Secondary Containment of Large Aboveground Storage Tanks

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To line or not to line...
In previous issues of PE&T, Philip Myers has provided incisive articles on detecting and preventing leaks in large aboveground storage tanks (ASTs): “How to Find Leaks in Large Aboveground Storage Tanks,” April, page 36; and “Preventing Leaks in Large Aboveground Storage Tanks,” May, page 46. In this article, Philip describes the concept of secondary containment of large ASTs, related codes and standards, and various types of containment systems and materials. He also airs the controversial question as to whether liners should be mandated for secondary containment areas.
The concept of secondary containment of flammable and combustible liquid storage systems originated several years ago through efforts by the National Fire Protection Association (NFPA). The concept is, simply, that containing petroleum liquids that are leaked or spilled from storage and distribution systems prevents the associated fire/explosion hazard from spreading to adjacent property. As with leak prevention and detection concepts, secondary containment has been adopted by state and local authorities as an environmental protection measure, as well as a fire safety measure.

Some controversial issues have arisen on just how liquid-tight or impermeable the secondary containment area of a large AST field needs to be. Should impermeable liners be required in such areas? Before discussing this question further, let’s consider some basics about secondary containment of large aboveground tanks.

Figure 1: Aerial view of dike containment in AST field. Photo courtesy of Chevron.

What is secondary containment?
Secondary containment for ASTs is defined as capturing the entire contents of the largest tank in the containment area in the event of a leak or spill. Doing so allows sufficient time for cleaning up the product before it moves beyond the secondary containment envelope and poses a more serious safety and environmental contamination hazard.

Secondary containment usually consists of some combination of dikes, liners, ponds, impoundments, curbs, outer tanks, walls or other equipment capable of containing the stored liquids (see Figure 1). The most common forms are dikes and berms (see Figure 2).

Secondary containment can be as simple as mounding up earth in the area to form earthen dikes, or as complex as constructing a steel-reinforced, liquid-tight concrete slab and coating it with an epoxy finish. In most cases, the simpler earthen-dike system is satisfactory. But there are several factors that should be considered in evaluating what kind of system is adequate for new or existing facilities. Some of the important factors are as follows:

- Regulatory requirements
- Required minimum containment volume
- Permeability of the containment system and liner (if used)
- Substance(s) being stored and the properties that affect release containment
- Site conditions, environmental sensitivity, leak detection and monitoring systems
- Release cleanup (sometimes the use of liners actually impairs the ability to clean up and remove a spill and contaminated soil)

These factors are discussed in the remainder of this article.

Figure 2: Secondary containment showing berm and dike, courtesy of Chevron.

Designing the system

When considering secondary containment, it is usually considered in conjunction with the entire facility drainage plan, which includes storm water drainage. Storm water cannot be drained to navigable waters if it is contaminated; therefore, it is important to segregate those areas with a high potential for spilled hydrocarbons and treat them accordingly. Such areas may include pump and equipment slab areas, tank car and truck loading areas or process areas. These areas are usually directed to some kind of oil separation or processing unit, such as an oil/water separator.

A good starting point in considering the effectiveness of, or when designing, secondary containment facilities is to develop a process diagram. This shows all process and discharge flows, including anticipated flow rates. This diagram includes not only the secondary containment area but all plot areas of the facility. The needed design criteria and treatment capabilities, as indicated by the process diagram, can then be developed and documented.

The capabilities of the treatment processes (e.g., phase separation of oil and water, oxidation, biofiltration and dehalogenation) should be considered in estimating the worst case releases and how they should be handled. In addition, the system designer should identify any bottlenecks and implement modifications that address them.

Of particular concern to the designer should be the presence of the oxygenate, MTBE (methyl tertiary butyl ether), which is considered by many to be a very serious groundwater contaminant, even at low levels of concentration. Terminal operators should be particularly aware that one area where MTBE can escape to the environment is right through the oil/water separator because whenever process water (such as tank water bottoms) contacts MTBE oxygenated gasoline, it will remain in the water phase even if it passes through the oil/water separator.

Codes and regulations

For petroleum products, the most widely recognized standard on secondary containment is in NFPA 30, Flammable and Combustible Liquids Code. This code provides that Class I through Class IIIA liquids (liquids with flash points below 200 degrees F, including most petroleum liquids other than heavy fuel oils) shall be contained in the event of a spill or rupture, and that the volume of the containment system be large enough to hold the contents of the largest tank. It further specifies that the containment area be constructed of earth, steel, concrete or solid masonry designed to be liquid-tight.

The requirements stated in other fire codes such as the Uniform Fire Code (UFC) are similar to those in NFPA 30. Some NFPA 30 and UFC requirements are duplicated in the federal Occupational Safety and Health Administration's (OSHA's) Flammable and Combustible Liquids Code (29 CFR 1910.106).

Also at the federal level, secondary containment is driven by the Clean Water Act. This act mandates that Spill Prevention Controls and Countermeasures (SPCC) be planned and implemented. SPCC covers facilities that handle oil or petroleum products. The Oil Pollution Act of 1990 expanded the financial responsibility of tank owners as well as the requirements to respond to and mitigate a worst case discharge of oil or other hazardous substances.

Some facilities storing toxic or hazardous substances regulated under the Resource Conservation and Recovery Act (RCRA) (40 CFR 260-282) are required to have secondary containment. Secondary containment is also required for hazardous waste treatment, storage and disposal (TSD) facilities.

Although the federally mandated SPCC plans must include impervious secondary containment, there is no specification that it be in the form of an impermeable liner other than native soil. Some states, however, have interpreted the federal rule as requiring such a liner. Check the rules in your area to find out how this provision is interpreted.

In most, if not in all, jurisdictions, secondary containment must be sufficient to contain a volume greater than the volume of the largest tank in the area. On a local level, the local fire chief is responsible for enforcing the requirement. Sometimes, state and federal officials check not only to see that this volume criterion is met, but also that the permeability of the secondary containment area is sufficient.

The term permeability refers to how easily petroleum liquids can penetrate into the soil. A highly-permeable material, such as gravel or sand, permits petroleum liquids to pass quickly through and into the ground. A relatively impermeable material, such as clay, significantly increases the time it takes for the same volume of liquid to pass through.

The state of being "sufficiently impermeable" is one of the most controversial issues associated with secondary containment. Does it mean that the secondary containment area must be lined with a clay or a plastic liner that is nearly impermeable—or sufficiently impermeable to allow the operator to clean up a spill without oil passing into the environment?

If one looks at the problem of specifying a performance-based or goal-oriented solution, then either method will work depending on the site specific conditions. The problem arises when specification-based standards prescribe that only a clay or plastic liner are mandated; the efficiencies of engineering solutions are then thown out, regardless of the circumstances. We will discuss this in more detail later.

Figure 3:
Contour map and drainage of tank field contained by diking, courtesy of Chevron.

Meeting the volume requirements

NFPA recognizes two types of secondary containment structures. One type is a diked area that surrounds the existing tanks. The other is a remote impoundment area in which the liquid is drained into a pond area away from the tank field.

For diked areas, most state regulations require that secondary containment must also hold an amount of precipitation (usually a level of six inches) in addition to the volume of the largest tank in the tank field as required by NFPA, UFC and other codes. The SPCC program requires that the secondary containment area equal the volume of the largest tank plus ten percent. The safest approach to ensuring compliance with criteria in your area is to size the secondary containment areas according to SPCC program requirements.

When two or more tanks are permanently manifolded and hydraulically connected so that the tank levels move together, the sizing of the secondary containment area should be based on the combined volume of the connected tanks, plus 10 percent (unless there is a single tank in the field with a larger volume).

Remote impounding is an acceptable secondary containment method under NFPA 30 because the code primarily focuses on fire safety and emphasizes the importance of moving leaked or spilled flammable liquids away from the tank by adequate draining. A remote impoundment must be able to contain the contents of the largest tank. However, when this is not possible, partial impounding can be used in combination with diking to meet the largest-tank criterion.

For tank fields contained by diking (as shown in Figure 3), NFPA 30 requires that a slope of not less than one percent away from the tank shall be provided for at least 50 feet or to the dike base, whichever is less. This ensures that small spills will not accumulate against the wall of the tank. Also, if remote impounding is used, the drainage path to the pond should be designed so that if the drainage path is ignited, the flames will not pose serious risk to tanks or adjoining property. For an illustration of drainage to remote impoundments, see Figure 4.

Figure 4: Diagram of drainage to remote impoundment area, courtesy of NFPA.

Environmental protection

It is not unreasonable to require the use of secondary containment to substantially reduce the risks of soil and groundwater contamination. However, requiring that secondary containment systems be completely leak-free would be unreasonable, because such a requirement is nearly impossible to meet (if this requirement could be tested).

One of the most significant debates taking place today has to do with defining an acceptable permeability rate for secondary containment areas. The correct definition, in my opinion, requires a case-by-case, cost-benefit analysis, as well as engineering analysis.

The amount of contamination that can escape into the ground below a spill in a secondary containment area depends on the:

- volume of leaked or spilled liquid;
- time that the liquid remains in the area before cleanup;
- permeability of the containment area, including any liner material;
- number and sizes of any cracks or breeches in the liner, if one is used; and
- depth of the liquid leaked or spilled.

The five factors cited above are interrelated. While the exact relationship is complex, changing any one of the variables will increase or decrease the amount of product released to the environment. For example, if a spill is immediately cleaned up, then even if the soil is relatively permeable, the oil will not have had time to permeate deeply. The removal of the soil to a shallow depth completely prevents a contamination. Of course, disposal of contaminated soil must be dealt with as well.

Of the factors cited, the volume of leaked or spilled liquid is probably the single most important one. If the volume is so small that the contaminated dirt is collected and disposed of, there is no release to the environment. This is usually the case when the volume is so small that the liquid does not form a "puddle" of some depth; only surface contamination occurs. This can be cleaned up before any hydrocarbon enters the environment.

The timing of the cleanup is also significant, as previously mentioned. Cleaning up a spill immediately after it occurs is the best way to prevent contaminants from escaping the secondary containment area. Most, if not all, companies have a policy to immediately clean up leaked or spilled product and correct whatever caused the leak or spill. In addition, most local regulations require that the leak or spill be stopped and cleaned up as soon as practical.

The permeability factor

The permeability of the secondary containment area, including any liner material used in the area, is an important and often controversial factor. While the concept of permeability is relatively simple (see definition on page 38), some state regulations tend to be vague on required permeability, often using such terms as "impervious" or "sufficiently impervious" in reference to secondary containment and liner materials.

Other states' regulations specify a numerical value for the maximum permeability of secondary containment material. A review of these state standards indicates that the maximum permeability rates range from 10-6 to 10-7 cm/sec.

Even if a totally impermeable membrane were to be used, the problem of spill containment would not be solved. For example, the weak links in membranes used for secondary containment are the seams. Also, tears or punctures during installation, and settling after installation, represent possible vulnerable points of the membrane. The effect of the imperfections in the membrane may far outweigh its low permeability.

The American Petroleum Institute (API) Publication 315, Assessment of Tankfield Dike Lining Materials and Methods, has an excellent discussion of both vapor and liquid permeability and methods of testing. For practical purposes, simple rules of thumb may be sufficient to select the liner.

Generally, materials such as sand, aggregate or other open-grained soils have relatively high permeability, regardless of the liquid spilled. In these cases, a major spill would seep rapidly into the aquifer below. However, clay-like soils or other tight soils can prevent liquid penetration if the spill is cleaned up quickly. The adequacy of an earthen containment area depends not only on its permeability, but also on the type of liquid stored, the liquid’s hazardous properties and other factors.

The toxicity, mobility and persistence of the liquids stored at a facility play a major role in evaluating the need for, and appropriate type of, a secondary containment liner. Materials that can move quickly through soils and are highly toxic warrant special consideration.

Highly toxic, water soluble components with low viscosity and those that do not degrade easily are more likely to need a leak-proof liner than substances with high viscosity, low toxicity and lower degrees of water solubility. Examples of the former are pure benzene, methanol and some halogenated hydrocarbons. Examples of the latter might be typical fuels, heating oils, crude oil or other hydrocarbons.

Liner materials

Many different types of liners have been used for secondary containment areas. Some of the common materials are:

- Native soil
- Bentonite and soil-bentonite admixtures
- Asphalt
- Concrete
- Synthetic flexible membranes
- Spray-on applications

The most commonly used liner material has been compacted native soil. In assessing the options for liner material, it may be useful to do a “what-if” analysis—a risk assessment based on a hypothetical spill, its consequences and remediation efforts and costs. For example, a spill of methanol requires a substantial cleanup effort, because it has a low viscosity, is toxic and water soluble. All this means that methanol can contaminate large quantities of groundwater quickly. Because of this, remediation efforts would be costly and spread over large areas. In addition, methanol is toxic to bacteria and, in concentrations greater than a few hundred parts per million, would prevent the use of organic methods of remediating the soil.

Some regulated chemicals pose unique handling problems if spilled, because hazardous waste management requirements would be triggered. Examples are benzene and toluene in concentrated form.

Basic design considerations

As previously discussed, permeability values generally are not specified in rules on secondary containment liners—just design criteria are given. When permeability requirements are specified, a common value is 10-7 cm/sec (minimum). This specification can only be met by using clay or by lining the secondary containment area with elastomeric or membrane fabrics.

Permeability of the liner material is not the most important element in preventing liquids from escaping the containment area. Rather, the two most important considerations are the ability to (1) make liquid-tight joints or seams and to (2) inspect the system.

While attempts are made to achieve these two objectives, there have been no universally accepted or even workable standards for construction or performance of these systems for secondary containment. Also, there is no generally accepted way to test a secondary containment area for integrity after it has been constructed.

This is why liners should not be advocated, in my opinion, unless it is clear they will perform better than a system that is designed to prevent leaks and spills in the first place. To date, this has not been demonstrated.

Figure 5: Tanks in a concrete vaults. Source: Technical Resource Document for the Storage and Treatment of Hazardous Waste in Tank Systems, US EPA.

Beyond traditional dikes and ponds

Secondary containment for ASTs is not necessarily limited to traditional tank field diking and remote impoundment systems. Tanks may be individually diked using (1) a vault; (2) a double-walled tank; or (3) a tank that includes an integral diking system. A vault is a concrete containment tank that houses the primary containment. It is often used for aboveground and underground applications (see Figure 5).

Figure 6 shows a double-walled tank. The volume between the two walls must be equal to the volume of the primary containment (inner tank).

Tanks that are constructed with double walls or with integral dikes or pans that fulfill the secondary containment function are recognized in the proposed Seventh Addition of UL Standard 142, Standard for Steel Aboveground Tanks for Flammable and Combustible Liquids.

Figure 6: AST with a double wall for secondary containment. Courtesy of Chevron.

Should liners be required? Certain states, such as Florida, Alaska and some eastern seaboard states, have required that secondary containment areas of existing tank farms be retrofitted with liners, such as clay or an elastomer. From the perspective of the regulator, the concept of mandating an impermeable liner seems appropriate. From the perspective of the petroleum industry, however, such a mandate represents a high cost that does not mitigate the containment problem. Let's explore some reasons for the industry's viewpoint.

Figure 7:
Diagram depicting liner penetrations and soil-to-air interfaces.
Courtesy of Chevron.

As illustrated in Figures 7, 8 and 9, a typical tank farm has many penetrations that create serious problems with artificial liners. For an existing tank area, there is usually piping, pipe supports, structural steel, foundations, concrete slabs and instrument tubing that pass from above to below ground.

When a liner is to be retrofitted over an existing tank farm, these penetrations are difficult to seal. Even if they could be sealed, the seals break shortly after installation because of the movement of the ground. Experience shows that these penetrations leak, either when installed or soon afterward. Even if the installation could be made without leaks, leaks can develop from the differential movement. The terminal in Figure 1 on page 37 has 384 penetrations; the number of penetrations is probably representative of the average terminal.

Figure 8: Pipe rack support structure. Courtesy of Chevron.

Another problem is that a liner creates a sudden change in the level of moisture, oxygen and salinity at the liner interface. This tends to aggravate corrosion of piping and tanks that pass through the liner. These "soil to air interfaces" accelerate corrosion and, thus, the use of elastomeric liners may undermine the integrity of the piping and tanks.

Should a spill actually occur in a lined area with defective seals at these points, the effectiveness of the liner system may actually be less than a naturally graded secondary containment area that is quickly cleaned up.

Another problem with liners is associated with any facility that uses cathodic protection. Liners act as a blockade to protective current flow from cathodic protection systems. In some industries, such as the breakout tank business of the pipeline sector, the use of cathodically protected tank bottoms is widespread. Certainly, any elastomeric liner jeapardizes the effectiveness of systems that are already proven helpful to the environment by mitigating corrosion damage to tanks.

Figure 9:
Concrete slab. Courtesy of Chevron.

API surveys liners

The controversy over the use of liners prompted API to do a survey to determine just how effective liners are. The resulting survey report (API Publication 341, A Survey of Diked-Area Liners Used at Aboveground Storage Tank Facilities), describes the survey scope and results as follows:

• The survey involved 32 facilities, operated by 13 different companies in the marketing and transportation sectors. These facilities handled both gasoline and distillate products. Twenty-nine of the diked liner facilities were retrofits around existing tanks and three were applied as the tank fields were being constructed. The general liner area ranged from one to four acres. The lining materials included clay geocomposites, extruded sheet, spray-on coatings and coated fabric liners. Nearly all liner systems were installed as a result of state regulations.

• According to the survey, most of the respondents stated that the dike liners failed to maintain their integrity (91 percent). Major causes of failure were the result of vehicular traffic and general maintenance equipment brought into the secondary containment area. Material failures were common and included de

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