testing results indicated leakage and, indeed, a crack was discovered in the tank top. Two other tank systems in another nearby town also failed testing. Both were situated close to building foundations and grounded equipment was nearby. Other tank systems tested in the area were all in grassy rural areas and passed precision testing.

The cases of urbanized tank system failure occurring in an otherwise rural region substantiate the conclusion that urbanized areas create adverse environments for unprotected steel tanks. Although any of these influences could occur at any given location, the probability of a tank system experiencing them is much greater in urban settings.

Geologic Environment

The galvanic and electrolytic corrosion mechanisms discovered in urban areas are governed not only by the potentials involved, but also by the electrical resistances of the paths travelled by the currents. (Husock 1976) In underground systems, the soil is the medium through which the current must move. Larger corrosion currents are generated in soils having lower resistivity than those with higher resistivities. Soils containing a greater amount of clay than sand possess a lower resistivity.

Interpretation of the available geologic and soils information for Baltimore County revealed that much of this area may be ameniable to assisting in galvanic and electrolytic corrosion. The rocks in the Baltimore area may be classified into two general groups; the older hard crystalline rocks exposed in the Piedmont Plateau, and the younger soft unconsolidated sediments that lie above the crystalline rocks in the Coastal Plain. The crystalline rocks are composed chiefly of granite, gabbro, gneiss, and schist and have undergone stream erosion which transported the material to the depressed area to the east. The Coastal plain rocks are typified by irregularly bedded and lenticular, non-marine sands, gravels and clays.

There are three general soil groups which occur in Baltimore

County: residual soils, formed in place through the disintegration of and weathering of the underlying crystalline rocks; soils of the Coastal plain, formed by the weathering of unconsolidated sedimentary deposits; and alluvial soils, which represent recent water-deposited sediments along streams.

The igneous and metamorphic rocks of the Piedmont plateau have weathered into a stony or silty loam approxi- mately 8 to 18 inches thick. Underlying this loam is a clay or clay loam which occurs at about 8 to 12 inches below the surface. This clay typically extends to a depth of 24 to 36 inches and rests upon less weathered parent material. Fragments of the partially weathered bedrock may be encounted throughout the loam and clay.

The sedimentary materials of the Coastal Plain have produced sandy loams, silty loams and clays. The most important soil forming process in this area is the chemical and physical weathering of the parent material into silicate clay minerals. These minerals include kaolinite, illite, and montmorillonite. Information published in the soil survey of Baltimore County, Maryland (1973) states that the soils are characteristicly highly corrosive to unprotected steel.

The alluvial soils consist of silt, sand, and clay transported from the Piedmont Plateau and deposited in narrow strips along streams throughout the county.

The soils of Baltimore County, regardless of their origin, are predimonantly silty or clayey in nature. However, high resistivity sandy or gravelly soils are interspersed throughout the county, therefore we can not assume that the entire area's soils are corrosive to unprotected steel tanks.

However, in many areas the soil does create a good environment for the generation of corrosion currents. In particular, many of the areas possess a clay band that occurs at a depth of 12 to 16 inches and ranges from 10 to 18 inches in thickness. Tanks are typically buried 2-1/2 to 3 feet below ground surface placing the position of tank tops and, more importantly, of piping in this band of highly conductive clay. Hence, it is highly probable that the corosion of tank systems at many of the facilities in Baltimore County was accelerated by the material in which they were situated.

Conclusion

Investigation of testing failures revealed that piping leaks were much more common than tank leaks. Most of the piping leaks were associated with corroded threads and fittings in the vicinity of the tank top. The capacity of the tank, and consequently, the amount of tank surface area does not appear to have any influence in causing leaks.

Contrary to popular belief and the State of Maryland's criteria for testing underground storage systems, precision testing results indicate the primary cause of leaks was not a result of age, but rather a result of the environment directly influencing the tank systems. The affects of urbanization, particularly those of structural loading and corrosion, created the harshest environment in which an underground storage system must survive. These adverse affects were concentrated in the Baltimore area and appear, at some locations, to have been accentuated by the low resistivity clays characteristic of much of the region. In small cities located in the rural regions, these affects also occurred and resulted in tank system failures.

Obviously, as witnessed through the testing results, a precision testing program should not be based solely on the age or size of the system. However, a comprehensive assessment of each location should be made which takes into consideration the other adverse conditions which may be affecting the entire underground storage system.

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Biographical Sketch

Diane H. Heck is the Coordinator of the Underground Storage Tank Testing Program for Tetra Tech Richardson of Newark, Delaware. In addition, she has directed geohydrologic site evaluations and investigations for government and private clients. Ms. Heck holds a Bachelor of Arts degree in Geology from the University of Delaware and has additional training and experience in Emergency Response to Hazardous Materials.