Risk information – Property

Flammable and combustible liquid hazards

Introduction

Flammable and combustible liquids represent a severe fire and explosion hazard due to their ease of ignition, rapid flame spread and high heat release rate. Such liquids are present to some extent in almost every type of industrial and commercial facility. Fires involving flammable or combustible liquids are difficult to extinguish and the need for effective storage and handling systems is paramount. Leakage, spillage, vaporisation and ignition can result in large fast growing fires with enormous potential for damage.

Consider for a moment that just one litre of petrol has enough energy to move the average car about 10 kilometres, and that is via an engine that is only about 35% efficient.

Flammable liquids present hazards that are unique; being hard to see, spreading and igniting readily and having ignitable vapours that are denser than air. The process and storage of flammable liquids, and the transition between the liquid and the vapour phases, via the application or removal of heat or pressure, has associated hazards.

Flammable liquid fires and explosions result in countless dollars worth of property damage and business interruption annually, not to mention numerous deaths and injuries.

This fact sheet is intended to promote a basic understanding of the properties of flammable liquids and measures that can be taken to reduce both the likelihood and consequence of a fire or explosion.

Combustible vs flammable liquids

Australian Standard AS1940 'The Storage and Handling of Flammable and Combustible Liquids' distinguishes between liquids having a flashpoint below 60.5˚C, terming these 'flammable liquids', and liquids with a flashpoint greater than or equal to 60.5˚C, terming these 'combustible liquids'.

As many of the lower flashpoint 'combustible liquids' have the same tendency to burn rapidly with intense heat as flammable liquids do, the term 'flammable liquids' will be used throughout to refer to both types of liquids. Indeed when heated (such as when involved in a fire), or atomised, the higher flashpoint liquids exhibit similar properties to lower flashpoint liquids.

There are various sub-classifications within the two groups depending on the specific flashpoints or boiling points of the liquids.

Flashpoint

The flashpoint is the lowest temperature at which a flammable liquid gives off sufficient vapours to form an ignitable mixture with the air near the surface of a liquid or within the vessel containing it. It is not the flammable liquid that burns but the vapours from the flammable liquid that burn.

The flashpoint is a measure of the ignition temperature, not the fuel loading. The hazard associated with liquids that have elevated flashpoints is still severe and these liquids can burn vigorously – see Table 1.

There are numerous other properties of flammable liquids, some of these are defined in this Fact Sheet. Further information is also available in AS1940.

Flammable liquids in industry

Industries in which flammable and combustible liquid hazards commonly exist include:

- Machine shops (dip tanks, cleaning/plating, spraying, and hydraulics);
- Manufacturing (spraying, dip tanks, flow coaters, storage and waste treatment);
- Automotive (paints, solvents, solvent recovery, and hydraulics);
- Sheet metalworking;
- Steel mills (hydraulics, lubricants, coating);
- Food and beverage (flavours, essences, alcohol);
- Printing (inks, blanket washes, plate washing and solvents);
- Chemical; and
- Plastics.

The potential for major loss varies, but is dependent on such factors as the area over which the liquids are piped/spread, pressures and temperatures of the liquids, and the availability of oxygen, etc.

Hydraulic and HTF systems

Hydraulics systems are common in many industries and represent a unique hazard due to the pressures and potential for oil to become atomised in the event of a fine leak in a seal or hose. Once atomised high flashpoint liquids are readily ignited.

Heat Transfer Fluid (HTF) systems often involve large volumes of heated oil (typically heated in a hot oil boiler/heater) piped over small or large distances. The hazards associated with the heaters/boilers and the piping systems are unique.

Further information can be obtained from Vero Global and Risk Managed regarding hydraulic oils, heat transfer fluids or any other type of system outlined above.

Other facilities

Many more seemingly benign types of facilities such as offices, data centres, hospitals, universities and retail facilities will commonly have large quantities of diesel fuel associated with generators and/or fire pumps, heated oils associated with oil cookers (fryers) and various flammable liquids associated with laboratories etc.

Warehousing activities may also be a concern depending on the products stored. Common flammable items, (often poorly stored within general product storage) include aerosols, motor and vegetable oils, inks and paints etc.

Table 1 lists some of the properties of some of the more common flammable liquids. As can be seen, whilst the flashpoint of a liquid varies greatly, the heat of combustion and energy available from the fuel is often similar.

Some common terminology

MSDS – Material Safety Data Sheet – Document providing information on the identification, health hazards, precautions for use and safe handling of a specific chemical product.

Ignition Source – source of energy sufficient to ignite a flammable atmosphere. Examples include hot work, naked flames, exposed incandescent material, electric welding arcs, mechanical or static sparks and electrical, electronic or mechanical equipment not suitable for hazardous areas.

Hazardous Area – Area in which an explosive atmosphere is present, or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of potential ignition sources.

HOC - Heat of Combustion - The amount of heat released per unit mass or unit of volume of a substance when it undergoes completion combustion.

Table 1: Flammable liquid flashpoints and associated heat of combustion

Flammable liquid	Flashpoint	Heat of combustion
Acet one	-20°C	31,000
Benzene	-11°C	41,900
Ethanol	13°C	29,700
Hydraulic Oil	Typ 150 - 250°C	Typ~45,000
Kerosene	38°C	48,000
MEK	-3°C	33,900
Methanol	11°C	22,700
Mineral Oil	Typ 150 – 250°C	Typ~30,000 – 45,000
Olive Oil	Typ >175°C	~39,000
Propanol	23°C	33,700
Toluene	4°C	42,500

Science of flammable liquid fires and explosions

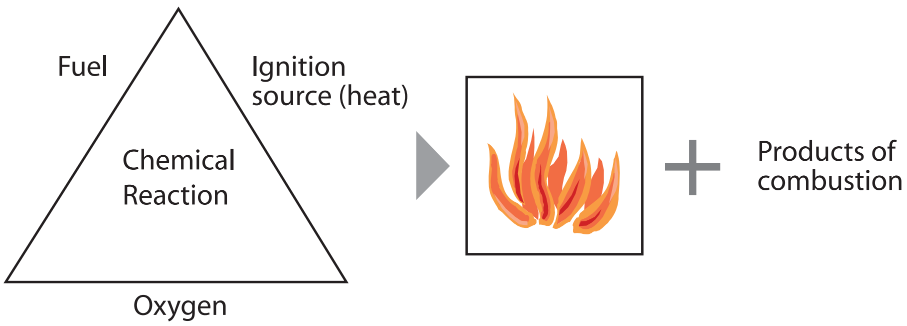

Figure 1: Flammable liquid fire process

Most of us are aware of the classic fire triangle required for a fire to occur, as outlined in Figure 1.

Relating this back to the flashpoint definition we can see that all three elements are referenced. When heated (heat), as necessary, to its flashpoint, a flammable liquid (fuel) liberates sufficient vapours (mixed with oxygen) for combustion to take place.

Flammable vapours will only ignite and sustain combustion within a limited range of fuel to air mixtures. Too much air and too little fuel and the mix is too lean, too little air and too much fuel and the mix is too rich. The flammability range is defined by the Upper and Lower Flammability (Explosive) Limits (LFL/LEL and UFL/UEL).

If there is insufficient heat or the fuel is not within the flammable/explosive range combustion cannot take place. This explains why a sealed 200 litre drum of ethanol (flashpoint 13°C) won't burn or explode on a 40°C day.

Typically for an explosion hazard to be present there is a fourth factor that needs to be present, confinement. When vapours are allowed to enter the flammable/explosive range in a confined space, such as a vessel or room, there is potential for explosion to occur.

Aerosol cans are a special hazard. When involved in a fire the cans are able to rocket, resulting in both multiple fires as well as making fighting fires hazardous.

Factors influencing flammable liquid behaviour and control methods

Other than flashpoint, there are numerous other physical properties of flammable liquids that influence their behaviour and can assist in determining the best method of minimising or mitigating the likelihood and consequence of a fire.

Some of the factors associated with the severity of a flammable liquids fire include the properties of the specific liquid (eg. solubility, specific gravity etc.), surface area (available for vapours to be liberated), pressure at which a liquid is piped, level of containment, etc. The heat release rate of a fuel is dependent on the Heat of Combustion (HOC).

Many flammable liquids are water soluble. These are diluted by sprinkler and hose water, increasing the flashpoint of the diluted mixture, reducing the temperature and eventually extinguishing the fire.

Some flammable liquids have a specific gravity of less than one and will float on water. If a liquid is not water insoluble and has a specific gravity less than one, applied water, whilst providing some cooling, will allow a fire to spread. If the liquid has a specific gravity greater than one, a layer of water will exclude the air supply from the fire.

Most flammable vapours are invisible and heavier than air, so will migrate and accumulate in low areas from the fire.

As can be seen, the factors dictating the best method of protection for a specific flammable liquid are many and varied. The actions that should be taken are generally a combination of prevention of fire and control of fire. MSDS information should always be available and utilised.

What follows is some generic guidance and tools to consider in order to appropriately minimise the hazard associated with flammable liquids.

Prevention and mitigation/ control of flammable liquid fires and explosions

Prevention of fires (reducing the frequency/likelihood of events) can be achieved by:

- Excluding/eliminating ignition sources
- Excluding/eliminating fuel sources (use less flammable or non flammable liquids where possible)
- Keeping liquids in closed containers or systems (minimising vapour liberation - prevent liquid or vapour escape etc)
- Ventilating to prevent vapour accumulations in the flammable/ explosive range
- Exclusion of air or use of an inert gas atmosphere.

Eliminating ignition sources

In industry there are numerous potential ignition sources of varying strength. These include open flames (inc. cutting, welding, matches/smoking), hot surfaces (motors, dryers, bearings, heaters), sparks from faulty electrical equipment, electrical and electrostatic discharges, mechanical impact, friction and spontaneous combustion.

Electrostatic charges are one of the most common sources of ignition of flammable vapours. Static charges build up on containers and people, especially in areas where dispensing takes place.

Bonding and grounding of equipment is paramount, especially where low flashpoint liquids are dispensed. Grounding refers to electrical connection between the dispensing vessel and the ground (earth). Bonding refers to electrical connection of containers/equipment involved in the transfer of flammable liquids to prevent sparks.

Electrical equipment should be suitably rated for the environment. E.g. Zone 0, 1 or 2 in accordance with AS/NZS 60079.10.1 Classification of areas – Explosive gas atmospheres. Facilities with more than minimal amounts of flammable liquids should be appropriately zone classified and equipment reviewed to ensure it is suitably rated. Electrical equipment is rated depending on the likelihood of flammable vapours in the area.

Other common sense items include strict enforcement of an appropriate **Hot Work** management and permit system and prohibiting **smoking** in areas with flammable liquids or potential for flammable vapours to accumulate. General equipment maintenance to minimise potential sources of **friction**, and thermography to identify **hot spots** in potentially hazardous areas, are also useful methods to identify or eliminate ignition sources.

Eliminating fuel

The nature of the operations and use of the liquids will generally determine as to the feasibility of **eliminating the fuel** (flammable liquid).

There are many applications where alternative liquids can be used. Water based paints can often be substituted for solvent based, less flammable (higher flashpoint) hydraulic fluids for lower flashpoint etc. Many major industries have made significant advances in choosing less or non flammable liquids.

Minimising the amounts of flammable liquids stored in production areas to no more than that required for one shift wherever possible is another means of eliminating fuel quantities in the event of a fire.

Housekeeping and maintenance cannot be ignored as other means of limiting/ reducing the amount of fuel. Preventative maintenance schedules for equipment (including minimising leaks), cleaning drip trays and pro-active spill response measures play a vital part in reducing the hazard associated with flammable liquids.

The **elimination of air/oxygen** from processes should also be considered. This can require modification to processes and equipment (re-engineering). Closed loop systems (tanks and piping), eliminating air/oxygen, are generally preferred. Such systems don't allow the flammable vapours to enter the flammable range. Open tanks should be provided with automatically closing covers where possible.

Containment and separation of flammable liquids from important processes, equipment and buildings is an intrinsic part of any prevention and control strategy.

Containment and separation includes physical space separation (location in low value detached buildings when possible), location within fire rated rooms, bunding and curbing, use of properly arranged tanks, safety cans, rinse and wash tanks, safety bungs, bench and plunger cans, drip cans, self closing faucets, storage cabinets and waste containers etc. Containment also helps prevent flammable vapours spreading to potential ignition sources such as improperly rated electrical equipment or hot surfaces.

Dissipation of heat to prevent flammable liquid vapour from reaching ignition temperature is another function built into certain types of safety equipment. This is accomplished by a flame arrester, which is common in safety cans and faucets, bench cans and other equipment. The flame arrester in the form of a wire mesh screen or perforated baffle plate, permits escaping vapour to burn but dissipates heat so that vapour inside the container will not ignite or explode.

Restricting oxygen supply is yet another function of certain safety containers. For example, when lids of self closing rinse and cleaning tanks shut they snuff out fire by closing off the oxygen supply.

Flammable liquid vapours, being heavier than air, accumulate in low areas such as at floor level. The use of natural and mechanical ventilation systems can and should be used as a means of dispersing vapours or removing them to a safe area.

There are also various vapour detection systems available that provide early warning of the build up of flammable vapours. These can be arranged to provide alarm, allowing mitigating action to be undertaken.

Atmospheric vents should be provided on drums and above ground tanks to prevent creation of a vacuum when the liquid is drained off. These also allow the interior of the tank or drum to remain at atmospheric pressure when cooled or heated thus preventing collapse or explosion.

Properly arranged and maintained process controls are vital in any process involving flammable liquids. Piping should be mechanically protected.

It is not possible to remove all the fuel and potential ignition sources. There will typically be need for mitigation and control measures to minimise the possibility of fire spread and potential impact of fires/explosions.

Mitigation/control of fires/explosions

Means of controlling a fire centre round reducing the rate at which flammable vapours are liberated, shutting down fuel supplies and suppression.

Containment (bunding, curbing and drainage etc), a key to prevention, is also a vital component to limiting the evolution of flammable vapours. By definition, minimising the surface area of a flammable liquid fire minimises the rate at which vapours are liberated at the liquid/vapour boundary.

Drainage systems can be used to draw flammable liquids to an area where they can free burn safely or are extinguished due to a lack of air/oxygen.

Should a tank or container be allowed to spill and spread over a large area, the potential for a large area, rapid heat release rate, pool fire is significant.

Isolation of piped fuel systems is also imperative. Piping systems can continue to feed a fire if not isolated. Isolation should be arranged to provide complete shutdown of liquid flow during a fire as well as to limit the quantity of liquid released in the event of accident.

Both safety and emergency (back up) shut off should be provided. Ideally both automatic and manually operated isolation valves should be provided. The use of positive displacement pumps can also be arranged for isolation. Actuation should be achieved via interlocks with fire protection or detection systems, release of dead man type control or self-closing valves or abnormal system conditions such as high/low pressure and excess flow.

Control and suppression of flammable liquid/vapour fires

The best means of control and suppression of flammable liquid/vapour fires using automatic extinguishing agents is dependent on the particular flammable liquid.

Standard automatic sprinkler (water only) systems (closed head or deluge), whilst not always the most effective means of fire suppression for such fires, are often still very useful, particularly in enclosed flammable liquid storage rooms. Sprinkler water absorbs heat from the fire and keeps the surroundings cool.

Despite this, over a large floor space such as a warehouse, the rapid fire propagation and high heat release rate associated with a flammable liquids fire usually results in rapid fire spread over a large area. Sprinkler systems can often be overtaxed.

Fire protection of tank supports is often overlooked. This cooling helps to reduce the likelihood of tanks collapsing, potentially adding large amounts of fuel.

Automatic foam/water systems (closed head or deluge) are generally the most effective way of suppressing a flammable liquids fire. There are various types of foam systems. Generally the foam concentrate is mixed with water in a specified concentration and agitated in air forming bubbles. This foam forms a barrier between the flammable liquid and the air inhibiting the combustion process.

Foams are available in low, medium and high expansion foams. The suitability of a specific type depends on the particular application.

Foams shouldn’t be used on electrical fires, as they conduct electricity.

Carbon dioxide (CO_2) is another option. CO_2 is a gas at room temperature and extinguishes fire by displacing air. These systems are either local application, such as within a particular container, or total flooding systems, which are generally the most effective systems. These are where an enclosed space is filled with a gas via spray nozzles actuated via a heat or smoke (or combination) detection system.

Flammable liquid/vapour explosions

As outlined earlier, confinement of liberated flammable vapours can result in explosion. Venting systems for drums and tanks (suitably ducted to a safe area), and ventilation systems and damage limiting construction (blow out walls) for rooms and buildings provide means of mitigating damage to equipment and buildings.

Appropriate location and orientation of tanks and drums is paramount. Location of equipment subject to explosion in isolated areas of the site is an effective means of segregating the explosion hazard. Some equipment can also be designed to withstand the internal explosion (explosion resistant). Various explosion suppression systems are also available.

In all cases explosion relief venting, blow out walls and suppression requirements should be calculated and designed by an expert in the field using recognised methodology.

Conclusion

Many industries have flammable and combustible liquid fire and explosion hazards. Awareness and understanding of the potential, and means to eliminate or minimise the likelihood or impact of such an event, are critical to ensuring an acceptable level of risk for a facility.

No one solution is the best fit for a particular industry, plant or process. Generally a site with flammable and combustible liquids will require a combination of prevention and mitigation/control measures to obtain an economically viable as well as effective loss prevention strategy. Further guidance and assistance can be obtained from your Vero Global & Risk Managed, Risk Engineering Consultant.

When designing flammable liquids process and storage systems always consider carefully the location, containment, isolation and protection of the systems. In conjunction, maintenance of equipment and process controls, emergency training and hazard awareness are critical to minimising the likelihood of an incident and, should there be an incident, minimising the extent of the damage.

Know the basic properties of any flammable liquids that your site uses in any significant quantity. Know your potential ignition sources.