New England Interstate Water Pollution Control Commission

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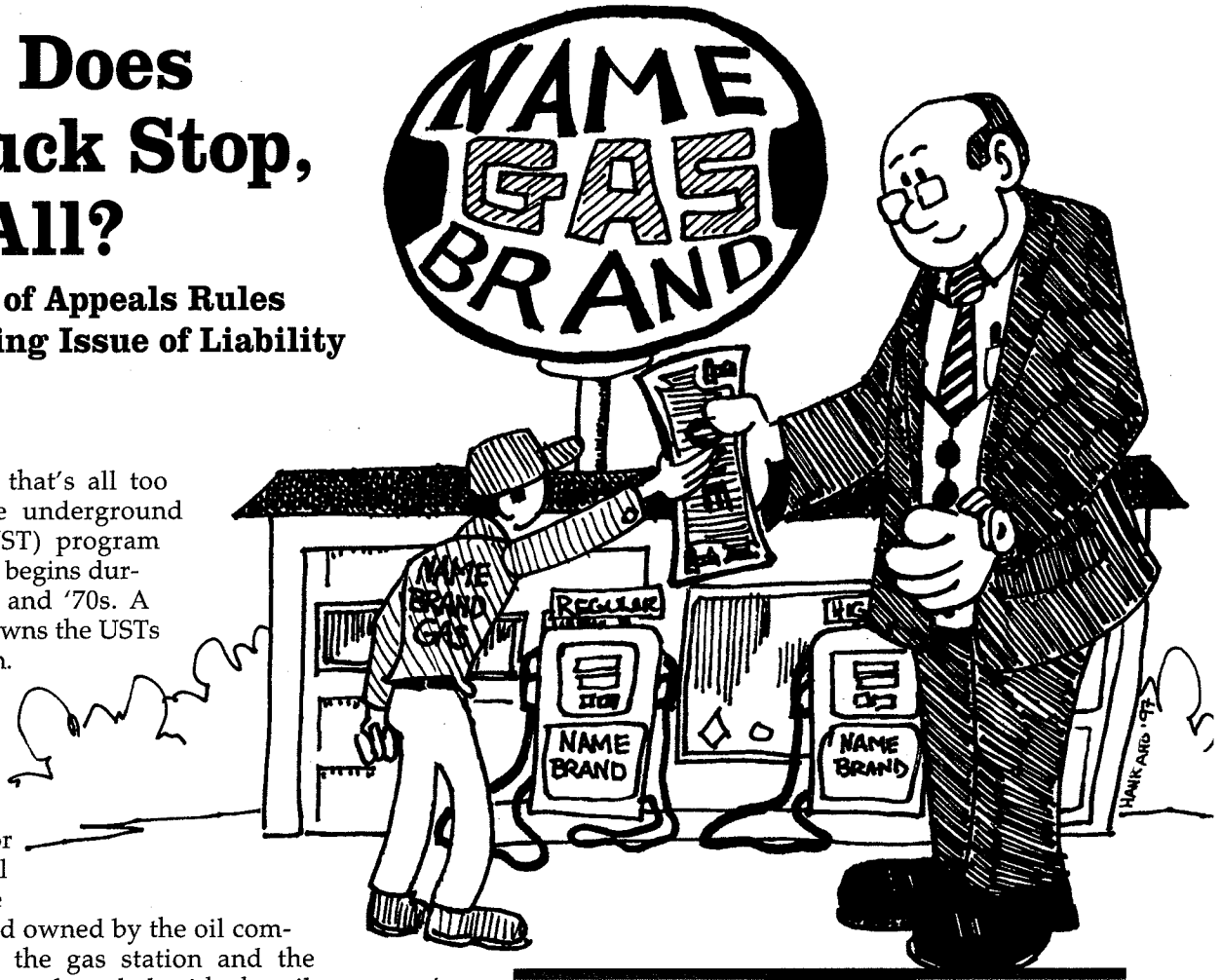
L.U.S.T.LINE

A Report On Federal & State Programs To Control Leaking Underground Storage Tanks

Where Does The Buck Stop, After All?

Indiana Court of Appeals Rules On the Lingering Issue of Liability

by Mary-Ellen Kendall



It's an old story that's all too familiar to state underground storage tank (UST) program personnel. The story begins during the 1950s, '60s, and '70s. A major oil company owns the USTs at a corner gas station. The property on which the USTs are located is owned by a small businessman, who also operates the USTs for the oil company. All of the product in the tanks is supplied and owned by the oil company. The signs at the gas station and the employee uniforms are branded with the oil company's name and logo. The gasoline is delivered to the station in trucks that display the oil company's name and logo. The oil company maintains control of both the USTs and the products sold at the gas station.

But by the 1980s, things would change. The catalyst for change, in part, was the issue of liability. By the mid-70s, the oil companies began to take more and more notice of certain fundamental and troublesome particulars associated with USTs: The vast majority of the USTs installed prior to 1980 were constructed of steel; the buried bare steel tanks are subject to corrosion; any corroding tanks eventually leak; the notion of leak prevention technology was mostly just a

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■ Where Does the Buck Stop?

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notion; station employees were unable to detect slow leaks from USTs by sticking the tank and keeping inventory records; the engineering expertise and financial resources necessary to solve the problem of slow leaks were beyond the capabilities of independent gas station owners; and leaking gasoline was a potential liability—it could find its way into the groundwater and pollute drinking water.

As these facts became apparent, the oil companies took steps to address the problem at the stations that they owned and operated. Corrosion-resistant UST technology became more prevalent. Oil company personnel were made aware of leaking UST issues and, in many cases, were trained to prevent, detect, and respond to leaks. This investment in storage system training and technology did not, however, extend to the independent station owners, who continued to operate their businesses using the same signs, logos, and products, but without the awareness of potential environmental problems.

LUSTLine

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In fact, the oil companies began to require the low-volume retailers to purchase the USTs outright. The tanks were often sold to the independent station owners at the bargain price of $1 per tank. At the time of the sale, there was generally no assessment of the integrity of the storage system or of the presence of any contamination. Because these retailers did not have the benefit of the knowledge about the environmental consequences associated with bare steel USTs, they didn't realize that the "bargain" they had just bought might make them liable for tens of thousands of dollars in damages and/or cleanup costs.

The ownership for many of these USTs was transferred prior to the time that federal laws governing the underground storage of petroleum were enacted. The Environmental Protection Agency promulgated regulations that set minimum standards for new tanks and required owners and operators of existing tanks to upgrade, replace, or close them. In anticipation of a leak occurring, UST owners or operators had to be able to demonstrate that they had the financial ability to pay for the costs associated with cleaning up the release and compensating third parties. If a leak did occur, UST owners and operators were held responsible for the cleanup.

As far as the oil companies were concerned, they were not responsible for any UST-related liability associated with facilities they had sold to independent station owners. It was quite another matter for the small retailers who unwittingly assumed that liability and later found they had a petroleum release on their hands. Many could not afford to stay in business. Numerous USTs at the closed gas stations continued to leak, unchecked. The oil companies that formerly owned the USTs had not been determined to be responsible parties for these cleanups... until now.

Will the Real "Operator" Please Stand Up?

On August 19, 1997, the Indiana Court of Appeals determined that oil companies that had supplied gasoline to USTs at an independently owned gas station were liable as UST operators for groundwater contamination caused by leaks from the USTs. (*Shell Oil Co.* v. *Meyer*, No.79A04-9512-CV-470 (Ind. App. Aug. 19, 1997).) It marked the first time that a court had extended operator liability to gasoline suppliers that neither owned nor maintained daily control over the leaking USTs.

The liability determination was based on events that began in 1946 and culminated in the discovery of contaminated drinking water wells in 1989. Fred Smith purchased property in West Point for use as a gas station. From 1946 until 1971, Smith leased the gas station to others who operated it as a Shell station. The employees wore Shell uniforms and sold only Shell products. When the bulk plant that supplied the gasoline switched from Shell to Union Oil in 1971, Union Oil's signs, uniforms, and products were used at the station. Smith died in 1979. The business remained in operation as a Union Oil station until it closed in 1981.

Kim Meyer lived in West Point. She noticed a petroleum odor in her well water in 1989. The local health department confirmed the presence of gasoline constituents in Meyer's well and wells belonging to five other homes in the neighborhood. The Indiana Department of Environmental Management hired a contractor, who eventually determined that the source of the contamination was the closed gas station formerly owned by Fred Smith. The Meyers and the other affected landowners sued Shell Oil Company, Union Oil Company, the current property owner, and Smith's widow in 1993.

The lawsuit had six grounds for liability of the oil companies: negligence, trespass, nuisance, strict liability for abnormally dangerous activities, operator liability, and antidumping (later deemed not relevant). The trial judge separated the case into two parts: common law grounds and operator liability. A jury heard the part of the case that dealt with liability based on common law grounds (negligence, trespass, nuisance, and strict liability for abnormally dangerous activities) and decided that Shell and Union Oil were not liable for damages.

The judge then tried the case dealing with the issue of the oil companies' liability under Indiana's

Underground Storage Tank Act ("USTA"). In 1995, the trial court found Shell and Union Oil liable under USTA as UST operators, awarded the landowners $2,743,660.21 for cleanup and $1,459,721.25 in attorneys' fees and costs, and required Shell Oil to pay 70 percent and Union Oil 30 percent of the award to the landowners. This August, on appeal, the Indiana Court of Appeals affirmed the liability of the oil companies as operators of the USTs.

Defining the Issue

The court began its analysis by reviewing the stated purpose of USTA, which is to preserve, protect, and enhance the environment to ensure clean air and water. The court then reviewed the definitions in USTA to determine what the legislature intended. As is the case in many states, the Indiana USTA adopted the definition of operator from federal law and regulations: "An operator is a person in control of, or having responsibility for, the daily operation of the UST." In the absence of a statutory definition of the terms "control" and "responsibility," the court used the "plain meaning" (i.e., the dictionary definition) of the words. The court agreed with the oil companies that they did not exercise direct influence (control) over the daily operation of the USTs.

The court did note, however, that control was only one factor in determining liability. Because the legislature created a two-part test (an operator could either exercise control OR have responsibility for the daily operation of the USTs), the court then looked at "responsibility for" the UST, which was defined as "moral, legal, or mental accountability."

This decision was the first time that a court had determined what constitutes operator liability under state UST laws, so there were no precedents applicable to *Shell Oil*. Using the history of the USTA and court decisions concerning operator liability under both the Resource Conservation and Recovery Act and the Comprehensive Environmental Response, Compensation, and Liability Act to support its decision, the court said that oil companies could be held liable as operators if they had the authority to control a facility, whether or not they actually exercised that authority.

Using the history of the USTA and court decisions concerning operator liability... the court said that oil companies could be held liable as operators if they had the authority to control a facility, whether or not they actually exercised that authority.

In applying this rule to the facts in *Shell Oil*, the court found that the oil companies did have authority over the USTs, as evidenced by their ability to force independent stations to stop selling leaded gasoline. The court also found that the evidence showed that the oil companies attempted to avoid liability when they required the independent station owners to purchase USTs in the 1980s. Quoting two prior cases from the Indiana Supreme Court, the appeals court concluded that:

> *A business should bear its own costs, burdens, and expenses of operation, and these should be distributed by means of the price of the resulting product and not shifted, particularly, to small neighboring property owners for them to bear alone. We can understand no sensible or reasonable principle of law for shifting such expense or loss to persons who are not involved in such business ventures for profit.* (Shell Oil *at 12.)*

The court found that attorneys' fees included costs for lawyers, paralegals, and expenses such as copying, but that the amount approved for fees by the trial judge was too high. Although the landowners were entitled to attorneys' fees for the USTA trial, they were not entitled to attorneys' fees for the jury trial, which the oil companies won. The case was remanded back to the trial court for a redetermination of the issues relating to the percent allocation of costs between the oil companies, the procedure by which the landowners will notify the court and the oil companies each time they withdraw money from the $2.7 million cleanup account (set up by the court for all the costs incurred, except legal fees), and the amount of attorneys' fees and costs that were incurred for the USTA trial. It is highly likely that the final decision on the issues in *Shell Oil* will be appealed to the Indiana Supreme Court.

Time and Many More Court Cases Will Tell

While this case is significant because no other court has held product suppliers liable as UST operators under federal or state UST laws, there are two Iowa cases in which the major oil companies were also found to have liability for USTs. (*Hagen* v. *Texaco Refining & Mktg.*, 526 N.W. 2d 531 (Iowa 1995); *Iowa Comprehensive Petroleum Underground Storage Tank Fund Board* v. *Amoco Oil Co.*, 883 F. Supp. 403 (N.D. Iowa 1995).)

Dean Lerner of the Iowa Attorney General's Office says that, as a result of these two cases, Iowa was successful in recovering $33 million in settlements with 11 major oil companies. Although the issue of operator liability was not the basis for the decision in the Iowa cases, Dean says that *Shell Oil* and the Iowa cases indicate a willingness on the part of the courts to find major oil companies liable for USTs under state UST laws.

These three cases provide a new ending for an old story. The sale of USTs for $1 to unsuspecting independent station owners has often resulted in the transfer of a financially crippling liability to either a small business owner and/or the taxpayers (through state cleanup funds or the federal LUST Trust Fund). If more courts in other states make similar determinations of liability for UST releases, oil companies may find in the future that the buck stops with them, after all. ■

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Leak Prevention

Tank-nically Speaking

by Marcel Moreau

*Marcel Moreau is a nationally recognized petroleum storage specialist whose column, **Tank-nically Speaking**, is a regular feature of **LUSTLine**. As always, we welcome your questions, opinions, and technical interests.*

PIPING'S PROGRESS

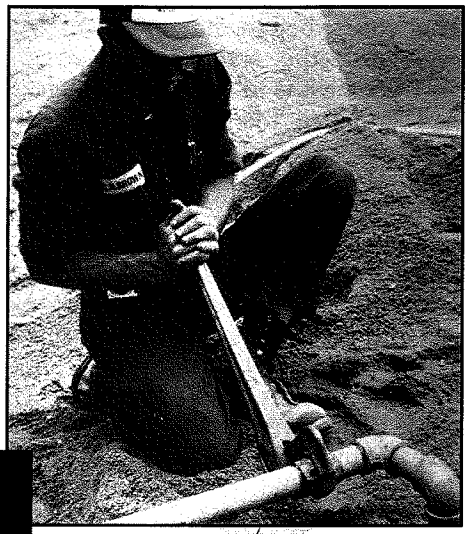
While Many Old Problems Have Been Solved, Piping's Not Out of the Hole Yet

A decade ago I wrote an article (LUSTLine #7) entitled "The Weak Spots in Piping." The article pointed out that the leaking tank problem actually had a lot to do with piping and that there were five major areas of concern:

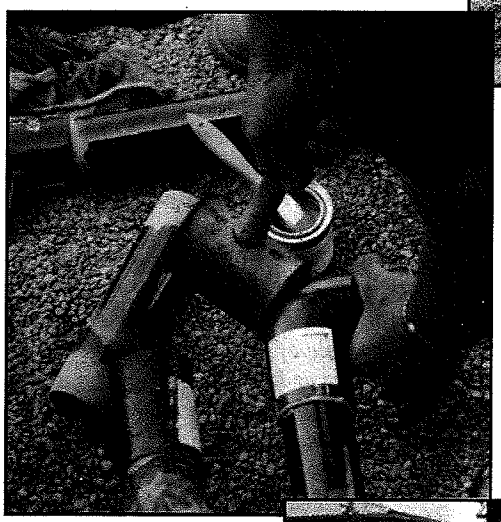
- **The use of unions** (steel pipe fittings used to join sections of steel pipe). Unions failed frequently when subjected to the stresses of the underground environment.
- **The use of swing joints** (a combination of steel pipe elbows and short lengths of pipe). Swing joints were supposed to permit flexibility in steel piping, but they were often a source of leakage and piping failure.
- **The use of fiberglass/metal connections.** These connections evolved during the period when there was no integrated system available for running piping from tank top to dispenser. Various materials needed to be joined together using less than ideal methods.
- **Improper installation.** Haphazard installation practices often led to premature, if not immediate, piping failure.
- **Lack of testing.** Testing piping prior to placing a system in operation was an often overlooked installation step that allowed many installation errors to go unnoticed until much later.

Today, I am happy to report that many of these problems are on the way out:

- Because steel piping is rarely seen at new installations, unions appear only at tank tops and under dispensers, where they are commonly surrounded by liquid-tight sumps.
- Swing joints have been replaced, for the most part, by flexible connectors.
- Piping systems have evolved from mongrels—made up of a variety of materials cobbled together—to integrated systems, which include the piping and all the specially designed fittings necessary to get the product from the tank to the nozzle.

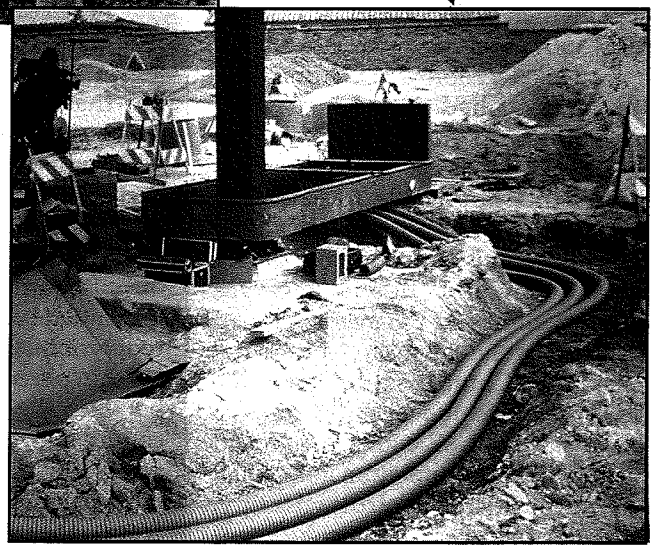


▲STEEL PIPING



◄FIBERGLASS REINFORCED PLASTIC (FRP)PIPING

▼FLEXIBLE PIPING



- The advent of flexible piping systems has simplified installation practices, by greatly reducing the number of field-installed connections.
- Testing piping prior to burial and before placing the piping in service is now routine.

So are the problems with piping solved? While most of the old issues have been addressed, I would venture to guess that most failures in storage systems installed in the last decade still originate in the piping. While technological improvements have solved many problems, the fact remains that knowledgeable, conscientious installers are a prerequisite for leak-free underground storage systems. This is especially true for piping, which is still very dependent on proper installation for long-term integrity. One of the lessons that a great many tank owners have yet to learn is that leak-free, quality construction is not synonymous with "low bid."

While the advent of new materials and methods in the realm of underground piping has addressed most of the old problem areas, it has also created some entirely new problem areas. As often happens with emerging techniques and technologies, the solutions to the new problems are not quite so clear-cut as the solutions to the old problems. Thus, we have some new piping questions lingering out there in search of answers. I don't know the answers, but there might be some value in exploring a few of the questions. Let's try these three:

- ***Where can low-melting-point materials be used?***
- ***Is it really necessary to slope piping?***
- ***How deep should piping be buried?***

Where Can Low-Melting-Point Materials Be Used?

Fires associated with gasoline are fearful events. Fire authorities have been concerned with preventing the escape of gasoline at gas stations ever since gas stations were invented in the early part of this century. The problem was fairly benign as long as tanks were buried and all pumping systems were suction-based. If a car knocked over a suction pump, only a little gasoline would be spilled because the pump ceased to function when the piping was broken.

But the introduction of the submersible pump in the mid-1950s upped the ante. With the pump in the tank and the piping operating under pressure, a knocked-over dispenser could result in a geyser of gasoline and, potentially, a serious hazard. However, a fairly straightforward solution to this problem was developed. Fire codes required the installation of a device variously called an "impact valve" or "crash valve" at the base of dispensers. Crash valves automatically close off the flow of gasoline at the base of the dispenser if the dispenser is knocked about or if a fire develops in the base of the dispenser. Thus, as long as all piping was buried, the situation was again under control.

If a fire should occur in a sump where fiberglass or flexible piping is exposed and if the submersible pump continues to operate, the piping could melt, and the specter of a geyser of flaming gasoline rears its ugly head again.

A new concern has emerged, however. It is associated with the widespread use of secondary containment and nonmetallic materials in piping systems. Before the days of secondary containment, fiberglass piping usually remained completely buried in backfill, and there was little risk that it would be exposed to fire sufficiently hot to melt the fiberglass and release more fuel into the fire.

With the advent of secondary containment and liquid-tight tank tops and under dispenser sumps, sections of nonmetallic piping are now commonly exposed to plain view (good for leak detection). However, these piping sections now risk potential exposure to a flammable liquid fire in the sump (bad for fire extinguishing). If a fire should occur in a sump where fiberglass or flexible piping is exposed and if the submersible pump continues to operate, the piping could melt, and the specter of a geyser of flaming gasoline rears its ugly head again. In this situation, the crash valve is rendered useless because the piping fails upstream of the crash valve location.

Underwriter's Laboratories (UL) is an organization whose mission is to evaluate the safety of consumer products. To achieve a UL listing, a product must undergo a battery of tests designed to establish whether it will present hazards under conditions similar to those expected to be encountered when the product is in service. Although galvanized steel piping, the traditional storage system piping material, has never achieved a UL listing, most piping materials and piping components in use today do have a UL listing.

UL listings come in a variety of flavors and colors depending on the testing that was completed on the product. In the area of service station piping, a product is typically listed for underground, aboveground, or underground/aboveground use. The distinction among the listings centers on whether the product is able to withstand fire exposure. The UL fire test consists of exposing the product to a pool of burning kerosene for 45 minutes. If the product passes the test, it earns an aboveground/underground listing. If it fails the test, or if the vendor chooses not to conduct the test because he or she knows what will happen, the product receives an underground use only listing. None of the nonmetallic piping (i.e., fiberglass, flexible composites) materials that I know about has passed this fire exposure test.

Flexible connectors, however, do come in two varieties: one listed for underground use only, and the other listed for underground or aboveground use. The underground/ aboveground variety of flex connector is, in general, constructed entirely of metal; the strictly underground variety uses nonmetallic materials to contain the liquid.

Fire codes initially held to their traditional restrictions on the use of low-melting-point materials. These codes stated that these materials should be used aboveground only when 1) suitably protected against fire exposure, 2) located such that leakage resulting from failure would not unduly expose persons, buildings, or structures, or 3) located where leakage can readily be controlled by operation of accessible, remotely located valves (National Fire Protection Association (NFPA) Code 30, Section 3-3.4, and Uniform Fire Code, Article 7901.11.1.2).

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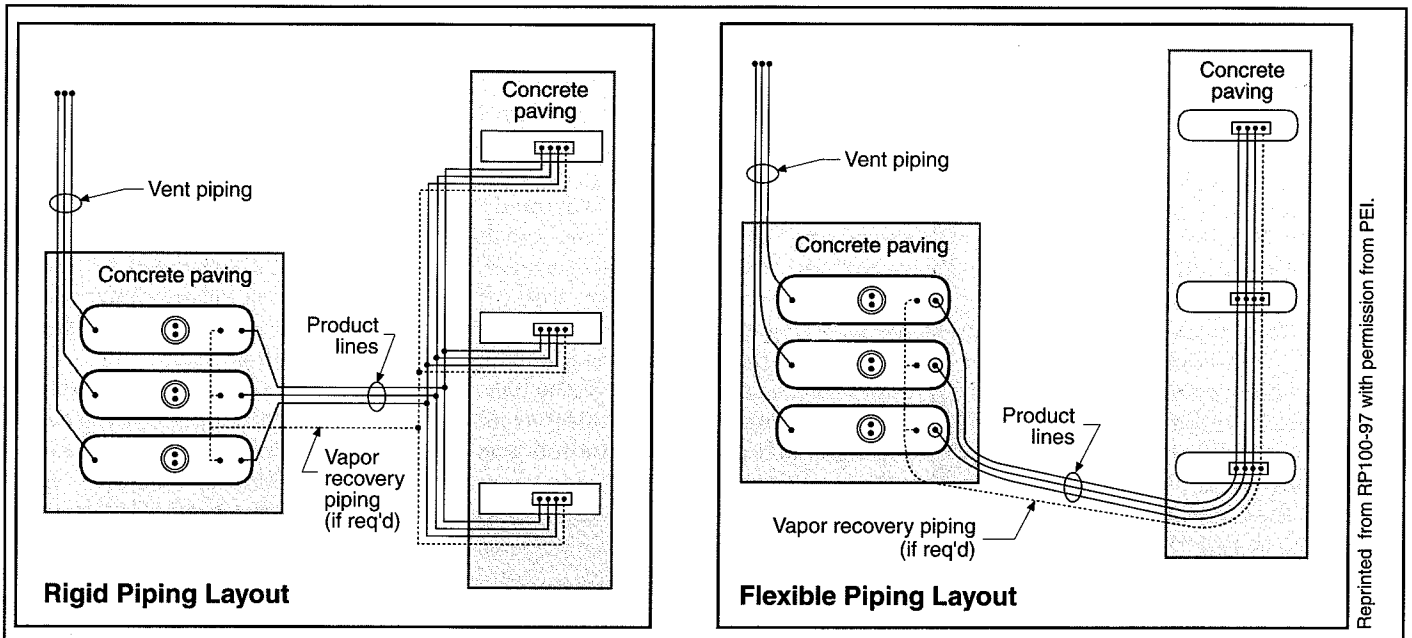

These diagrams illustrate the evolution of UST piping systems from rigid rectangular layouts with many buried joints to flexible, curved layouts with minimal joints in the system.

■ Piping's Progress *from page 5*

Terminating the low-melting-point material outside the dispenser sump (i.e., where it is surrounded by backfill and not exposed to fire) and using fire-resistant piping inside the sump are not what the piping manufacturers intended when they designed their systems. In addition, this convoluted design is rather inconvenient.

A possible solution to the dilemma is to add backfill to the bottom of the sump, thereby burying the low-melting-point materials. This approach somewhat defeats the purpose of the sump, however, in that it no longer allows for direct visual observation of piping and piping joints. It also complicates any future work on the piping because the backfill would need to be removed (most likely with small hand tools) to gain access to the piping.

Another solution is to install miniature fire extinguishers inside the sumps that automatically and immediately extinguish any fire that might occur. One manufacturer of flexible piping systems now offers such a device.

Another concern of fire personnel is whether or not a fire would be sustained in a sump. Theoretically, the oxygen in the sump would be consumed in a very short time, and the fire would die. So far, fire authorities do not appear to be convinced by this line of reasoning.

The 1996 edition of NFPA Code 30 now explicitly allows low-melting-point materials to be used in tank-top sumps that are usually remote from dispensers and the general public. The code still prohibits the use of low-melting-point materials in dispenser sumps that are in close proximity to areas where the general public is likely to be present. The 1997 edition of the Uniform Fire Code contains no similar provisions.

Is all this concern justified? How many fires have actually burned in sumps? I don't know. Does anyone have any stories they'd like to share?

Is It Necessary to Slope Piping?

Piping slope is another issue that's steeped in history. When all pumping systems were suction systems, piping that carried product had to be sloped because otherwise it was very difficult for the pump to remove all the air in the piping and operate properly. Piping slope became less critical for pressurized piping, but high spots could trap air that would restrict the effective diameter of the pipe and affect the performance of the piping system.

But this concern arose in the days of rigid piping with 90-degree bends. Recently, a representative from a flexible piping manufacturer pointed out to me that with the gentle curves and smaller diameters that are common in flexible piping systems, air pockets are unlikely even if the piping is not sloped uniformly. As a result, he explained, piping slope is not nearly as important to the proper operation of product piping as it used to be. It made sense to me, but I'd like to see some testing to verify this point.

But there are reasons for sloping the piping that go beyond efficient delivery of the product. For example, a uniform piping slope facilitates the draining of piping during repair work or removal.

Another rationale for sloping piping applies to double-walled pipe. Most secondary-containment piping systems are designed so that leaked product flows back to a sump (low spot) in order for the leak to be detected. This strategy is especially important for ducted systems, where the secondary containment is much larger in diameter than the primary pipe, and the interstitial space has considerable volume.

For coaxial secondary containment systems, where the secondary and primary pipe are installed as a single unit and the interstitial space is very small, it is likely that the small volume of the interstitial space and the pressure of the product from the primary pipe would cause the

product to flow quickly to the ends of the pipe, even if it had to flow up a few small hills.

The difficulty with sloping piping uniformly back to the tank top is that flexible piping configurations typically involve a single run of pipe that goes to a dispenser and then continues on to the next dispenser and then the next. This piping layout results in single piping runs that can be much longer than those of traditional rigid piping, where dispensers were fed from branches off of a single main line. If the piping is required to slope back to the tank top from the farthest dispenser, the depth of dispenser sumps and the burial depth of the tank could become excessive.

For example, piping is traditionally sloped 1/8 inch per foot of pipe, or about 1 foot of slope per 100 feet of pipe. A large, multiple-island facility might entail a 500-foot-long piping run, for a total slope of about 5 feet. Add to this the minimum burial depth of the piping (1.5 feet) and the fact that the piping is likely to be about a foot above the tank, and you end up with the top of the tank some 7.5 feet below the surface. An 8-foot-diameter tank, with 1 foot of bedding underneath, would, therefore, require a 16.5-foot-deep excavation.

This situation not only requires a deeper excavation that is more likely to encounter groundwater and need shoring or some other method of stabilization, but also incurs the expense of excavating and removing additional native soil as well as bringing in more proper backfill. The deep burial depth may also create a problem with the structural integrity of the tank; the maximum burial depth for fiberglass tanks is 7 feet and the burial depth recommended for steel tanks is one-half the tank diameter. (The maximum burial depth for steel tanks is also a moving target—see sidebar.) Maintenance on pumps that are 6 feet deep is also very inconvenient and quite possibly hazardous.

Industry-recommended practices such as API 1615 still specify uniform slope back to the tank. This requirement creates conflict between regulators, who insist that installers follow the industry practices, and the installers, who wish to avoid burying tanks any deeper than necessary.

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The most recent edition of the Petroleum Equipment Institute's *Recommended Practices for Installation of Underground Liquid Storage Systems* (PEI RP100-97) specifies that product piping must be sloped, but it does not require that the piping slope to the tank. Piping may slope to dispenser sumps or to intermediate sumps installed along the piping run. This alternative may result in the installation of more leak detection sensors in dispensers and intermediate sumps, but it allows for more traditional burial depths for the tank—even those with lengthy piping runs.

How Deep Should Piping Be Buried?

Based on industry-recommended practices, the minimum burial depth for piping has traditionally been 18 inches from finished grade. Adequate burial depth is important to protect the piping from traffic loading, frost movement, and accidental damage during future construction or remodeling activities. Some pipe manufacturers' instructions, as well as the 1996 edition of API 1615, however, now state that 18 inches is more than what is required, and they specify shallower burial depths.

I believe that this issue relates to the piping slope issue discussed earlier in that, if uniform piping slope to the tank is required, then a deeper minimum burial depth requirement for the piping equates to a deeper burial depth requirement for the tank. This means deeper tank excavations and a greater volume of appropriate tank and piping backfill materials are required to complete the installation. Deeper excavations and more backfill mean that the installation costs more money.

So how deep should piping be buried? I don't know, do you? ■

New Construction Standard for Steel Tanks

Beware the Maximum Burial Depth!

A recent change in UL 58, the construction standard for steel underground storage tanks, which went into effect on September 30, 1997, is worth noting. The thickness of steel plate used in building a tank is one of the factors that determines the pressure required to collapse the tank from external forces. In the old version of UL 58, the thickness of the steel plate to be used in constructing different sizes of tanks was specified as part of the standard. In the latest edition of UL 58, the thickness of the steel plate is left largely to the discretion of the tank manufacturer, with the caveat that each tank must bear a label indicating the maximum burial depth for that specific tank. The tank must also be able to withstand at least a 5-foot burial depth.

In other words, it is now possible for a tank manufacturer to produce an 8,000-gallon tank with a specified maximum burial depth of 5 feet, and an 8,000-gallon tank with a specified maximum burial depth of 8 feet. Because of the physics of the situation, the tank with the deeper burial depth will need to be constructed of thicker steel. Because steel is sold by the ton, the tank with a maximum burial depth of 8 feet will weigh more and cost more than the tank with a maximum burial depth of 5 feet. Thus, installers and regulators will need to verify that the planned burial depth for a steel tank is less than the maximum permissible burial depth indicated on the tank label. ■

Leak Prevention

EPA Issues Guidance on Alternative Integrity Assessment Methods for Steel Tanks

In order to maximize the number of USTs that will be upgraded in an effective, safe, and affordable way, EPA's Office of Underground Storage Tanks (OUST) issued a guidance document on July 25, 1997, that is meant to strike a balance among several competing interests. On the one hand, EPA is recommending that implementing agencies adopt a consistent policy on this issue; on the other hand, each agency retains the flexibility to follow its own policy if it chooses.

The guidance leaves the door open for the use of alternatives to human entry (i.e., corrosion modeling, video camera, remote ultrasound via robot). However, after March 1998, the door is open only if the alternatives meet certain attainable standards. While this approach allows flexibility on the part of industry, it discourages fly-by-night operators and substandard procedures. The guidance provides industry with two options that may be used to meet minimum recommended standards and with sufficient time to accomplish the necessary work. Finally, the guidance allows methods that are both affordable and protective, so that owners can meet the December 1998 deadline and avoid future leaks.

In essence, this final guidance recommends that agencies continue current policies until March 22, 1998. After that time, integrity assessment methods should either (A) meet a national code, or (B) be evaluated by a third party to meet certain performance criteria. Agencies should not require monthly leak detection monitoring for methods that meet option A or B, but they can consider a range of other conditions.

Option A - Standard Codes of Practice

No standard codes currently exist (ASTM ES 40 has expired). A draft replacement is currently in the ASTM process under Committee G-01. A draft was balloted once and is currently being revised. It will probably be reballoted in December. Thus, it is possible (although uncertain) that a new ASTM standard will be approved by March 1998.

Option B - Evaluation and Certification

No alternative integrity assessment methods have undergone third-party evaluation to date. However, the same process as is used for UST leak detection systems applies. An *EPA Quality Assurance Project Plan** that was prepared for a research effort provides a viable test protocol. Protocols that are more specific can be written by interested parties. The process will be carried out by the private sector. OUST will provide information on how evaluators can qualify and "short forms" so that evaluation results are reported in a concise, consistent format. Depending on how many vendors choose option B, states and EPA may want to form a work group to review evaluations, similar to the National Work Group on Leak Detection Evaluations.

What About Using Leak Detection Alone as an Integrity Assessment?

Although OUST recognizes the important role leak detection plays in preventing serious releases into the environment, it does not recommend that leak detection alone be considered sufficient to assess the integrity of USTs that are 10 years old or older.

What Next?

OUST will continue to monitor all integrity assessment code development and evaluation efforts, and pass along any new information to the states. ■

**For information about this document, contact Carolyn Esposito at (732) 906-6895.*

Tank Bits

$65 Million Appropriated For LUST Trust Fund

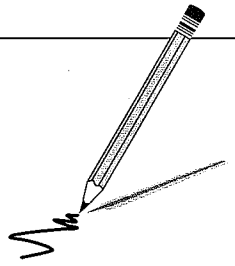
On October 27, President Clinton signed the Environmental Protection Agency's fiscal 1998 appropriations bill, which included $65,000,000 (to remain available until expended) of federal LUST Trust funding. The fund may be used for necessary expenses associated with carrying out leaking underground storage tank cleanup activities as authorized by the Superfund Amendments and Reauthorization Act of 1986, and for construction, alteration, repair, rehabilitation, and renovation of facilities. Congress directed that EPA distribute at least 85 percent of this funding to the states and use no more than $7,500,000 for administrative expenses. Other portions of this funding will be used by EPA to provide technical assistance to states, to assist with the implementation of the LUST program on Indian lands, and to support EPA Office of Research and Development (ORD) research efforts (primarily MTBE research). ■

U.S. Postal Service Pushes UST Improvements

The U.S. Postal Service has taken its UST responsibilities very seriously, spending more than $200 million since 1989 on tank replacements, upgrades, and closures; its UST population has been reduced from 10,000 to around 3,000 tanks. Postal Service management is pushing hard to make sure that all remaining tanks are in compliance with the 1998 deadline. Management offers its facilities managers both "carrots and sticks" to comply: (1) headquarters will provide full funding for all tank work done before December 22, 1998, but after that facilities will have to use money from their own budgets; and (2) facility managers can be fined (or even fired for gross violations) for violating both Postal Service and EPA UST regulations.

The Postal Service continues to take a hard look at whether each UST is necessary. A tank—even one installed recently and in perfect condition—may be removed if there is no longer a need for it, thus avoiding future problems and liabilities. The Postal Service is also converting the majority of its vehicles to run on alternative fuels to reduce its need for USTs altogether. ■

Qs and As



Leak Prevention

Where USTs are concerned, questions do pop up. Our answers are based on a carefully considered interpretation of the federal rule and, where available, on EPA guidance. Keep in mind, individual state requirements may differ from federal requirements. Your questions and comments are welcome.

Q. *Currently, I am using inventory control with periodic tightness testing to meet the release detection requirements of 40 CFR §280.41(a). There is one thing I don't understand. In recording fuel deliveries for use in inventory reconciliation, am I supposed to use gross gallons or net gallons?*

A. First, a word of explanation to readers who may not understand your question. When you receive a fuel drop, the amount delivered can be expressed as gross or net gallonage. Gross is a purely volumetric measure—think of gross volume as how many gallon cans you could fill from the delivery truck at the time of delivery. The problem with gasoline, however, is that its volume is very sensitive to temperature changes. Warm gasoline expands; cold gasoline contracts. As a result, there is actually less gasoline by weight in a gallon of warm gasoline than in a cold one—a tanker truck with 10,000 pounds of warm fuel could fill many more gas cans than the same truck filled with 10,000 pounds of cold fuel. It's the same amount of fuel, but the dispensed volumes are different.

Fuel distributors can compensate for this discrepancy by using net volume. Net represents the volume of product you would have if the product were brought to a temperature of 60 degrees Fahrenheit. The difference can be sizable. For example, if a tanker delivers 5,000 gross gallons of gasoline that's at an ambient temperature of 70 degrees Fahrenheit, its calculated net volume is only 4,965 gallons.

EPA generally recommends using gross rather than net measurements. While your distributor may have the capability of figuring net gallons, you most likely do not. The sales you make with your dispensers and the tank measurements you make with your wooden stick are gross measurements. If you don't treat deliveries as gross measurements, too, then you will be introducing errors into your inventory calculations. In the example above, for instance, you are already off by 35 gallons on the day of delivery, and that's only for a 10-degree temperature difference!

The use of gross gallons is only a general recommendation. In cold climates, fuel dispensing as well as fuel deliveries may be represented in thermally compensated net gallons, and the use of net figures may be more appropriate. Owners and operators of petroleum USTs should check with their local implementing agency for additional guidance on the use of gross or net measurements.

Q. *What is the basis for the federal threshold for suspecting a problem in inventory control records? I understand the 1 percent of throughput part, but why the 130 gallons?*

A. The origin of the 1 percent + 130-gallon standard for suspecting a problem in inventory records lies in a study funded by EPA in 1988. EPA commissioned the study in order to determine the threshold for suspecting a release through inventory control records. The long-standing American Petroleum Institute (API) standard of 0.5 percent of sales was the only standard around at the time, and EPA wanted to have it evaluated. In the study, 20,036 individual computerized inventory control measurements were reviewed, and some interesting conclusions were reached.

One disturbing discovery (from a regulatory standpoint) was that the 0.5 percent standard put forth by API resulted in a false-alarm rate of 30 percent. In other words, inventory records exceeded the 0.5 percent allowable variance 30 percent of the time, when no problem existed with the storage system. In addition to the "crying wolf" syndrome that this eventuality might foster in the regulated community, it was simply not desirable to have 30 percent of the storage systems using inventory control reporting releases every month.

A 1-percent standard would lower the false-alarm rate, but one problem remained. Any standard that is based solely on a fixed percentage is going to produce a high false-alarm rate at small-throughput facilities. For example, a facility with a 100,000-gallon per month throughput is allowed a 1,000-gallon variance each month, but a facility with a 1,000-gallon throughput is only allowed a 10-gallon variance. The whole theory of inventory control is based on the assumption that inventory errors in nonleaking storage systems are largely random and will tend to cancel one another out. Thus, it should not be too difficult to stay within the 1,000-gallon limit for a facility pumping 100,000 gallons. On the other hand, keeping inventory records accurate to within 10 gallons would be very difficult, because a single delivery error or measurement could easily exceed 10 gallons.

One way to escape the problem of high false-alarm rates at small facilities is to add a constant to the volume percentage that allows the small facility more wiggle room. The EPA study concluded that a threshold of 1 percent + 130 gallons would produce a false-alarm rate of 5 percent for inventory records. This number was consistent with the false-alarm rate allowed for other leak-detection methods. The downside of this threshold is that the probability of detection is 95 percent for a leak of 1.1 gallons per hour. The study also noted that these statistics were valid for retail-type facilities with storage capacities in the range of 500 to 50,000 gallons with throughputs of 1,000 to 10,000 gallons per month.

■ *continued on page 10*

■ Qs and As *from page 9*

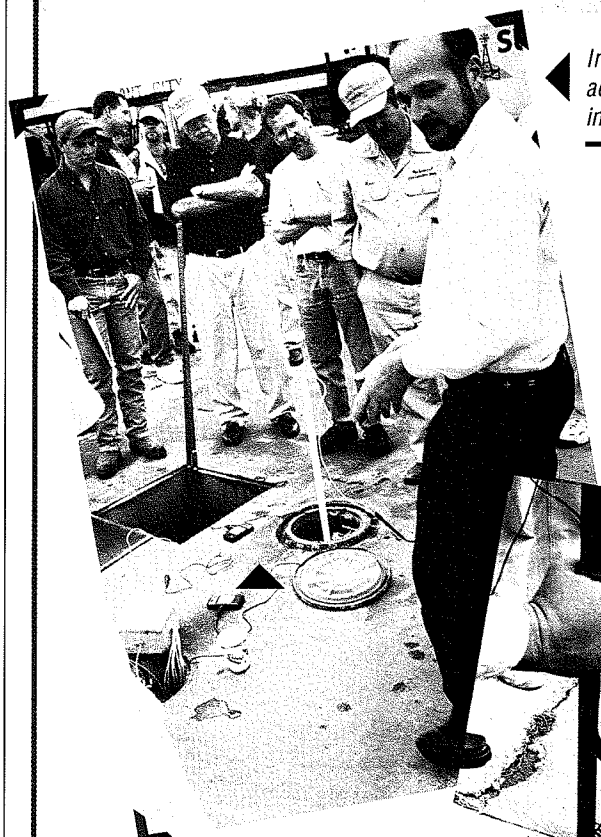
Q. *Owners and operators of USTs are required to demonstrate financial responsibility for taking corrective action and for compensating third parties for bodily injury and property damage caused by accidental releases. UST owners and operators may use one or a combination of mechanisms in 40 CFR §280, Subpart H, to demonstrate financial responsibility. If an UST owner/operator decides to switch from one financial responsibility mechanism to a different one, do any financial responsibility notification requirements apply?*

A. There are no specific federal financial responsibility notification or reporting requirements associated with switching from one UST financial responsibility mechanism to another. Owners and operators may substitute an alternative financial mechanism at any time, provided that financial assurance is always maintained (§280.111(a)).

UST owners and operators are, however, subject to the general reporting provisions of §280.110. Under these provisions, owners and operators must submit evidence of financial responsibility to their implementing agency in the event of a confirmed release or incapacity by a financial assurance provider. The implementing agency may also require reporting or a demonstration of compliance at any time.

SNAPSHOTS FROM THE FIELD

Liz Shepherd, an Inspector with the Kentucky UST program, sent us these snapshots from the field. In September, she attended a corrosion and cathodic protection testing training program in Bowling Green, Kentucky, for inspectors in EPA Region 4. She writes: "Over a period of three intense days, we learned basic theories of electricity and applied them in soup cans and then out in the field at UST facilities. Corrosion protection is more complicated than most of us anticipated! It was yet another reminder that it's not just UST facilities that shouldn't wait until '98—the inspectors have some catching up to do as well!"



Instructor Marcel Moreau advises inspectors on how to interpret the data.

Inspectors test a tank shell for continuity with other storage system components.

Inspectors examine a corrosion protection system test station.

If you have any UST/LUST-related snapshots from the field that you would like to share with our readers, please send them to Ellen Frye c/o NEIWPCC.

Field Notes

from Robert N. Renkes, Executive Vice President, Petroleum Equipment Institute

PEI's Recommended Practice for UST System Installation (RP100) Has Been Revised and Is Now Available

The federal underground storage tank regulations (40 CFR 280.20) require that all underground storage tanks and piping subject to these rules be properly installed in accordance with a code of practice developed by a nationally recognized association or independent testing laboratory and in accordance with the manufacturer's instructions.

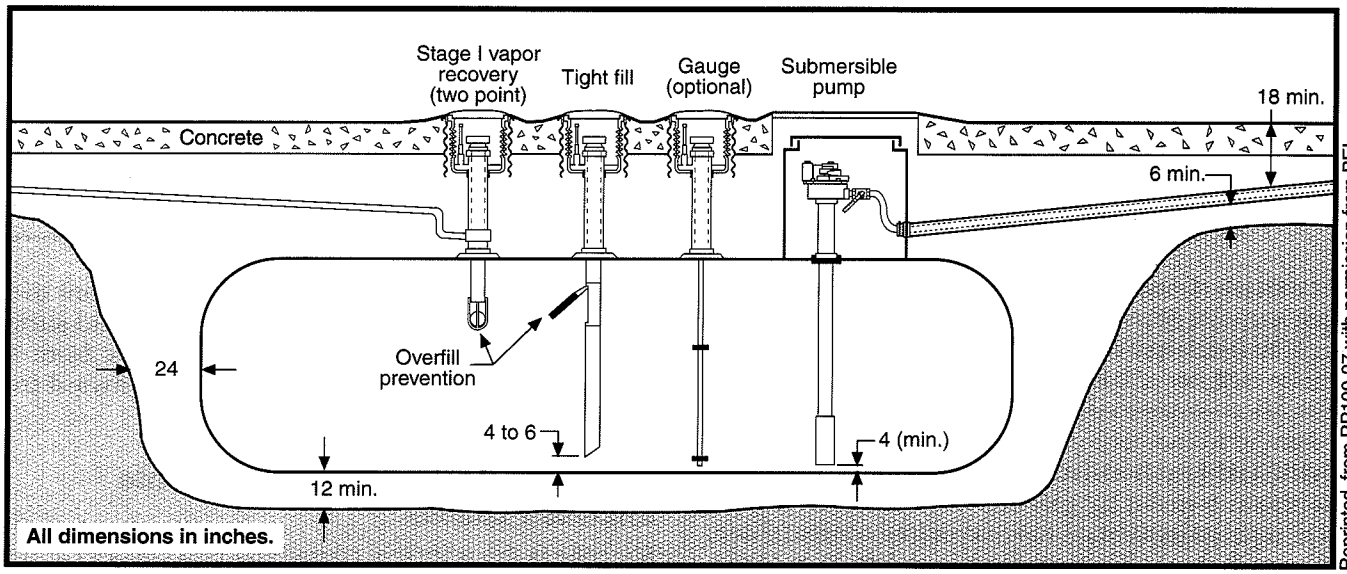
Of the three recommended practices mentioned in 40 CFR, only one, PEI's *Recommended Practices for Installation of Underground Liquid Storage Systems* (PEI RP100-97), has been updated on a regular basis since it was first published. The group responsible for writing the recommended practice, PEI's Tank Installation Committee, continually monitors changes in equipment and installation techniques and revises the document when circumstances warrant—PEI's RP100 has been revised about every three years since it was first issued in 1985.

The recommended practice has been revised once again and is now available to individuals and firms interested in the latest word on proper techniques and methods for installing underground storage tank systems.

Readers of the 1997 document should note that the recommended practice has undergone extensive changes. Three chapters (spill containment and overfill prevention, secondary containment, and leak detection) were completely rewritten. Significant additions were made to the flexible piping section of Chapter 9. Twenty figures were changed in some manner (see diagram), and extensive editorial revisions were adopted to make the text more readable and to clarify the meaning of some of the recommended practice's provisions.

The method PEI uses to amend the recommended practice is unique among trade associations in the petroleum marketing industry. While the Tank Installation Committee consists solely of PEI members who install underground systems, everyone involved in the UST community is given an opportunity to review and submit comments to revise RP100. For this edition, for example, 50 percent of the comments were received from tank manufacturers, 27 percent from regulators, 9 percent from tank installers, 7 percent from trade associations representing oil marketing groups, and 4 percent from industry consultants.

RP100-97 supersedes the previous recommended practice of the same name, published in 1994. Copies are available for $25 (includes postage and handling) from PEI, P.O. Box 2380, Tulsa, Oklahoma 74101-2380. Phone: (918) 494-9696. ■



Reprinted from RP100-97 with permission from PEI.

This cross section of an UST system illustrates the new graphic detail in RP100-97.

Investigation and Remediation

The Upward Migration of Vapors

by Blayne Hartman

A Note From The Editor: *Recent changes in environmental cleanup ideology and regulations have led to the increased application of natural attenuation as a remediation strategy and risk-based corrective action (RBCA) as a means for determining the cleanup requirements for contaminated sites. As these approaches are implemented, consideration must be given to the fate and transport of contaminant vapors in the subsurface and the potential risks they pose to human health. In this article, Blayne Hartman examines the processes by which vapors move through the vadose zone and the potential risk caused by the upward migration of vapors into an overlying building. He concludes by recommending a protocol for determining the upward vapor flux in the field.*

While I recognize that the technical nature of this article—not to mention the preponderance of daunting equations—may scare off some of you (it scared me), I also recognize that this type of timely information will be of value to those of you who are struggling with remediation issues. For completeness of information, I chose to retain all of the equations submitted with the article. It is easy enough, however, to skip over the mathematics and still benefit from the discussion. In a future issue of "LUSTLine," Blayne will discuss the potential risk to groundwater resulting from the downward migration of vapors.

How Do Contaminants Move in the Vapor Phase?

A common misconception associated with vapors emanating from a subsurface source of contamination (i.e., soil, fractured bedrock, groundwater) is that the vapors will preferentially rise upward and escape into the atmosphere, much like smoke rising from a smokestack. To understand why this idea is a misconception, you need to understand how the transfer of contaminants occurs in the vapor phase.

There are primarily two types of physical processes by which contaminants are transported in the vapor phase: advection and gaseous diffusion. Advection refers to the bulk movement of the vapor itself (e.g., the movement of vapor by wind). In advective transport, any contaminants in the vapor are carried along with the moving vapor. Advective transport processes can be important in the movement of soil vapor through the vadose zone (e.g., near the surface due to atmospheric pressure variations or near buildings that create pressure gradients due to differential heating).

Gaseous diffusion refers to the motion of the contaminants by molecular processes through a nonmoving vapor column. It is the primary transport mechanism for contaminants in the vapor phase through the soil vadose zone. Contaminant transport by gaseous diffusion is described by Fick's first law as:

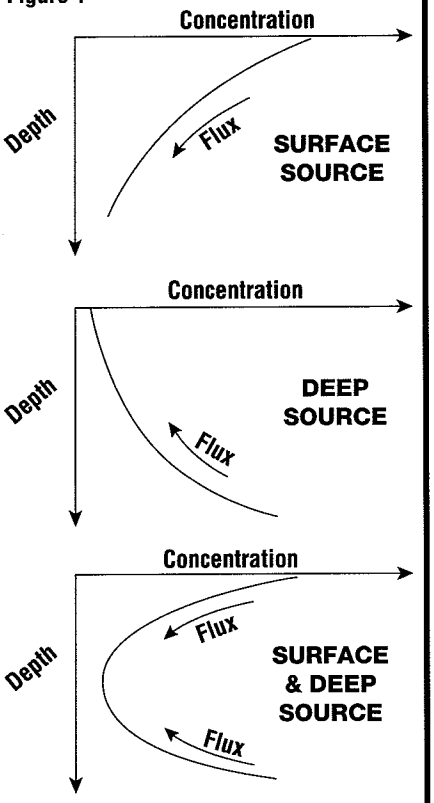
$$\text{Flux} = \frac{D_e * dC_{sg}}{dX}$$

Flux is the rate of movement of a compound per unit area.
D_e is the effective diffusion coefficient in the vadose zone.
dC_{sg} is the contaminant concentration gradient in the soil vapor.
dX is the depth interval in the vadose zone.

Similar to momentum transfer (e.g., water running downhill) and heat transfer (movement from hot to cold), contaminant transfer by gaseous diffusion moves from areas of high concentration to areas of low concentration. The flux will always be down the concentration gradient, regardless of the orientation of the concentration gradient with respect to depth below the surface. In the subsurface environment, diffusional transport occurs in all directions so contaminants move away from a source in all directions, similar to an expanding balloon. The key issues to remember are:

- Contaminant transport by gaseous diffusion does not move preferentially in one direction (e.g., up or down) but spreads out radially in all directions.
- The direction of movement is from high concentration to low concentration regardless of the orientation with respect to depth in the vadose zone. In other words, if high concentrations of a contaminant in the vapor phase are midway between the ground surface and the groundwater, the diffusive flux from the source will move both upward and downward from the source.

Figure 1

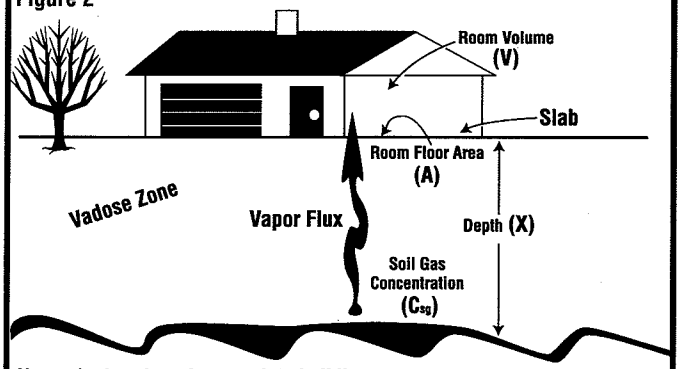


Common soil vapor profiles in the vadose zone for different locations of contaminant sources.

The Upward Migration of Vapors Into Enclosed Spaces

Benzene is the principal contaminant of concern at most sites because of its proven carcinogenity and common occurrence at gasoline-contaminated sites. Other common compounds of concern at fuel-contaminated sites

Figure 2



Upward migration of vapors into building.

include chlorinated solvents (e.g., vinyl chloride and tetrachloroethylene from oil sumps) and methane.

A simplified environmental fate and transport model for evaluating the inhalation exposure pathway for a contaminant is summarized in the 1995 ASTM Risk-Based Corrective Action (RBCA) Standard. The model assumes that contaminant vapor transport is by gaseous diffusion, that the contamination source is constant and nondiminishing, and that equilibrium conditions exist. Buildings with basements or subterranean structures, however, can create pressure gradients that initiate advective transport, which requires different assumptions than those presented in the following discussion. With these limitations in mind, the indoor air concentration of a contaminant (C_i) is computed as:

$$C_i = \frac{Slab * Flux * A}{V * E} = \frac{Slab * Flux}{Height * E}$$

C_i is the concentration in the room in µg/m^3.
Slab is the slab attenuation factor (unitless).
Flux is the contaminant flux into the room (µg/hr-m^2).
A is the room floor area in m^2.
V is the room volume in m^3.
Height is the room height in m.
E is the indoor air exchange rate (exchanges per hour, 1/hr).

As you can see, the indoor air concentration is dependent upon the flux, the height of the room, and the indoor air exchange rate with outdoor air. For residential buildings, an indoor air exchange rate of one room volume every 2 hours (or 12 exchanges per day) is typically used. Commercial buildings typically have faster exchange rates, which are obtainable from the architect or engineer.

In addition, the vapor flux is considered to be attenuated by the presence of a concrete slab or wall. The net result of the concrete is to decrease the soil vapor flux. For new or relatively new concrete slabs, an attenuation factor of 0.01 is typically used on the basis that approximately 1 percent of the slab consists of cracks that offer unrestricted vapor flow. For older slabs in poor condition, an attenuation factor of 0.10 gives a more conservative estimate of the reduction in vapor flux caused by the slab.

As described previously, the upward contaminant vapor flux into a building is computed by Fick's first law, using the gaseous diffusivity, corrected for porosity.

$$Flux = \frac{D_e * \Delta C_{sg}}{X} * 1{,}000$$

Flux is the rate of movement of a compound per unit area (µg/hr-m^2).
De is the effective diffusion coefficient in the vadose zone (m^2/hr).
ΔC_{sg} is the contaminant concentration gradient in the soil vapor (µg/L).
X is the depth below the surface (m).

For most cases, the contaminant concentration in the room air is negligible compared with the soil vapor concentration, so the measured soil vapor concentration (C_{sg}) can be plugged directly into the equation.

Calculation of the flux requires knowledge of the soil vapor concentration. In the absence of actual soil vapor data, soil vapor concentrations can be calculated from soil and groundwater data, assuming equilibrium conditions, using equations based upon Henry's law constants and soil-to-water partitioning constants. These equations (summarized below) can be found in the 1995 ASTM RBCA standard.

- **Calculating Soil Vapor Concentration from Soil Data**

The soil vapor concentration (C_{sg}) is computed based upon the equilibrium partitioning between the soil, moisture, and vapor phases as:

$$C_{sg}(\mu g/L) = \frac{H * C_{soil} * BD}{P_w + (K_s * BD) + (H * P_a)} * 1{,}000$$

C_{soil} is the concentration in the soil for the contaminant of concern (e.g., benzene). If the concentration values for the specific contaminant are not known, then the value may be estimated from its concentration in the fuel product as the mole fraction times the product concentration. For example, the concentration of benzene in soil may be estimated from TPH-gasoline data as the mole fraction of benzene (2.5 percent) times the TPH concentration.

- **From Groundwater with Floating Free Product or Soil with Free Product**

It is assumed that the vapor immediately above the groundwater is in equilibrium with the free product, based upon the contaminant's mole fraction and vapor pressure:

$$C_{sg}(\mu g/L) = \frac{VP * MW * MF}{RT} * 1{,}000{,}000$$

- **From Groundwater with Dissolved Contamination (No Free Product)**

It is assumed that the vapor concentration immediately above the groundwater is in equilibrium with the groundwater, and the concentration is given by the water concentration times the dimensionless Henry's law constant:

■ *continued on page 14*

■ Upward Migration of Vapors *from page 13*

$$C_{sg}\ (\mu g/L) = (C_{water} * H)$$

For the preceding equations:

VP is the contaminant vapor pressure in atmospheres.
MW is the molecular weight of the contaminant in g/mole.
MF is the mole fraction of the contaminant in the free product.
RT is the universal gas constant times temperature equivalent to 22.4 µL/µmole at 0 °C & 24 µL/µmole at 20 °C.
H is the dimensionless Henry's law constant.
C_{soil} is the contaminant soil concentration in mg/kg.
C_{water} is the contaminant water concentration in mg/L.
BD is the bulk density in g/cm^3.
P_w and P_a are the water porosity and air porosity, respectively (unitless).
K_s is the soil water distribution coefficient in cm^3/g.

Using these equations, it is possible to compute the maximum soil concentrations, water concentrations, and soil vapor concentrations versus depth from the surface that will yield room concentrations that meet acceptable EPA levels. These values are shown in the following table for benzene.

Depth bgs (ft)	Soil (µg/kg)	Water (µg/L)	Soil Vapor (µg/L-vapor)
5	20	120	25
10	40	240	50
20	80	480	100
50	200	1200	250
100	400	2400	500

bgs = below ground surface

Assumptions used in computing the tabulated values:

Air porosity:	0.2
Total porosity:	0.3
Bulk density:	2.0 (g/cm^3)
Slab factor:	0.01
Exchange rate:	0.5 (1/hr)

Acceptable room concentration for benzene at the 1 in 1 million cancer risk level: 0.24 µg/m^3.

This summary demonstrates that, based upon the assumptions used in the upward risk calculation, only modest concentrations in the soil, soil vapor, or water are required to result in room air concentrations that fail the acceptable levels. For some compounds with lower acceptable room concentrations (e.g., vinyl chloride ~11 pptr), the allowable soil and groundwater values can approach laboratory detection levels.

You must recognize, however, that the equations used to calculate the soil vapor concentration from soil phase data, water phase data, or free product assume equilibrium partitioning between the phases. Equilibrium partitioning is obtained only if a system is well mixed. This condition is very rarely accomplished in the subsurface, because there are no blenders or stirrers present to homogenize the vapor, soil, and groundwater.

A common analogy used to illustrate this mixing concept is the preparation of a salad dressing using oil and vinegar. When the ingredients are initially added to a container, they fall into separate layers; the container must be shaken to mix the ingredients. If the container is not shaken, the oil and vinegar mix very slowly, "equilibrium is not reached," and the resulting salad dressing does not taste very good.

In addition to the issue of equilibrium partitioning, the equations do not account for other processes that are operative in the vadose zone, such as bioattenuation, advective flow, and soil heterogeneity.

For these reasons, calculated soil vapor concentrations generally do not accurately represent actual soil vapor concentrations, and, in the case of fuels, calculated values often overestimate actual soil vapor concentrations by 10 or 100 times. The potential error in the calculated vapor flux introduced by the incorrect vapor concentration is likely to be greater than errors introduced by other parameters, such as porosity. Thus, in the event that a site fails the upward risk calculation from existing soil or water data, direct measurement of actual soil vapor concentrations near the surface is likely to be the easiest and fastest way to verify whether concentrations will pass acceptable levels.

Which Soil Vapor Method to Use?

A number of states are currently trying to decide which soil vapor method is the best one to employ for determining upward migration risk. Three methods are commonly employed to measure soil vapor contamination: active, passive, and surface flux chambers. A full discussion of the various measurement techniques is beyond the scope of this article. I will, however, present some summary thoughts here.

- **Active soil vapor methods** (withdrawal of the soil vapor from the subsurface and subsequent analysis of the vapor) give concentration data, which are required for calculating the contaminant flux using Fick's first law. Further, vertical profiles of the soil vapor concentrations can be obtained to aid in determining the direction and magnitude of the flux. Active soil vapor data can be collected and measured in real time, enabling decisions to be made in the field.

  The problem most often raised with active soil vapor data is whether the concentrations measured at any given time and day are representative of normal conditions (i.e., how "stable" are active soil vapor data?). Variations caused by factors such as barometric changes or building pressures are known to exist; however, they are difficult to quantify. These effects are known to lessen with increased depth below the surface (or away from the building), and it is generally considered that data collected from 3- to 5-foot depths are fairly stable.

- **Passive soil vapor methods** (burial of an adsorbent in the ground with subsequent retrieval and measurement of the adsorbent) provide a time-integrated measurement and, therefore, reduce the uncertainty associated with the temporal variations described above. Passive methods also are generally easier to

implement. However, passive soil vapor methods yield soil vapor data only in terms of mass, not concentration. Therefore, a "conversion" of the data from mass units to concentration units needs to be performed prior to determining the health risk. The primary assumption required in making the conversion from mass to concentration is the volume of vapor that passed by the buried adsorbent during the burial time period. There is no easy way to estimate this volume. Thus, the resulting values have a high degree of uncertainty. Further, because passive collectors are buried so close to the surface (generally 2 feet or less), the measured values are highly influenced by any near-surface effects.

- **Surface flux chambers** are enclosures that are placed directly on the surface (e.g., ground, floor) for a period of time (e.g., generally a few hours to a few days), and then the resulting contaminant concentration in the enclosure is measured. By dividing the measured concentration by the incubation time, a direct value for the flux is determined. This method offers advantages over the other two methods because it yields the actual flux of the contaminant out of the ground, which eliminates some of the assumptions required when calculating the flux by Fick's first law (e.g., effective diffusivity, influence of a cement slab). This technique, however, is not as fast or easy to implement as the other methods, is subject to near-surface effects (e.g., the stability of the measured fluxes), and provides no clues about what may be "hiding" below.

The bottom line is that each of the soil vapor methods has advantages and disadvantages for determining upward vapor risk; however, all are potentially applicable. Which method to use on a given site depends on the site-specific goals and the logistical limitations. In my view, the active soil vapor method offers less uncertainty and more versatility than the other methods in most situations.

A Protocol for Determining the Upward Migration Risk by Soil Vapor Measurement

Based on the discussion above, I recommend the following procedure for collecting soil vapor data near the surface for the purpose of determining the upward vapor flux into a room or enclosure.

1. Collect active soil vapor data at 5 feet below ground surface (bgs) at the location of highest contaminant concentration. If the location of highest contaminant concentration is unknown, collect soil vapor data at 5 feet bgs spatially, across the site, to identify the location of highest concentration.
2. Calculate the health risk as outlined above. If the risk calculation indicates that upward vapor poses no threat to human health, then this pathway may be eliminated as an exposure route, assuming the plume remains stable or diminishes.
3. If the risk calculation indicates that upward vapor migration may pose a threat to human health, then collect soil vapor samples at 5 feet bgs at the corners of the building or room to determine the spatial variation of the flux across the area of concern.
4. Recalculate the health risk using the average flux from all of the soil vapor locations. If the risk calculation indicates that upward vapor migration poses no threat to human health, then this pathway may be eliminated as an exposure route, assuming the plume remains stable or diminishes.
5. If the risk calculation indicates that upward vapor migration may pose a threat to human health, then repeat steps 1 through 4 at 3 feet bgs.
6. If the risk calculation still indicates that upward vapor migration may pose a threat to human health, then the soil vapor concentration at a shallower depth (i.e., <3 feet bgs) needs to be determined. Measured concentrations this close to the surface can be greatly influenced by soil vapor collection technique and atmospheric air infiltration caused by barometric pumping. Thus, "time-averaged" data may be appropriate to ensure that the measured soil vapor values are representative.

Time-averaged data may be collected using either active or flux chamber soil vapor techniques. With active methods, a sampling tube should be left in the ground and the soil vapor analyzed multiple times to demonstrate consistency in concentrations over time. I recommend that data be collected at 1-foot intervals and from 1 to 3 feet bgs to ensure that vertical variations are characterized adequately. Alternatively, a flux chamber may be emplaced to measure the flux directly. The time duration for the flux chamber should be long enough to enable adequate measurement of the contaminant.

For subsurface enclosures, such as basements or utility trenches, the same protocol can be used; however, soil vapor samples should be collected from 3 to 5 feet below the floor, rather than below ground surface. It may also be necessary to consider the potential flux through the walls as well as through the floor. In this case, the total flux into the room would be equal to the flux through the floor times the combined surface area of the floor and the walls. Alternatively, a soil vapor measurement may be made on each side of the wall (3 to 5 feet away from the wall) so that the flux through the wall can be computed separately. The total flux into the room would then be computed by summing the individual fluxes through the floor and walls.

Soil vapor data should be collected and analyzed using protocols that satisfy the local regulatory agency. Required detection levels are contaminant-specific and depend on acceptable room air concentrations. For example, for benzene, vinyl chloride, and tetrachloroethylene, detection levels of 0.1 μg/L-vapor (~30 ppbv), 0.05 μg/L-vapor (20 ppbv), and 1.0 μg/L-vapor (144 ppbv), respectively, are required. ■

Blayne Hartman, Ph.D., is Vice President and Technical Director of TEG, Inc., in Solana Beach, CA. This article is an excerpt from a chapter on soil vapor methods and applications written by Dr. Hartman for a book titled "Legal and Technical Considerations for Hydrocarbon Contamination," soon to be published by Argent Communications Group in Forest Hill, CA. For more information, or for a copy of the entire chapter, contact Blayne by e-mail at: bh@tegenv.com.

Investigation and Remediation

Three-Dimensional Sampling

A Vertical Perspective on Cleaning Up LUST Sites

by Gary A. Robbins

Once groundwater contamination occurs at an UST site, it typically takes a Herculean effort to bring the site to closure. In fact, UST sites that have experienced groundwater contamination are rarely "cleaned up." A number of factors contribute to this dismal situation. Through our research here at the University of Connecticut, we've found that an important contributing factor, if not the most important contributing factor, is the glaring lack of a three-dimensional perspective on contamination.

If I could give just one piece of advice to environmental consultants and regulators involved in tackling fuel releases at UST sites, it would be: Conduct multilevel sampling of groundwater and soil. Unfortunately, in this respect, common practice falls short. It is common practice to use monitoring wells to assess groundwater contamination and to locate product. Contamination varies with depth below the water table (see page 17), and wells provide vertically averaged information over their screened interval. It is also common practice to evaluate this information in a two-dimensional perspective, known as the "plume map."

But, such a perspective can be rather misleading in evaluating the contamination. Take a look at any plume map you have in your office and ask yourself: Is the plume 6 inches thick or 30 feet thick? Is the plume just below the water table or is it very deep? Is the plume plunging with depth or rising? The answers to these questions could well have a significant bearing on your understanding of the risk posed by the contamination, the remediation strategy chosen and the effectiveness of that strategy. Yet, these answers cannot be derived from data that completely ignore the vertical dimension.

If you knew that the groundwater contamination at a site was limited vertically to just a foot below the water table, would you attempt remediation by installing and pumping a near-field well that went 25 feet below the water table? If you knew that groundwater at a site was flowing in an upward direction through the contaminated sediment, would you put hundreds of thousands of dollars into drilling monitoring wells into underlying bedrock? If you knew that product was trapped within 2 feet below the water table and that the water table was only 5 feet down, would you remediate the site by investing in a series of wells to inject nutrients to a depth of 20 feet below the water table? I think not. Yet, as we have observed again and again, ill-suited remediation schemes for these types of site conditions are all too common. These ill-suited decisions can, more often than not, be traced to the lack of a three-dimensional perspective.

Into the Next Galaxy

As noted above, wells are used to detect mobile product. Wells cannot, however, detect immobile product in the unsaturated zone or immobile product trapped below the water table. As we have found, however, immobile product may be the primary source of groundwater contamination at UST sites.

Although multilevel sampling of soil is common practice, such sampling is generally restricted to the unsaturated zone and little attention is given to sampling the soil below the water table. It is as though the water table represents some Star Trek-like energy barrier at the edge of the galaxy that can't be crossed using soil sampling tools.

Our research at UST sites indicates that remediation efforts could be greatly improved if multilevel sampling were conducted both above and below the water table. Since 1989, we have conducted multilevel groundwater and soil investigations at sites where gasoline releases have occurred. In general, these sites have relatively shallow depths to groundwater, generally less than 20 feet. Site geology has ranged from compacted tills (silt) with very low permeability to highly permeable sand and gravel deposits.

Irrespective of site geology, we have observed, at site after site, that product becomes entrapped below the water table. For that matter, there have been sites where most of the product is entrapped below the water table. Despite its low density, petroleum product may become entrapped below the water table when the water table fluctuates. How?

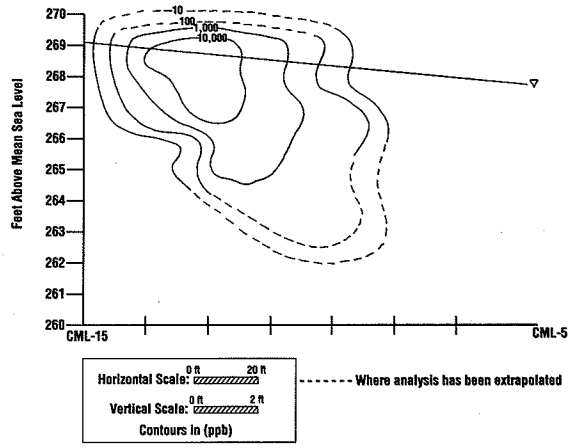
Because fuels have a very low solubility in water, they form a concave lens, or meniscus, when in contact with water in soil pore space. On the water side of the meniscus, the water adheres to soil grains. For product to rise to the water table, it must have enough buoyant force to overcome the adhesive force holding the water onto the soil. The strength of adhesion (or capillarity) is a function of the pore size (grain) of the soil. The water is held more tightly in fine-grain soils than in large-grain soils.

The buoyant force of the product is a function of the volume of product in the pore space. If product starts out as a mobile layer on the water table and is smeared into small globules when the water table falls, the globules may not have sufficient buoyancy to float up to the water table when the water table rises. This process leads to product entrapment and immobility below the water table. Product entrapment can also occur if the release starts from below the water table, as is the case with partially submerged tanks. In these cases, once entrapped, product becomes a continuous source of groundwater contamination, as contaminants slowly move from the product into the groundwater.

Vertically Speaking

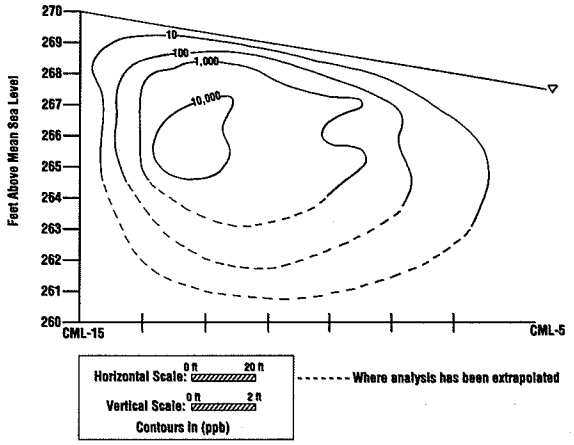
To effectively remediate product releases at UST sites, one must locate and delineate entrapped product below the water table as well as evaluate the three-dimensional distribution of the groundwater contamination. Interestingly, we have observed that most of the entrapped product tends to be close to the water table within a relatively narrow

Figure 1



Cross section of benzene soil contamination at an UST site.

Figure 2



Cross section of benzene contamination of groundwater at an UST site.

vertical zone—on the order of 3 to 6 feet. (See the example in Figure 1.) The vertical extent of entrapped product appears to correspond to the zone of water table fluctuation or somewhat less.

If near-field pumping has disturbed a site, the vertical extent of contamination may be greater. For example, at one site where the water table was on the order of 15 feet below the ground surface, entrapped gasoline was evident 15 feet below the water table. This deep-seated contamination corresponded to the maximum depth of drawdown achieved by a near-field well that was used years before in an attempt to recover product. It would appear that pumping resulted in product drainage and entrapment well below the water table. Again, as this example illustrates, if you don't know the vertical distribution of contamination, you can do something that can make matters worse.

With respect to the three-dimensional distribution of groundwater contamination, we have observed that this contamination tends also to be rather vertically restricted, even at significant distances from the source. (See the example in Figure 2—note the vertical exaggeration.) Typically, the contamination exhibits very little vertical dispersion and very high vertical concentration gradients. Near the source, the vertical extent of groundwater contamination tends to be similar to the product distribution. Beyond the source, the contamination exhibits very little additional vertical spreading, on the order of a few more feet. We have observed that groundwater contamination typically plunges with distance from the source, owing to the infiltration of fresh water on top of contaminated water. The fresh and contaminated water tend to exhibit little mixing.

The Technical Wherewithal

In the past, even if one wanted to conduct multilevel sampling below the water table at UST sites, the practice was inhibited by the costs for sampling and laboratory analysis and the lack of regulatory acceptance. Today, with the application of direct-push technologies in conjunction with field screening, the three-dimensional characterization of fuel contamination can be achieved in a cost-effective manner. A number of reliable and innovative tools and methods are available for conducting multilevel groundwater sampling and for soil sampling below the water table.

Clearly, there is a growing regulatory acceptance of the three-dimensional approach to site assessment. A number of states and the U.S. Environmental Protection Agency have published guidance on applying direct-push technologies and multilevel sampling and performing expedited site assessments. We have developed guidelines for performing multilevel sampling in conducting expedited site assessments for the Connecticut Department of Environmental Protection (DEP). (See *LUSTLine* Bulletin #26.) The guidelines contain the following information: reviews of methods for multilevel sampling for groundwater and soil; practical guidance on the application of methods; the results of studies to resolve key issues associated with conducting multilevel sampling; comparisons of results from different multilevel sampling methods; assessments of statistical uncertainties; and comparisons of results obtained by conventional groundwater monitoring wells and by multilevel sampling.

To provide further guidance on integrating multilevel sampling, field screening, and three-dimensional data evaluation in the context of conducting an expedited site assessment, we are developing guidance for the DEP in the form of a CD-ROM. The CD, which should be available in September 1998, will present the guidance material in a multimedia format that will include slide presentations, PC video, modules for performing calculations, and case studies. The CD will be designed to serve as a tutorial, a reference, and a guide for regulators, their consultants, and the regulated community on evaluating three-dimensional information at UST sites. Such an evaluation should go a long way in helping to solve problems that have historically defied resolution. ■

Gary Robbins is a professor in the Department of Geology and Geophysics at the University of Connecticut in Storrs, CT. For more information, contact Gary by e-mail at Robbins@uconnvm.uconn.edu.

MTBE Update

New National Science and Technology Council Report Provides a Comprehensive Summary of Oxygenated Fuel Issues

This June, the National Science and Technology Council released its *Interagency Assessment of Oxygenated Fuels* report, which presents current understanding of critical scientific issues related to oxygenates in gasoline. The assessment was undertaken by the Council in response to an Environmental Protection Agency request for a comprehensive, interagency review of the winter oxygenated gasoline program for potential health impacts, fuel economy and performance issues, and benefits. The document provides an authoritative evaluation of existing information and helps to identify areas where the data are too limited to draw conclusions about the impacts of the oxygenated fuels program.

The report identifies areas where the data are insufficient to make definitive conclusions about the costs, benefits, and risks of using oxygenated fuels in place of conventional gasoline. It also identifies where research is needed to help reduce uncertainties and allow a more thorough assessment of human exposure, health risks and benefits, and environmental effects. To get a handle on these uncertainties, several federal agencies are developing plans to expand monitoring and research efforts on occurrence of oxygenates in drinking water, the extent of human exposure to oxygenates, probable effects of human exposures, site remediation, and impacts on aquatic life.

The interagency assessment considers four main issues associated with the oxygenate program: air quality, groundwater and drinking water quality, fuel economy and engine performance, and potential health effects. Each of these subjects is addressed in a separate chapter. Each chapter underwent extensive external peer review before it was submitted for review to the National Research Council of the National Academy of Sciences. The entire assessment was reviewed by the National Science and Technology Council.

To obtain a copy of this report, contact GCRIO User Services by mail: 2250 Pierce Rd., University Center, MI 48710; by phone: (517) 797-2730; by fax: (517) 797-2622; or by e-mail: help@gcrio.org. ■

OUST to Release Series of MTBE Fact Sheets

OUST is developing a series of seven fact sheets on MTBE. Each of the fact sheets will focus on a specific topic. Fact sheets 1, 2, and 3 are called *Overview, Remediation of MTBE-Contaminated Soil and Groundwater*, and *Use and Distribution of MTBE and Ethanol*. The remaining fact sheets will cover the U.S. EPA health advisory, analytical methods for fuel oxygenates, impacts of MTBE releases on state UST programs, and potential oxygenate substitutes for MTBE. Illustrations and tables will accompany the text. OUST is planning to distribute hard copies of the fact sheets to states (including field offices), regions, and federal facilities. OUST anticipates that the first three fact sheets will be ready for distribution in early 1998. OUST will also post the fact sheets (in WordPerfect 6.1) on its web site at (http://www.epa.gov/ OUST/ mtbe/ mtbepubs.htm); you will be able to download them. ■

New Testing Requirements Will Help California Regional Water Quality Control Board Keep Tabs on Oxygenates

Gordon Lee Boggs, Underground Tank Manager at the Central Valley Regional Water Quality Control Board in California, has been learning more about gasoline oxygenate compounds than he'd ever hoped to know. He knew that MTBE and ethanol were principal players in the gasoline oxygenate arena, but then he found out that there were other common oxygenates in the arena as well—specifically, methanol, tertiary butyl alcohol (TBA), di-isopropyl ether (DIPE), ethyl tertiary butyl ether (ETBE), and tertiary amyl methyl ether (TAME). To get a handle on the situation, the UST program expanded its testing requirements to include soil and water analyses for TBA and the ether compounds to determine which oxygenated compound is present.

"We learned," says Boggs, "that the oil companies trade gasoline around the state and around geographic areas, which means, of course, that these different oxygenates are being traded around as well. When a gasoline release occurs, we won't know what's out there and where unless we test for it. We're finding out that more and more things are out there, but we don't know what to do about them at this time. We decided that by requiring testing for these constituents, we'll have the opportunity to locate problems and compile a database."

Once the Board got its facts together and established its testing requirements, Boggs wrote a "To Whom It May Concern" letter to spell out the facts. His letter, originally dated 18 July 1997, has undergone a few revisions and has generated a great deal of interest in the LUST community. Here is a slightly abbreviated version of the letter:

> Ethanol has been used for several years in California. MTBE, as you know, has been used as an octane enhancer since the late 1970s and is now used at a higher percentage as an oxygenate in gasoline. Now we have learned that TAME has been added to California fuels since 1995. DIPE has been used on the East Coast, but recently has been found in Southern California groundwater and San Joaquin County. TBA has been found in groundwater at a service station site in San Joaquin County. To date, we have no information about the use of ETBE in California.
>
> The introduction of these additives presents analytical problems for laboratories because the multiple analytes can co-elute from the column. For instance, TAME may co-elute with benzene in the EPA analytical method commonly used today. [See "MTBE—Beware the False Positive" in *LUSTLine* #26.] Therefore, we believe that Mass Spectrometry (MS) is the most definitive procedure for determining oxygenate compounds. MS will likely increase the cost of sample analysis; but, until another comprehensive analytical method is developed that can distinguish between compounds, we believe that EPA Method 8260 is the most reliable, readily available procedure

for laboratories. Completion of proposed studies on analytical procedures for oxygenate compounds by the Lawrence Livermore National Laboratory in early 1998 should provide additional guidance.

The problem of identifying which oxygenates are present is further complicated because of gasoline swapping; the oil refineries ship gasoline around the state and then trade gasoline among geographic areas. As a result, we don't know what oxygenate compound might be in the gasoline at a particular station—and what will end up in the groundwater if there is a release.

Research recently completed by DuPont-Dow (http://www.dupont.com/products/viton/lkprev.html) shows that oxygenates may be incompatible with some elastomer seals used on UST piping. One short-term test (168 hours) that used several concentrations of MTBE showed swelling could occur with some elastomers at current gasoline mixture levels. Presumably, this will be true, to some extent, for all ether oxygenate additives and conceivably, over a longer time, cause the failure of the seals, thereby releasing the oxygenated gasoline into the environment. We are particularly concerned that older tank seals or material used to upgrade tanks may not be compatible with the oxygenates and may fail due to high concentrations of oxygenates in the alternative fuel sources. [In the next issue of *LUSTLine* we will have an article on this compatibility issue.]

On 14 August 1997, a workshop was conducted at the Sacramento office of this regional board. It was attended by representatives of regional and state boards, local implementing agencies, analytical laboratories, and the petroleum industry. The objective was to provide guidance to the regulated community on how and where to analyze for the oxygenated compounds in gasoline until a definitive protocol can be established in several months. The goal was to allow closure of underground tank sites with assurances that the interim methodology can detect and quantify oxygenates.

The workshop attendees concurred that the methyl and ethyl alcohols can't be detected by EPA Method 8260 with certainty and that detection limits for methyl and ethyl alcohols are about two orders of magnitude higher than TBA and the ethers. Also, with the exception of one oil company and special, alternative fuel vehicles, ethanol and methanol are used infrequently in California and can be isolated by station and the more analytical methods used. Therefore, at this time, unless ethanol or methanol are specifically requested, we are requiring soil and water analysis only for TBA and the ether compounds by EPA Method 8260 in order to determine which oxygenated compound is present.

Presence or absence of the oxygenate must be reported whenever gasoline range hydrocarbons are present. However, because free product or high petroleum concentrations raise the detection limits of the oxygenates, the oxygenates cannot be detected with certainty. Therefore, at this time, we do not recommend sampling where product is present on groundwater.

Quarterly water samples for oxygenate compounds are to be taken from all monitoring wells at sites with ten or fewer wells. At sites with more than ten monitoring wells, requests to change the sampling procedure must be approved by the regional board or local implementing agency. Soil samples should be analyzed beneath the primary leak source(s) (i.e., tank, pipeline, dispenser) at regular depth intervals to the groundwater interface. If only MTBE is found in the initial sampling/analysis, as confirmed by 8260, the responsible party may continue analysis for the oxygenate by EPA Method 8020. Prior to requesting site closure, a "confirming round" must be completed for all oxygenate compounds.

Laboratories must include all listed oxygenated standards (TBA and ethers) in their calibration standards and follow the QA/QC protocol detailed in EPA Methods 8000 and 8020, or 8240-B or 8260, and the Code of Federal Regulations (CFR title 40, parts 136.4 and 136.5).

In addition to the compounds discussed above, we have found that both tertiary amyl ethyl ether (TAEE) and isopropyl alcohol (IPA) may also be added to gasoline; PRIST® (ethylene glycol monomethyl ether) is added to aviation fuel and, reportedly, some diesel fuels to prevent clogging of the fuel lines by microorganisms. PRIST is registered as a pesticide with antimicrobial properties: CAS#000109864. These compounds may be added to the analysis list as more information becomes available. ■

For more information on this issue, contact Gordan Lee Boggs at (916) 255-3139.

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We welcome your comments and suggestions on any of our articles.

A NOTE ON THE STATE FUND STATISTICS ON PAGE 28 OF LUSTLINE #26:

Because of the many questions regarding the high value for "average (cleanup) cost per site" in 1997, Vermont Department of Environmental Conservation staff took a closer look at all of the reported values for individual states. They discovered that, in fact, one state had misinterpreted the question. That state recalculated its cost per site and came up with a number that was considerably lower than originally reported. This new value, in turn, had a significant effect on the national average. Hence, the figure of $107,975 has been reduced to $60,158 as an average cost per site in 1997.

Bulk Copies of '98 Deadline Materials Available

With December 1998 only a year away, the EPA is sending a letter to EPA regional program managers and state UST program managers to remind them that OUST can provide bulk quantities of materials on the 1998 deadline.

New Publications from OUST

• ***Underground Storage Tanks: Requirements and Options*** (EPA-510-F-97-005). This leaflet reminds UST owners/operators who do not sell petroleum products but who may fuel vehicles from their own USTs (nonmarketers) that they need to comply with UST requirements. A list of additional documents and ordering information are included. All materials listed urge readers to check with state and local regulatory authorities for additional or more stringent requirements.

• ***Controlling UST Cleanup Costs: Fact Sheets*** (EPA 510-F-97-006). Five fact sheets originally published in May 1992 are reissued in this new compilation, which includes an update page noting new materials. The fact sheets have not been altered. They cover: hiring a contractor; negotiating the contract; interpreting the bill; managing the process; and understanding contractor code words.

• ***Straight Talk on Tanks: Leak Detection Methods for Petroleum Underground Storage Tanks and Piping*** *(Third Edition)* (EPA 510-B-97-007). The *Third Edition* of this popular booklet contains updated and revised text, a page clarifying the time restrictions applicable to the combination of tank tightness testing with either inventory control or manual tank gauging, more information on finding help and free publications using toll-free numbers or OUST's web site, and notice of the availability of the publication *List of Leak Detection Evaluations for UST Systems*. Please note that the booklet urges readers to check with state and local regulatory authorities for additional or more stringent requirements.

• ***Are You Upgrading an Underground Storage Tank System?*** (EPA-510-F-97-009). This leaflet, which is for UST owners and operators who are facing upgrade decisions, can help them make sound decisions about choosing tank integrity assessment methods and upgrading USTs to meet 1998 deadline requirements. Please note that the leaflet urges readers to check with state and local regulatory authorities for additional or more stringent requirements.

EPA HQ UPDATE

All of the materials listed above can be downloaded (in WordPerfect 6.1) from OUST's World Wide Web home page at http://www.epa.gov/ OUST/. Printed copies are available from NCEPI at (800) 490-9198 or via EPA's toll-free hotline at (800) 424-9346.

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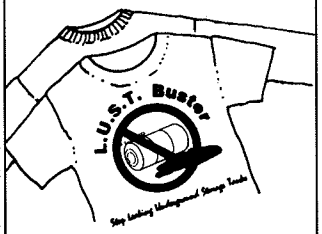

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