Chapter 13

Overpressure and Thermal Relief

The term pressure relief refers to the automatic release of fluids or gases from a system or component to a predetermined level. Pressure relief systems are designed to prevent pressures in equipment or processes reaching levels where rupture or mechanical failure may occur by automatically releasing the material contained within.

Almost all portions of a hydrocarbon process or system can conceivably be exposed to conditions that would result in internal pressures (either positive or negative) exceeding the normal operating pressures of the system. The most common causes are listed below:

- **Exposure to Fire**: If a vessel is exposed to a heat radiation from a fire, internal pressure may rise primarily due to the generation of vapor from the internal liquid or from thermal expansion of the contained commodity.

- **Excessive Process Heat Input**: Most hydrocarbon and chemical processes require or contain varying amounts of heat exchange. Should a process upset occur, which inputs more heat than design conditions have allowed an overpressure may result due to expansion of liquid or vapor contained within the system.

- **Failure of Flow, Pressure or Temperature Control Valves**: Control valves that regulate process conditions may fail causing a process upset to occur. Once the process upset occurs pressure regulation will not be effectively controlled and a pressure increase may result.

- **Unexpected Process Chemical Reactions**: Unexpected chemical reactions which result in heat or vapor evolutions may produce overpressures that have not been planned for.

- **Failure of the Cooling Water Supply**: A reduction in cooling water flow to condense vapors in a vessel may lead to an increased pressure drop through the condensers resulting in an increased pressure in the vessel.

- **Vessel Isolation**: If a vessel becomes isolated either fully or partially, from normal process conditions, internal pressure may build up if it has no outlet for venting.

- **Failure of Heat Exchanger Tubes**: If a heat exchanger shell rating is less than the pressure level of the circulating medium and an internal heat exchanging tube ruptures or leaks it will overpressure the vessel.

- **Introduction of a Volatile Material**: The introduction of a liquid into a vessel where the
temperatures is above the boiling point of the commodity will result in the rapid vaporization of the material causing an increase in vapor output requirements and raising the pressure of the vessel. Materials with low molecular weight are especially prone to this effect.

- **Reflux System Failure:** The quantity of reflux used in fractionation systems determines the amount of vapor generation and the consequent pressure differential through the condenser system. If a reflux system fails, lower pressures through the condensers and the vessel may result in higher pressure rise in the system as a whole.

- **Internal Detonations or Explosions:** An internal detonation or explosion may occur due to several scenarios. Air leakage into the system may cause a combustible mixture to form, undesired chemical reactions may occur, and extremely rapid vapor expansion may occur. These almost instantaneous events have to be carefully protected against as many overpressure devices do not react quickly enough to prevent the vessel from rupturing.

- **Thermal Expansion:** Contained liquids may be subject to heat input that causes them to expand resulting in a pressure increase. Typical heat sources are direct sunlight and fire exposures.

- **Non-Condensable Gas Accumulation:** If noncondensible gases are not removed, overpressure can result when a heat exchanger surface becomes blanketed or pressure drop through the condensers is increased by the presence of the non-condensable gas.

- **Outflow Rate Exceeds Inflow Rate:** If material is being withdrawn from a tank or vessel faster than the incoming rate to compensate for the removal suction a vacuum will occur. If the vessel or tank is not strong enough to withstand the negative pressure levels it will collapse in on itself.

There are numerous types of pressure relieving devices available, which include relief valves, safety valves, rupture or frangible disc and blow out hatches or panels.

**Pressure Relief Valves (PSV)**

Pressure relief valves are provided to cater to two main conditions of the process - normal conditions and emergency conditions. Normal conditions relate to the designed operation of the process which emergency conditions can be caused by either (1) external fire conditions, (2) failure of reflux or cooling, (3) failure of the power supply, (4) failure of steam supply, (5) heat exchanger failure (6) introduction of incompatible materials, (7) thermal expansion with outlets closed.

Because these causes of overpressures are considered random and infrequent, the pressure relief capability has to be automatic and constantly available.

Where relief valves are provided on liquid storage tanks or vessels, where there is a possibility of liquid release, i.e., liquid slug, careful evaluation of the release disposal system (e.g., flare header) needs to be undertaken. In some cases, a liquid slug may block a header from releasing pressure and defeat the purpose of the pressure release system.
Thermal Relief

Thermal relief is necessary in section of liquid piping when it is expected that the liquid will be isolated when the piping is also subject to temperature rises from solar radiation, warm ambient air, steam tracing, fire exposures or other external sources of heat input.

High temperature input to a piping system will cause both the pipes and the fluid contained within it to expand. Liquids have a high coefficient of expansion compared to metals (e.g., oil will expand approximately 25 the times of a metal pipe). It therefore can be expected that high pressures can be developed in piping systems that can be isolated and exposed to heat input. Thermal expansion of the pipe, expansion of pipe material from internal pressure or compressibility of the liquid may be adequate for relief of liquid thermal expansion before strength limits are reached for piping, valves or blinds. Research tests have shown that pressure from thermal expansion of liquid hydrocarbon may increase about 553 kPa to 789 kPa (70 to 100 psi) for each °F temperature increase. The length of the piping has no effect on the pressure that will result from thermal expansion of a liquid in an isolated section. However the volume of fluid that must be released to prevent excess pressure build up will be directly proportional to the line length.

Temperature increases in hydrocarbon process lines that are not in circulation but receive heat input can easily achieve temperature increases that will result in pressure build up that needs to be evaluated for thermal expansion relief. Normal solar radiation in some cases is enough to raise the pressure in lines containing liquids by as much as 23,685 kPa to 78,950 kPa (3,000 to 10,000 psi). The main reason why more ruptures have not occurred in lines without thermal pressure relief devices, is that most isolation valves have some tolerances of leakage and pipe flange gaskets may also leak or fail. Further reliance on quality isolation means such as double block valves, double seated gate valves, line blinds, etc., produces a greater chance of line rupture from thermal expansions. Also reliance on flange leaks to relieve trapped piping pressure is no longer an acceptable environmental alternative. The tighter verification of a leak-free facility to prevent VOC emissions to environment will require elimination of pressure release points that may have been unknowing relied upon in the past. Any relief design must assume that the relief effluent is contained within system piping and properly contained and disposed.

Overpressure from thermal expansion can occur in any pipe size or length with only a small rise temperature. It may be argued that all sections of piping which can be isolated theoretically need provisions for thermal relief. As pressure is built up in a line, sensors may warn of pressure increases, valves can leak, or the pressure build up is not a feasible scenario. There are some services where the provision of a thermal relief valve is not justified, such as cold water lines inside buildings, buried or insulated lines, firewater lines, piping operated at elevated temperatures, etc. There are also operational procedures that can be instituted to alleviate thermal pressure concerns such as partially draining liquid lines before isolation, continuous pressure monitoring, etc. These methods are not the preferred method of protection since they are prone to human error. Relief valves are the preferred method of preventing pressure build up.

Solar Heat

For geographical locations between 60° N and 60° S latitudes solar heat input to pipelines and the resultant thermal expansion is essentially the same. Orientation will have some effect to the total amount of heat input, i.e., North-South provides more exposure than East-West, however the maximum rate of heat input is the same that occurs at the highest sun position, i.e., at noon. This is a rather trivial aspect, as the cost of pipe length and installation costs generally overrule orientation concerns. Wind effects normally will dissipate some heat from pipelines. However for the case of thermal expansion concerns, it is common practice to consider no wind for purposes of heat input (or loss) to a piping system. Pipe color will as have an impact to heat absorption. Flat black is the highest heat absorber (1.0), while light colors are quite less (0.2. to 0.3). Reflectivity characteristics also assist in reflecting radiation.
Thermal Relief Fluid Disposal

There are three main methods to dispose of releases from thermal relief valves. Discharge around a block valve (isolation circumvention) is widely used in most situations, however where this is not practical or economical disposal to a sewer or release to surface runoff can be specified in certain cases.

Isolation Circumvention

Where the fluid is the same on each side of the isolation means, and no contamination will result this is the optimum choice for thermal relief release. Consideration of the possibility of backpressure onto the thermal relief valve, rendering the valve ineffective, should be evaluated before an analysis is finished.

Disposal to the Oily Water Sewer

A process oily water sewer system is a convenient location to direct oily wastes. The oily water system normally collects into a sump. If several lines connect into a common header, care should be taken to prevent backflow into another outlet source. In such cases use of an air gap, i.e., drainage in to a collection funnel has been advantageous.

Surface Runoff

Only when other alternatives are not available should a fluid release to the open environment be considered a viable disposal method. Additionally it should only be considered when the release is small and does not create an additional hazard - either from fire safety or environmentally. The relieved liquid should always be directed to a level surface away from other equipment, for containment by the facility surface runoff accommodations to mitigate any environmental or fire hazard. In no cases should discharge to the atmosphere be contemplated as it would create an immediate explosion or fire hazard and could also be considered an immediate environmental pollutant.

Pressure Relief Device Locations

Pressure relief capability is generally required at the following locations:

- **Pressurized Vessels**

  Unexpected process upsets may produce pressures above normal operating conditions.

- **Storage Tanks**

  All storage tanks subject to high flow rates in or out, requiring compensation for the displaced vapor.

- **Equipment Susceptible to Thermal Expansion**

  i. Vessel or tanks subject to ambient or fire hazard heat inputs.
  ii. The cold side of a heat exchanger if blocked off may be subject to excessive heat input from the hot side.
  iii. Circulation lines of heater where they can be blocked off.

- **Discharge of Compressors**

  Variable speed drivers can increase compressors discharge pressures about desired amounts causing a
process upset. With the provisions of constant speed drivers, such of electrical motors the possibility of overspeed is highly remote.

- **Pumps with Variable Speed Drivers**

  Variable speed drivers can increase pump discharge pressures about desired amounts causing a process upset. With the provisions of constant speed drivers, such of electrical motors the possibility of overspeed is highly remote.

- **Heat Exchanger**

  Heat exchangers that can be blocked in or where the shell of the exchanger may be subject to high pressure if an internal tube leak occurs.


8. Industrial Risk Insurers (IRI), **IM.7.0.5.0, Overpressure Protection**, IRI, Hartford, CT.