ENVIRONMENTAL, PERSONNEL AND PROPERTY PROTECTION THROUGH PROPER STORAGE TANK VENT SYSTEM DESIGN AND MAINTENANCE

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1.0 INTRODUCTION

Every year petroleum production storage tanks are ruptured, exploded or imploded due to improper vent system design and maintenance. The losses incurred from these accidents are considerable. Additionally, federal, state and local air quality regulations are becoming more stringent and new design considerations are required to meet these standards.

1.1 Scope

This paper reviews vent system design criteria, explosive gas-air mixtures and offers some operational and system safeguards that can significantly reduce the risk of loss due to improper vent system design and maintenance. The tanks considered in this paper are lease tank battery installations as described in API RP 12R1. The design recommendations are based on API standards, field experience, lab testing and an economical approach to current standards.

2.0 VENT SYSTEM DESIGN CONSIDERATIONS

A well engineered oil storage tank vent system design should consider three basic areas; protection from overpressure during normal and emergency venting, containment of emissions and maintaining a vapor composition that inhibits corrosion and flamability

2.1 Protection from Overpressure

The first and most basic consideration in vent system design is to allow the tank to breathe. As a tank is filled with liquid the air residing in that space needs to be released to prevent the tank from exploding. Conversely as fluid is being drawn out of a tank, air or vapor is required to fill the space to prevent the tank from imploding. The normal vent sizing considerations are based on the filling and emptying flow rates with any thermal effects in relation to the maximum pressure that the tank can safely withstand. Normal venting can be accomplished by the use of a pressure vacuum (PV) valve, combination hatch and PV valve (thief hatch) or a pilot operated relief valve.

Another consideration is emergency venting due to the following factors; Liquid overfilling, an operational upset such as failure of a control device and the venting required for fire exposure. Typically the venting capacity required for fire exposure will cover the overfilling and control device failure, however a further consideration would be the likelihood of a simultaneous occurrence of all conditions. Emergency venting is usually accomplished with the use of additional PV valves or gauge hatches, a connection between the roof and the shell that is weaker than the weakest vertical joint in the shell or the shell-to-bottom connection (frangible deck), or an emergency pressure relief valve.

2.2 Containment of Emissions
Storage of oil or other evaporative liquids require a closed storage system to protect against loss of product due to evaporation and environmental and regulatory considerations. National Ambient Air Quality Standards (NAAQS) control the quantities of air pollutants allowed. In areas of the country where these standards are not attained sources of volatile organic compounds (VOC) are being inspected. Petroleum liquids are a significant source of VOC. Maintaining oil lease storage with good gravity conservation practice is very cost effective and has a positive environmental effect. It is easy to overlook the loss of one or two degrees gravity. When oil was sold on the basis of gravity it was widely acknowledged that one degree gravity loss represents a loss of 2-1/2% of the oil in storage. The lighter fractions are the most valuable as they are virtually gasoline. An affordable means of retaining these rich vapors is through the use of vent lines on a tank battery. When a tank battery is being filled, pressure is created in the tank because of compression of the vapor space with the incoming oil and the release of entrained gasses from the oil. The vent lines allow these vapors to travel to the other tanks where the lighter fractions of the oil will be condensed. Conversely when emptying a tank in the system, the vapors are drawn from the other tanks through the vent lines instead of using air from the atmosphere. This technique controls emissions from fixed roof storage tanks due to working and breathing losses and reduces the amount of hydrocarbon vapor concentrations released to the atmosphere.

2.3 Vapor Composition
The introduction of air (oxygen) into the storage system has two effects. First, the acceleration of corrosion that can occur in various forms, such as pitting, cracking or erosion to all metal surfaces. Secondly and probably most important, the combustible gas-air mixture. Liquid fuel doesn't burn, the vapors in the vapor space above the liquid fuel can burn if mixed with air. A combustible gas-air mixture is ignitable between the lower explosive limit (LEL) and the upper explosive limit (UEL) on either side of this range the mixture is either too lean to burn or too rich to burn. To illustrate we can use methane, a principal gas in crude oil light ends as an example. Trace amounts of methane in air can be readily oxidized on a heated surface, but a flame will propagate from an ignition source at ambient temperatures and pressures if the surrounding mixture contains at least 5% (lean limit) and but less than 15% (rich limit) volume

methane (see figure 1). The objective is to obtain a tank vapor space that is too rich to burn.

3.0 PROPER VENT SYSTEM DESIGN

The ideal vent system hook-up for oil in storage would provide an adequate vent for normal filling and emptying, an additional vent for emergency conditions, protection against fire and explosion and the means to easily inspect and maintain these devices.

3.1 Primary Venting

Two devices should be considered when selecting the proper method of providing primary venting for a tank battery, a vent line valve and an PV hatch . The reason that both should be used is to achieve the goal of maintaining a gas blanket inside the tank system. When a vent valve and PV hatch are used in combination the relief settings can be designed to allow the vent line valve to facilitate normal flow and any thermal breathing, the hatch valve can then be reserved for any overpressures or vacuum relief that would bring a minimum of air into the system. By utilizing the flow curves of the manufacturer's products the pressure and vacuum settings could be designated to allow the vent line valve to relieve the tank pressure and vacuum up to a certain capacity. If that capacity is exceeded, the hatch could then be set to open at a higher specific internal pressure or vacuum relief.

A vent line valve would be sized to provide the normal pressure and vacuum relieving flow rates. Flow curves should be provided by the valve manufacturer to insure that the selected brand or model can provide the required relief volume at the appropriate internal pressure. There are typically two styles of vent line valves available in the market inline and end of line (stack). Of the two types the preferred is the inline configuration due to the ability to position it for ease of maintenance. (see figure 2)

The PV hatch would provide additional pressure and vacuum relieving capacity. The capacity charts should be provided by the hatch manufacturer to insure that the brand or model selected can provide the required relief volume at the appropriate internal pressure. There are many different models of gauge hatch valves, lock down types that don't vent, pressure only types that don't provide vacuum relief, springloaded types that have restricted relieving capacity, and deadweight models that have greater relieving capacity. Another factor that should be analyzed is the hatch's sealing capacity due to the seating surface design, gasketing method and material. One should also review the valve's ability to provide the proper relief setting, it's material composition, resistance to corrosiveness, and the ability to easily service and maintain.

3.2 Emergency Venting

Currently the most common method of meeting this venting capacity requirement is the "frangible deck" allowing the roof of the tank to separate from the side walls which will keep the liquid inside the tankage but allow excess pressure relief through the damaged roof. This method has two drawbacks. When a tank is situated in an open field the occurrence of the top of the tank and it's associated piping flying through the air is not cause for great concern. However if the tank is located in a municipality with houses or businesses nearby this becomes a more serious consideration. We have all seen or known of lease batteries that were installed in the country now located in a shopping center parking lot. The cost of rewelding or replacing a tank and it's associated piping is much more expensive than the additional cost of supplying an emergency pressure relief vent that will continue to work over the life of the tank. Secondly, the catastrophe associated with possibility of igniting vapors in a ruptured roof tank allow the cost of a separate venting device to appear minuscule.

Good design prepares us for the contingencies of the future. The recommended method of meeting the emergency pressure relief venting required would therefore be a separate emergency pressure relief valve. The pressure setting on the EPRV should be sufficiently above the setting on the vent line valve and the PV hatch to accommodate the back pressures associated with maximum normal flows yet below the storage tanks maximum capacity rating. The relief setting should also take into consideration the EPRV's flow characteristics at the set pressure.

When selecting an emergency pressure relief valve a user should review the capacity charts of the model selected to insure that the brand or model can provide the required relief volume at the appropriate internal pressure. A primary function that should be analyzed is the valve's ability to reseat consistently and securely. This is a function of the seating surface, gasketing material and operation design. Another factor to review is the valve's ability to provide the proper relief setting, the material composition, it's resistance to corrosiveness, and the ability to easily maintain and service.

3.3 Protection from Fire and Explosion

In spite of all efforts to maintain an oxygen free environment in the storage tanks there are ways that air can enter the system. When oil is being pumped out of a tank at a high rate, large volumes of air can be drawn in if there is insufficient make-up from a gas blanket. Air can be gradually taken in through the thief hatch valve during thermal inbreathing of a still tank if there is insufficient make-up gas from the gas blanket system. Wind blowing into an opened hatch can ram air into a tank headspace and generate an explosive condition in a very short time. When a flammable gas/air mixture has formed in a tank it immediately possesses the risk of ignition from multiple sources. Some sources of ignition come to mind quickly; lightening, open fires, cigarettes, gasoline and diesel engines, electric tools and sparks produced by other electrical or mechanical means. There are also sources from frictional heat generated by faulty machinery or vibrating pipes, sparks produced from aluminum on impact with corroded steel, and the formidable hazard presented by static electricity.

No matter how safety conscious you are it is never possible to eliminate all sources of ignition therefore you must take precautions to protect against fire and explosion. The most common entry source of an ignited gas/air mixture is from the end of the vent line. When flame travels down a pipe it restricts the ability to vent the rapidly expanding combustion products. This causes the pressure of the flame to rise and an acceleration in its velocity. This spiralling cycle of flame acceleration and rise of pressure can cause flame speeds up to supersonic velocities and explosive pressures. The object is to quench the flame before it has the opportunity to create this effect. The recommendation therefore is to install a flame arrestor near to or on the end of the vent line.

A flame arrestor will allow free passage of a gaseous mixture but will prevent flame propagation by cooling the flame front to the point where it extinguishes. Flame arrestors are typically designed in two configurations, inline or end of line (stack) type. Both designs are effective, however when selecting an inline model the installation location should always be within the limitations of the flame arrestor's design. If the flame arrestor is not designed to withstand sustained burning on the surface, a provision must be made to detect and suppress continued burning.

To select a flame arrestor the user should first review the flow charts of the manufacturer's model to determine that the pressure drop across the unit will not restrict the venting capacity required for the tank. The greater the flow capacity, typically the longer the maintenance interval due to clogging. Review the flame arrestor's maximum operating pressure, maximum flow rate, connection type, material selection and any optional features. A primary feature of the flame arrestor selection should be ease of maintenance.

4.0 PROPER VENT SYSTEM MAINTENANCE

A well engineered vent system design is of value only as long as it remains in good operating condition. To ensure the proper operation of the system, regular maintenance must be performed. Inspection frequency has been the subject of numerous studies. Results of such studies show that effective safety inspection programs will reveal defects developing within the equipment and is recognized so unexpected failures hazardous to life and property may be avoided. Standardized procedures may not always be directly applicable because of varying local conditions. A production supervisor who is diligent and thorough should have the knowledge and ability to make decisions based on their particular operation. Regular inspection should include keeping records of each valve's and flame arrestor's condition. This will prove invaluable in determining frequency of repairing or replacing equipment.

4.1 Gauge Hatch Valve

A visual safety inspection should be performed every month. This would include inspection from the outside of the performance of all venting devices to check for any leakage or continual venting.

Scheduled maintenance should be performed every three to four months or more frequently in corrosive or dusty atmospheres. This maintenance would include inspection and cleaning of the valve's working parts, the springs on springloaded models and the gaskets on all models. A simple check by hand to test the tension is sufficient for the springs. The pressure and vacuum gaskets and seats should be wiped clean and carefully inspected for splitting, cracking, pitting, brittleness, softness or elongation. Under average conditions the "working" gaskets (pressure and vacuum) should be replaced every year. The springs could be removed during this maintenance routine every year and tested to insure proper relief settings. The seats and disks and other parts need be replaced only if they are deteriorated or damaged.

4.2 Vent Line Valve

A visual safety inspection should be performed every month. This would include inspection from the outside of the performance of all venting devices to check for any leakage or continual venting. Scheduled maintenance should be performed every three to four months or more frequently in corrosive or dusty atmospheres. This maintenance would include inspection and cleaning of the valve's working parts, the pressure and vacuum disks, seats and gaskets. The pressure and vacuum gaskets and seats should be wiped clean and carefully inspected for splitting, cracking, pitting, brittleness, softness or elongation. The sliding surface of the valve stems, the valve lid, hole in lid that guides the valve stem and lid gasket should also be cleaned and inspected. Under average conditions the gaskets should be replaced every year. The seats and disks and other parts need be replaced only if they are deteriorated or damaged.

4.3 Emergency Pressure Relief Vent

A visual safety inspection should be performed every month. This would include inspection from the outside of the performance of all venting devices to check for any leakage or continual venting. Scheduled maintenance should be performed every three to four months or more frequently in corrosive or dusty atmospheres. This maintenance would include inspection and cleaning of the seating surface and gasket. The gasket and seat should be wiped clean and carefully inspected for splitting, cracking, pitting, brittleness, softness or elongation. Under average conditions the gasket should be replaced every year. Any other parts need be replaced only if they are deteriorated or damaged.

4.4 Flame Arrestor

A regular inspection and maintenance schedule is unique to each application and should be governed by the amount and type of particulate in the system to which it is installed. The appropriate interval can be determined after a few inspections and cleanings of the flame arrestor. A spare element assembly and gaskets should be kept on site to facilitate maintenance on a rotating basis and reduce downtime. All apertures of the flame arrestor element should be inspected for blockage or buildup of residue. If flame stabilization has occurred it should be inspected for deformation. Corrosion and other particles can be removed by blowing air or steam through the arrestor. Hydrocarbon film and buildup can be removed by soaking the element assembly in an appropriate solvent and then blowing air through it. It is important to keep the openings clean to prevent loss of efficiency in absorbing heat. Special care should be taken not to damage or dent the cell openings as this could render the unit ineffective. When the flame arrestor element assembly is replaced, clean and inspect the seating surface and install new gaskets to insure a vapor tight seal. If an element assembly cannot be cleaned satisfactorily or if it is damaged it should be replaced.

5.0 SUMMARY

A well engineered tank vent system design will provide the ability to operate an oil lease that is safe for personnel and property. It prepares for future contingencies by protecting against potential events. It is cost effective to operate and maintain. These features will pay for themselves over time, both in terms of dollars and our obligation to protect the environment for the future.

6.0 REFERENCES

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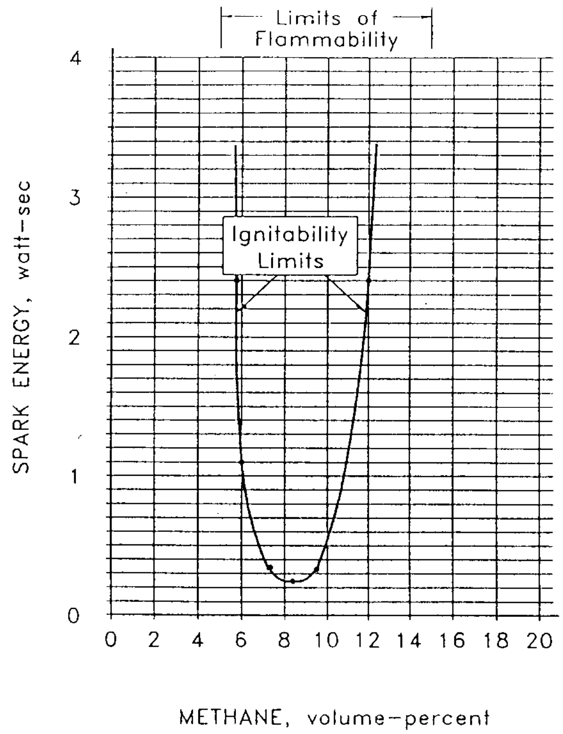

Figure 1 - Methane ignitability, flammability chart

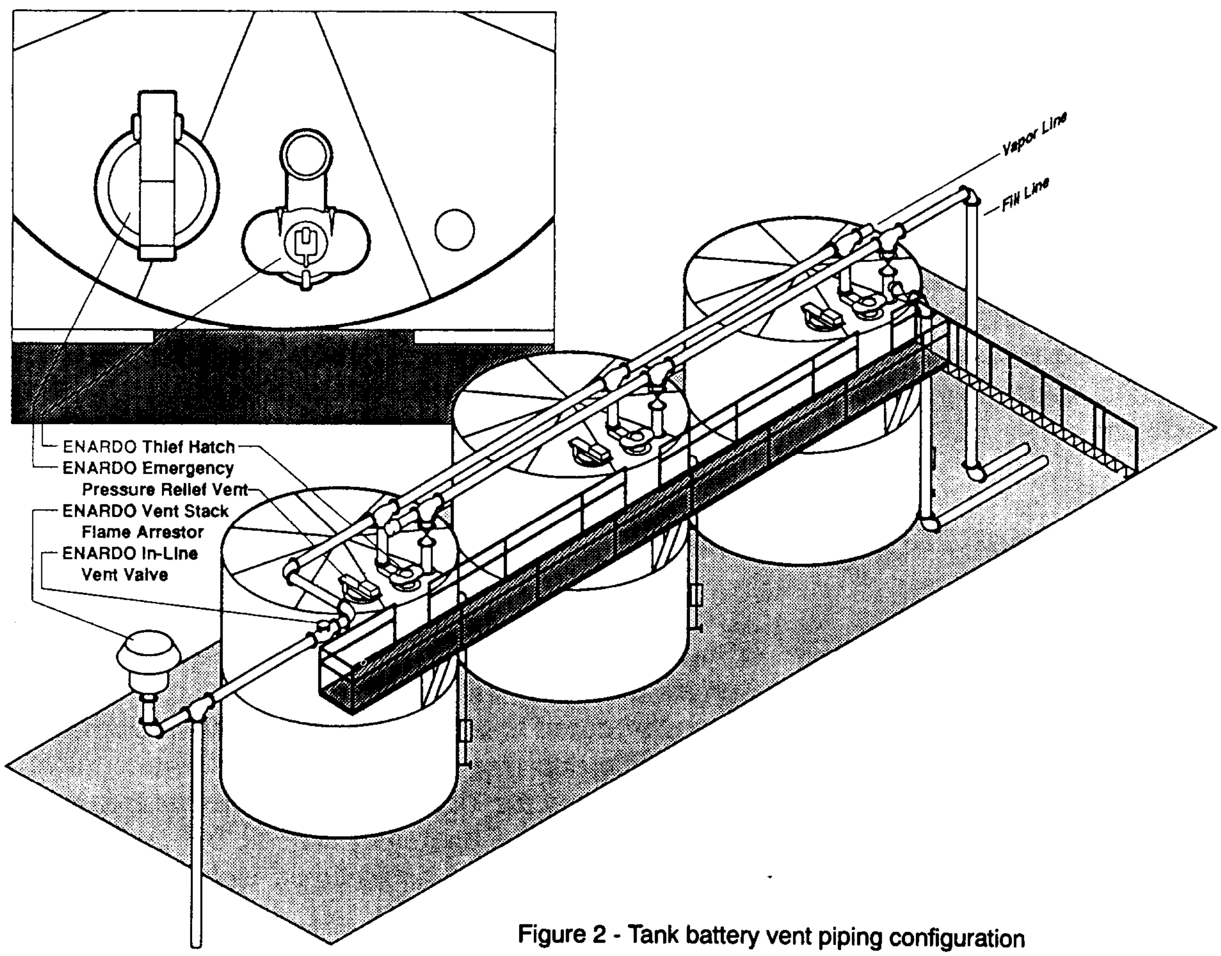

Figure 2 - Tank battery vent piping configuration