DRAINAGE FOR OUTDOOR OIL AND CHEMICAL PLANTS

INTRODUCTION

Oil and chemical plants handle large quantities of flammable and combustible liquids. These liquid products will, if released and ignited, form pool fires that can severely damage exposed equipment and structures. Removing a flammable or combustible liquid spill rapidly will reduce the amount of fuel that could be involved in a fire. Grading, impounding, diking, trenching, and providing underground or enclosed drains will remove fuel and reduce the pool fire potential. Product spills must be controlled effectively and rapidly and routed away from buildings, structures, tanks, pipe racks and process equipment to a safe location without exposing adjacent equipment or units to a fire, or causing a risk of flooding by fire protection or rain water runoff.

This Property Risk Consulting Guideline material focuses on requirements for drainage systems to control product spills, storm water, and fire protection water for outdoor oil and chemical facilities. Treatment and disposal of waste water, as well as the handling of spills for environmental concerns are not discussed. Drainage for areas subject to flooding from rivers, lakes or seas is not included in this section. Drainage for indoor flammable and combustible liquids storage facilities is covered in NFPA 30 and PRC.8.1.0.

POSITION

Design drainage systems to remove spills and fire protection water simultaneously. Design to the largest of the following criteria:

- Expected liquid spill that can be released from equipment that is not readily isolated.
- Fire protection water to be used for manual and automatic fire protection in a loss incident. Use Property Risk Consulting Guidelines PRC.14.1.1.1 and PRC.12.2.1.2 to determine the expected fire protection water flow rates.
- Heaviest expected rainfall: heaviest rainfall of 1 hour rainfall with a 1% chance of exceedance (100-yr) period.

Drainage Methods

To provide the needed drainage, use one, or a combination, of the following methods, listed in descending order of preference:

- Grading
- Remote impoundment
- Dikes

- Trenches
- Underground or enclosed drains

Grading

Slope the ground appropriately in both process and storage areas to carry any spills and fire protection water away from the point of release to a collection point, such as a drain, trench or basin. Orient the slope so that spills flow away from equipment. Use a 2% minimum slope. Install smooth surfaces. Concrete surfacing is preferred, especially in process areas. If rougher surfacing, such as gravel or crushed rock, is utilized, increase the slope above 2% accordingly.

Do not consider the absorption of the spill, rain or fire protection water by the soil for drainage purposes. The ground might be very quickly saturated and the absorption of contaminants by the soil will lead to extensive cleanup and remeadiation costs.

Remote Impounding

Direct the spill away by sloped ground to a remote impounding basin where its exposure to equipment is minimized. Locate the basin in a safe area where the spill can burn, if ignited, without exposing buildings or equipment.

Keep the impounding basin empty so that the full volume is available for spill and fire protection water runoff. Keep the basin dry and limit the surface area of the retention basin to reduce the vaporization of spilled liquefied gases. Apply foam on spills to reduce the formation of vapors and to extinguish fires.

Size the impounding basin to handle the largest liquid spill volume that cannot be readily isolated plus the fire protection water. Keep in mind the capacity of the waste water handling facility when determining the impounding basin holding capacity.

For tank farms, size the remote impounding basin to handle the contents of the largest tank within the basin, assuming the tank is full, or the largest liquid volume which cannot be readily isolated, plus the fire protection water. As a minimum, size the impounding basin to handle 110% of the largest tank.

Diking

Install dikes to hold, control or contain a spill. Use diking in storage areas where very large spills can be expected in emergency situations. Do not use diking in process areas because the fuel would pool and be an unacceptable exposure to the process structure.

Design containment dikes to contain at least 110% of the contents that can be released from the largest tank within the enclosure, assuming the tank is full. Consider the volume of the tanks within the diked area, up to the height of the dikes, as unavailable space for the spilled liquid. Always use this method to calculate the volume of diked enclosures.

Subdivide a diked area with spill dikes, where two or more tanks are within a single containment diked enclosure. Design spill dikes to retain 10% of the largest tank volume within the spill dike area to prevent any small spill from exposing other tanks or equipment within the enclosure. Restrict spill dike heights to 1.5 ft – 3 ft (0.45 m – 0.9 m) or a height well below the containment dike height. Also use spill dikes to control the liquid spill from pressurized storage tanks.

Construct dike walls of compacted earth, concrete or solid masonry, designed to be liquid tight. Design dikes and all dike penetrations to withstand the full hydrostatic head of the impounded spill. Install liquid tight fire resistive expansion joints and sleeves with similar packing for all piping penetrations in all concrete dikes. If masonry dikes are installed, use very careful design and heavily reinforce them against thermal and hydraulic stresses, otherwise they are not likely to survive for any appreciable time when exposed to a major tank fire. Design dikes for refrigerated storage tanks to withstand the thermal shock in case of a spill. Also design all dikes to withstand fire, earthquake, wind and rainfall exposures.

Restrict dike heights to 6 ft (1.8 m) to allow easy fire fighting access, as well as better natural ventilation and vapor cloud dilution. Do not use high walls close to flammable storage tanks in place of dikes because of difficult fire fighting access. Construct each dike with sufficient slope to allow easy transit and fire fighting.

Avoid tank fire ignition by vehicles by restricting vehicle access ramps into diked areas as much as possible. Require entry permits for vehicle entry into diked areas. Avoid locating tank farm access roads on top of the dikes, because the roads are inaccessible for fire fighting equipment when the material within the dike is on fire. Such practice would be acceptable only if roads on at least two sides of the tanks are outside the diked area. In addition, heavy traffic on dikes can damage and settle the dike, especially if it is of earthen construction.

Minimize piping within diked areas, because once involved in ground fires, pipes usually fail within 10 or 15 min of initial exposure. Do not use fittings, such as quick couplings or cast iron fittings, which can quickly fail when exposed to fire. Bury pipes wherever possible. If buried piping is not feasible, install fill and suction lines above a small raised berm to help prevent burning liquids from pooling under the piping. Do not run piping from one tank through the dike area of another tank. Properly seal piping passing through dikes. Check the integrity of the dikes on a regular basis. A typical tank diking arrangement is shown in Figure 1.

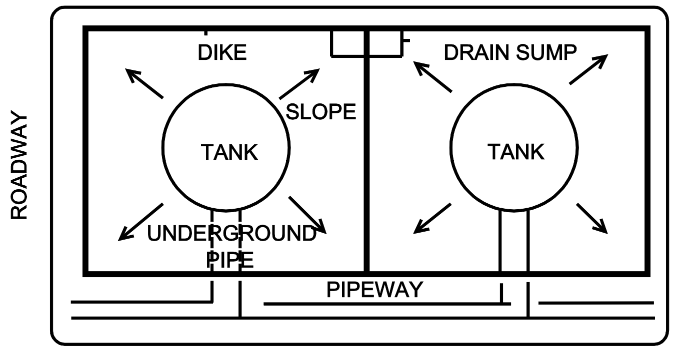

Figure 1. Tank Diking Arrangement.

Maintain enough distance between the tank shell and the base of dikes to contain a liquid jet spill streaming out of the tank. NFPA 58 recommends the following equation to determine the minimum distance to the base of the dike:

$$X \geq Y + \Delta P$$

Where:

X = distance between outer tank shell and base of dike

Y = elevation difference of the maximum tank liquid level and the top of the dike

Δ P = equivalent pressure difference between internal tank pressure in the vapor space and atmospheric pressure

This equation, initially developed for refrigerated liquefied gas tanks, is valid for any type or shape of tank. For atmospheric tanks, the minimum distance between the outer tank shell and the base of the dike equals the maximum liquid height in the tank.

In addition, space tanks in accordance with PRC.2.5.2.

Provide diked areas with trapped drains to allow for possible removal of the rainwater, fire protection water or a spill. Keep the drain valves closed and open them only as needed, because permanently opened drain valves will not retain discharged liquids if the tank suddenly fails or leaks. Establish a schedule for checking the drain valves. Drain water accumulation within diked areas immediately, because it only takes a few feet (meters) of water within a diked area to float a tank when the tank contents are low. Locate drain valves outside the dike and where they are accessible under fire conditions. Size drain piping to handle the maximum flow of fire protection water.

If sump pumps are used, they should be rated for the intended service and be started manually.

Trenching

Direct spills, rain, or fire protection water from an area to trenches by sloping the ground. Locate trenches at the edges of process units. Size the trenches to handle the expected spill and the fire protection water from fixed and manual systems. Slope the trench at least 1%. Do not use open ditches or trenches where they could expose other equipment. Use partly covered trenches, per NFPA 15, to direct the spill and fire protection water to a safe area without exposing any other equipment, because partly covered trenches can control burning without seriously exposing the adjacent equipment. Partly covered trenches are shown in Figure 2. Make trench covers of concrete or heavy steel plates.

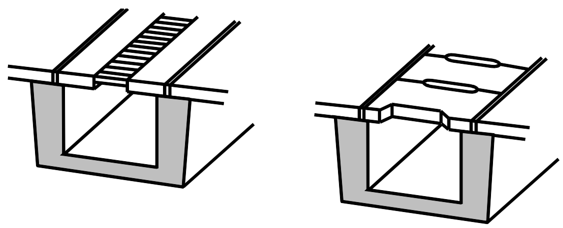

Figure 2. Partly Covered Trenches.

Install fire stops at regular intervals, at road crossings, and at locations where ditches extend to adjacent units. If the trenches discharge into an underground drainage system, provide seals to avoid flame propagation into the underground drains.

Do not install piping or cabling in or above open drains or trenches. If this is unavoidable, cover the trenches, or fireproof the exposed piping or cabling as outlined in PRC.2.5.1.

Underground or Enclosed Drains

Install drains to collect spill and fire protection water at a low point and carry it into underground piping. Such drains can either replace or be used with a trenching system. Seal all points of connection liquid tight or install traps in all such connections to prevent propagation of flame or explosions through the drainage system. Remember, the safe operation of an underground drainage system depends upon minimal inflow of flammables, proper layout, well maintained seals and proper venting to reduce the hazard of accumulated vapors in the system.

Design the underground drainage system to handle the largest anticipated flows, irrespective of whether it is spent cooling water, condensate, fire protection water flows, the largest anticipated spill or rainwater. This means that trunk drain designs tend to be dominated by maximum anticipated rainfall calculations while smaller branch drains sizes are driven by the other flows.

Do not interconnect laterals servicing incompatible processing areas within the battery limits of a process unit. For example, do not tie laterals which serve furnace areas into laterals which serve light hydrocarbon process areas.

Since drains can be plugged by foreign material or debris, include safety factors when designing drainage systems. Establish a minimum drain size of 4 in. (100 mm) in diameter to avoid plugging problems. Because a minimum velocity of liquids in the drains will provide some self-cleaning effect, try to maintain a minimum speed between 2.5 ft/s – 4 ft/s (0.75 m/s – 4 m/s). In all cases, establish and enforce a regular drainage system inspection and cleaning schedule.

Design liquid seals or traps with sufficient depth to prevent vapors from escaping into any area where sources of ignition might exist and to stop flame fronts that may be moving through partly filled drains. Maintain seals on various drains when units are shut down, either permanently or for repairs. Run a small amount of water into the drains to offset evaporation losses. Install blinds or blocks on unused branch lines or laterals where they enter an active underground drainage system.

Check water seals in enclosed drains on a regular basis. Do not use mats to cover water seals to avoid excessive evaporation.

Use the following three types of trapping devices as appropriate:

- **P-traps** - Cast iron soil pipe P-traps provide a 2½ in. (65 mm) water seal in sizes 3 in. – 6 in. (80 mm - 150 mm), and a 3 in. (80 mm) water seal in sizes 8 in. – 12 in. (200 mm – 300 mm).
- **Junction Boxe**s – Seal laterals from open drains and catch basins at all junction boxes. A typical junction box is shown in Figure 3.
- **Gas-trap Manholes** - Typical design for these is shown in Figure 4.

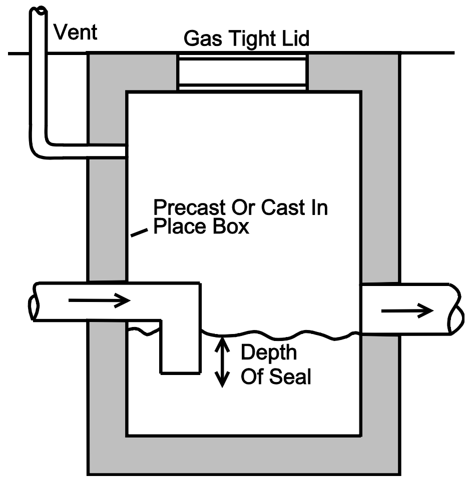

Figure 3. Junction Box.

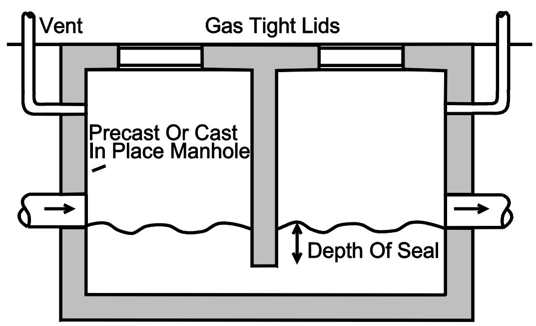

Figure 4. Gas Trap Manhole.

Install vents to maintain atmospheric pressure on the underground drainage system and to release any flammable vapors to a safe location, because drains generally are designed for gravity flow. Since any trapped air or vapor will reduce the design capacity of the drain, install vents in sewer systems to release vapors and to prevent vapor locks.

Include the following features:

- Extend all vents away from areas with possible ignition sources.
- Do not place vents near operating platforms or ventilating fan intakes.
- Extend vents high enough to allow vapors being expelled to readily dissipate into the atmosphere, or connect vents to a waste gas treatment facility rather than allowing vapors to accumulate at grade level.
- Identify properly all vents to warn personnel of possible release of toxic or flammable vapors.
- Ensure that all vents are not less than 4 in. (100 mm) in diameter. Smaller pipe sizes tend to freeze or clog up in cold weather.
- Keep manhole or junction box vents free of obstructions.

- Provide steam jets in the vents to maintain a constant vapor flow and a steam atmosphere in the top portions of the vents. Steam jets may be used to extinguish vent fires caused by lightning.

Drainage Areas

Processes Handling Flammable and Combustible Liquids

Provide a clean and smooth concrete grading slope to carry major spillage to the outer limits of a process unit. Provide partly covered trenches at the limits of the process unit. Further collect the spill and fire protection water in trenches or underground drains connected to catch basins, remote impounding areas or separators. This system is described by Van Gaalen in *Chemical Plant Drainage, An Overlooked Subject?* and is shown in Figure 5.

Avoid the use of underground drain intakes within units, if possible, as debris, such as insulation, rags, plastics, and dirt, will be washed to the floor drains together with the spillage and will block the underground drains. A pool will form increasing exposure to the process unit and possibly spreading fire to neighboring units.

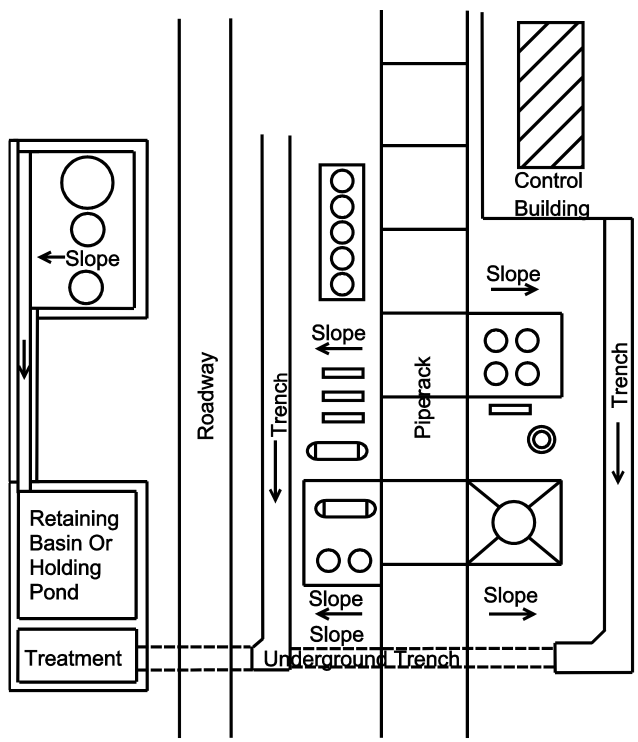

Figure 5. Process Area Drainage.

Consider the use of foam. Foam discharging through water spray or deluge sprinkler systems, as described in PRC.12.2.1.2, will blanket flammable ground pool fires. The foam will also cover the flammable liquid throughout the drainage path to further reduce exposure to equipment and structures located along the drainage path. When foam is used, lower amounts of fire protection water are used which allows for faster spill and drainage control.

Do not use diking in process areas. However, small diverting curbs can be used to reroute a spillage that could expose equipment.

Processes Handling Liquefied Flammable Gases

Construct adequate sloping, open trenching and catch basins to allow safe removal of a spill and fire protection water. Do not use underground or enclosed drainage systems because of the explosion hazard.

Tank Farm Drainage

Do not locate flammable or combustible liquid storage tanks within the same impounding or diked area as flammable gas or liquefied gas storage tanks. Flammable or combustible liquids could accumulate under liquefied gas storage tanks and create a BLEVE (Boiling Liquid Expanding Vapor Explosion) should the spill ignite.

Atmospheric Storage Tanks

Use remote impounding in tank farms, especially for jumbo storage tanks in excess of 300,000 barrels (48,000 m^3). Provide a sloping grade carrying spills away from the tank shell to the impounding area. Locate the impounding basin so as to allow safe handling of the spill and fire protection water without exposing other tanks or property. Use dikes or trenches to divert the spillage away from other tanks. If the impounding basin is to be drained, use provisions similar to those used to drain the diked areas.

Where impounding basins cannot be used, provide containment dikes around the tanks.

Where remote impounding is not possible, provide individually diking for all atmospheric storage tanks in excess of 25,000 bbl (3975 m^3) containing flammable liquids (Class I. For smaller tanks containing flammable liquids, the total capacity within the same diked area should not exceed 25,000 bbl (3975 m^3). These maximum capacities can be doubled for combustible liquid (Class II and III) storage. In addition to containment diking, provide spill diking or trenches for flammable liquids storage tanks larger than 10,000 bbl (1590 m^3) within the same diked enclosure. NFPA 30 has additional requirements for unstable materials or special tanks.

Equip diked areas with drain valves located outside the diked area, and keep the valves accessible under fire conditions. Use liquid seals in the drain lines to prevent fire propagation. Size the drains to handle the maximum flow of fire protection water.

Pressurized Storage Tanks

Provide remote impounding for handling liquefied flammable gas spills. If remote impounding is not possible, provide diking to control the liquid spill and fire protection water. Use a 2% sloping grade. Burning material accumulating under a vessel or tank could create a BLEVE (Boiling Liquid Expanding Vapor Explosion), therefore always slope the spill away from the tank. Do not use high dikes. They limit the natural ventilation and dilution of the gas cloud. However, some authorities do not allow any diking; in such cases, remote impounding remains the only choice.

Do not use enclosed drainage channels to drain liquefied flammable gases because of the explosion potential.

Refrigerated Storage Tanks

If a refrigerated storage tank suddenly fails, a large portion of the liquefied gas would spill on the ground. Design the impounding basin or dikes to handle the contents of the largest tank.

Use remote impounding as the preferred spill control method. Where impounding is not possible, provide diking sized to handle the largest stored liquid volume. Refer to NFPA 58 for additional information.

Additional Requirements

Provide adequate housekeeping, proper inspection and regular cleaning of drainage systems at all times to maintain spill and fire protection water control during emergencies. To avoid restricting or plugging the drainage system, keep the process and storage areas clean and free of debris. Flush the systems on a regular basis. Waxy or viscous liquids will plug drains; therefore, do not use enclosed drains or trenches when these materials are present.

Segregate building or sanitary drains from the unit drainage system.

Control weeds and grass growing on and inside diked areas.

When hot work is performed near drains, trenches or catch basins, temporarily seal all drain and manholes in the area. Use properly designed, commercial drain and manhole sealers. As an expedient, use sand covered tarpaulins dampened with water to cover the drains and manholes. However, sand will inevitably be washed into the drainage systems and plug the drains, requiring clean out. Remove all drain covers immediately when welding is complete to return the drainage system to operation. Covered drains can severely impede spill control and fire fighting operations should an emergency occur in the unit.

DISCUSSION

Outdoor oil and chemical facilities generally require separate drainage systems defined as follows:

- Storm water drainage is a large system intended primarily for storm water runoff. The system may go to a retention basin before going through an oil separation process. It will also carry off flammable or combustible spills and fire protection water.
- Oily water drainage is usually a small system, serving process sample point drains, pump base drains, and any other sources of expected hydrocarbon spillage. This system generally uses underground sewers and flows directly to an oil separator.
- Chemical effluent drainage is a small system that collects chemical wastes. Chemical effluents may require different treatment than oily water streams. Chemical wastes may need to be segregated because they could react with each other or may require different disposal methods.
- Sanitary water drainage is a system that collects waste from sanitary facilities and usually conveys it to a municipal sewer system, on-site treatment facilities or septic tank.

If a pressurized storage tank suddenly fails, a large portion of liquefied gas will vaporize immediately and reduce the expected amount of spill on the ground. The amount of the remaining liquid spill depends on the climatic conditions and the boiling point of the spilled product. In standard weather conditions, the maximum liquid spill will be about 50% of the tank contents, if the product vapor pressure is less than 100 psia (6.9 bar abs.) at 100°F (37.8°C). For lighter products, the maximum liquid spill is an estimated 25% of the tank contents.

Since drainage from dikes, trenches, impounding basins or underground systems generally is collected in a basin where the spill and fire protection water can be safely handled, emergency holding basins might be required when the expected spillage exceeds the waste disposal handling capacity.

The last issue to be considered is that of retention basin size. However product spills are handled by sloping or grading, diking, trenching, and underground drains, the material still has to go somewhere. Whether impoundment is remote or right under the equipment or tank from which the spill originated, all of the spilled material and all of the fire fighting water must be accounted for. In theory this should be a straightforward proposition; start with the volume of the largest vessel or train of vessels which can not be readily isolated. Add the maximum expected quantity of fire fighting water. This can be calculated by adding up the design flow rates of maximum expected number of automatic and manual systems and multiplying by the maximum expected duration, which in the case of chemical plants is usually 4 h. The result of this approach, however, is a calculated retention requirement of several hundred thousand gallons. The expense of providing that much retention capacity often causes designers to reconsider the duration of the expected fire. It is true that the 4 h time assumes a fire under reasonably adverse conditions. If all required protection were in place and everything operated as it was supposed to, a duration of 30 min is more likely. Assuming a duration less than that is marginal as even with a quick and successful extinguishment of the fire there are bound to be delays in securing the fire site and turning off the operating automatic and manual systems. Remember, whatever assumption for fire duration is made when designing the retention system, if a fire occurs which exceeds that duration, the burning liquid is going to go somewhere when it overflows. Designers should always know where that somewhere is.