MIST FIRES AND EXPLOSIONS: FACT OR MYTH?

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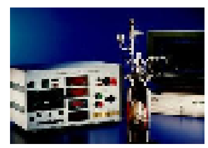
Introduction

- In this presentation I will answer the title question by quoting examples of fires and explosions involving flammable mists.
- I will also give ideas on how to assess where flammable mists could occur and how to control them.
- References will be quoted where applicable.
- The opinions quoted are those of the presenter, and not necessarily those of Chilworth Global as a whole.

Chilworth Technology- what we do

- **Process Safety**
- **Risk Management**
- **Environmental**



Consultancy **Laboratory Testing** **In company Training** **Instrumentation**

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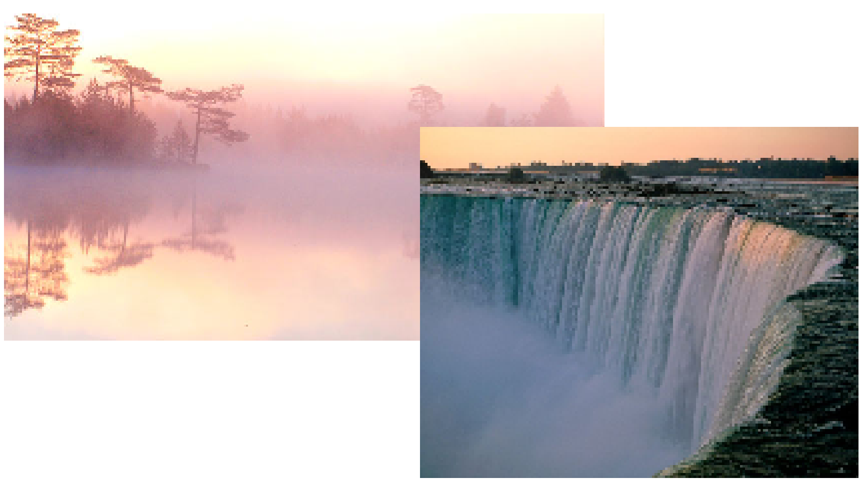
Example of mists from nature



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Historical

- Mist fires and explosions have been recognised a possibility for many years.
- As long ago as 1955, Eichhorn published an article in the Petroleum Refiner on the subject, entitled "Careful! Mist can explode".
- His article introduced the concept of a mist flammable range at temperatures below those on the dew point (saturated vapour) curve for a liquid.

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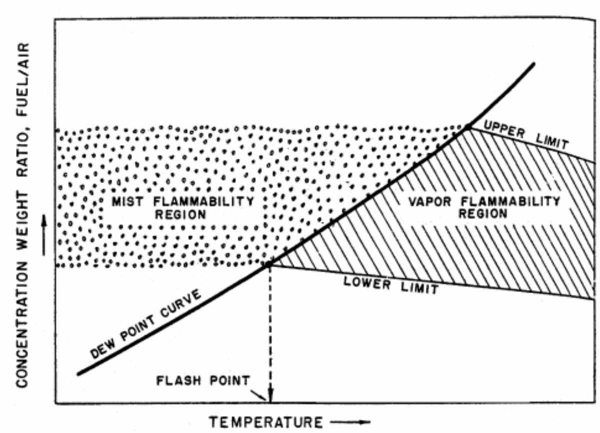
Flammability diagram at a fixed pressure



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Are mist fires and explosions a fact?

- Yes, is the answer!
- One common cause:
  - Liquids are sprayed from a nozzle at high momentum onto a liquid or solid surface;
  - Causes droplet break up and the creation of a fine mist, which may be electrostatic charged.
- Mist fires and explosions can also be caused by liquid leaks under pressure.
- Flammable mists can also form when hot vapours are suddenly cooled ref. crank case explosions in marine diesel engines.

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Incidents due to liquid spraying

- Liquid spraying has caused explosions. The liquid does not have to be above its flash point for this to occur, and the consequences can be tragic:
  - A road contractor's employee received fatal burns in 2003 while cleaning a bitumen tanker using a spray of mixed gas oil and kerosene.
  - The HSE investigation concluded that static electricity was a possible cause, though other ignition sources such as smoking and hot work were not effectively controlled.
- The company concerned had not learned from the past. Kerosene spraying of aviation tanks had killed three men over 20 years earlier.

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Electrostatics guidance

- Electrostatics guidance (e.g. CLC/TR 50404:2003) recognises that high pressure jets can create charged mists.
- It therefore recommends that spraying using hydrocarbon solvents is only acceptable if:
  - The spray pressure is less than 50 barg.
  - The container being sprayed has a volume of less that 5000 litres.
  - The liquid throughput is less than 1 litre/sec.
- It is also recommended that conducting and static dissipative objects, including people, are earthed.

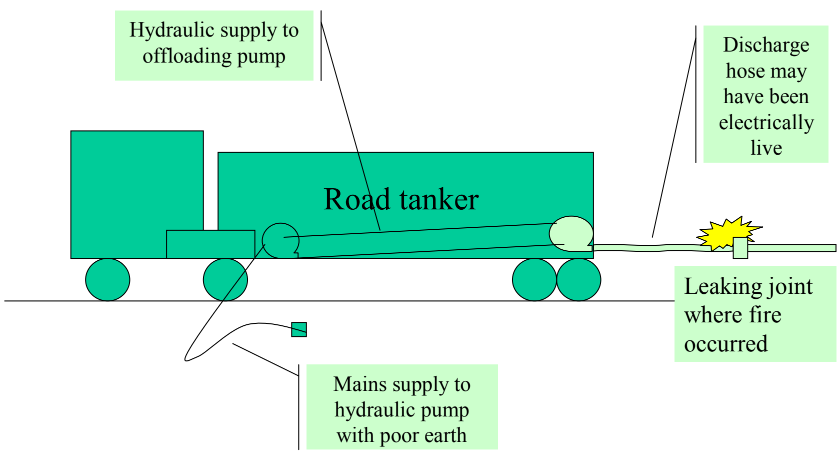
Incidents involving liquid leaks

- Evidence suggests that the formation of aerosols from leaking heat transfer fluids have contributed to several explosions
  - e.g. Factory Mutual Research report published at AIChE Loss Prevention Symposium in 1995.
- One possible example (from *Loss Prevention Bulletin*):
  - A leak of heat transfer fluid from a 12 mm orifice at 4 barg and 300°C led to the formation of a mist cloud, possibly through a combination of spraying and vapour cooling.
  - Ignition occurred when a flameproof light was damaged when a water deluge system caused the protective glass to rapidly cool and crack.

Two minor incidents investigated by Chilworth Technology

- Road tanker was offloading high flash point (FP > 100°C) printing inks to customer storage tanks.
- Offloading was carried out using the tanker's pump so hose was under pressure.
- Poorly made hose connection led to the formation of a small mist cloud at the coupling, which then ignited. Small fire was quickly extinguished.
- Offloading continued, but a subsequent (internal) fire occurred when the hose coupling was loosened to clear using the tanker pump after offloading was complete.

Cause of the fires



Condensation mists-
Examples from the marine industry

- Explosions in in marine diesel engine crankcases have been attributed to hot bearings or other components where oil vaporises, which then cools to form a mist when it moves away from the heated area.
- Numerous fires and explosions have occurred (14 were recorded between 1995 and 2002). Some of these had fatal consequences, particularly when the explosion propagated into the engine room.
- Crankcases are now fitted with relief valves with flame arresters to guard against internal explosions propagating into the engine room, but preventative maintenance, careful installation and use of approved parts is also recommended.

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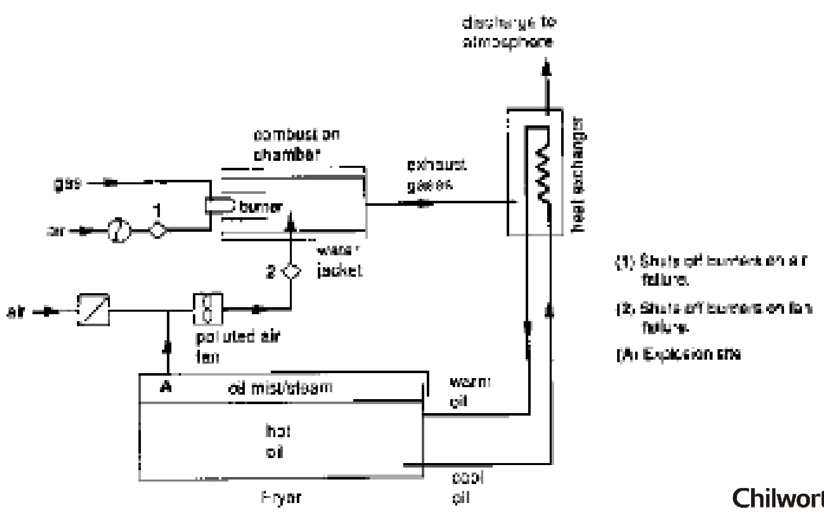
Condensation mists: 1986 fryer explosion



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Condensation mists: 1986 fryer explosion

- From HSE incident.
- Pollution fan shut down because belt drive was slipping. Burners then tripped out as designed.
- Smoke then observed coming from combustion chamber so combustion air switched on (to combat smoke), oil was pumped to storage and water then introduced to the fryer.
- Explosion then occurred. Attributed to air exacerbating the smouldering, air introduced into the fryer by emptying it and water displacing air/mist/vapour mixture into the combustion chamber.
- Better interlocking systems (e.g. a damper between the fryer and combustion chamber) would have prevented this incident.

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Could I have a mist fire or explosion?

- If you deliberately spray combustible liquids or they can condense to form a mist cloud, the default answer should be “yes”. However, in this case you should consider precautions to, in order of preference:
  - Prevent mist formation e.g. reduce spray velocities.
  - Prevent the formation of a flammable atmosphere (ref. fryers)
  - Control ignition sources.
  - Mitigate the effects of an explosion (ref. marine crankcases).

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Could I have a mist fire or explosion?

- The problem I most often encounter is whether or not flammable mists can form due to leaks from oil and other high flash point liquid lines.
- Evidence suggests that mists do not form at small orifices or at low pressures. For example, 1 barg has been used as a minimum pressure in the past.
- Therefore, most secondary grade release sources may not lead to flammable mist releases, and hence hazardous area classification may not be required for the mist. Such releases can also be prevented using spray guards.

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Could a flammable mist form at a release source? A more quantified approach.

- Use can be made of Lefebvre & Zanelli's correlation to define if a release could atomise or form a second wind-induced spray according to Faeth's definitions.
  - i.e. where $Ca > 17.8Z^{0.91}$
    - Where "Ca" is the Capillary Number (Weber number divided by the Reynolds number), and "Z" is the Ohnsorge number.
- Defining the mean diameter (Sauter Mean Diameter or SMD) of droplets has also been attempted, though note is made of the limitations of, for example, the Elkotb correlation.

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Notes on hazardous areas

- What hazardous areas should be defined around sources of flammable mists?
  - I have quoted 1m Zone 2 areas around secondary grade releases (e.g. joints) where spraying is not prevented by, for example, guards or lagging. However, this is purely qualitative.
  - The actual Zone 2 will depend on the lower explosion limit (LEL) of the mist, among other factors. Work in Japan (NIIS-SRR-17) has concluded that this is equivalent to the LEL of the vapour (around 40 g/m^3 for a hydrocarbon) but more recent work has indicated that the actual figure is 50% of the equivalent vapour LEL.

Notes on Minimum Ignition Energy (MIE)

- Another factor is whether or not a mist cloud could be ignited by an ignition source:
  - Work by Singh and Polymeropolous quoted in Bowen's 1994 paper suggests that spark energies of down to 3-4 mJ can ignite aerosols with a droplet diameter of 20-30 µm.
  - More recent work in Japan (NIIS-SRR-17) has found that alkane aerosols with a flash point above ambient temperature typically have an MIE of 4 mJ. This appears to concur with the earlier work. Otherwise, mists are as sensitive as the equivalent gas or vapour.
  - This would indicate that brush electrostatic discharges are incapable of igniting flammable mist atmospheres.

Conclusion

- Flammable mist fires and explosions are a fact. They can occur if mists are formed from spraying under pressure or condensation.
- Mist fires and explosions have sometimes had fatal consequences, and hence the phenomenon needs to be given serious consideration.
- Simple measures can sometimes be taken to prevent, control or mitigate against mist explosions.
- Methods are available to estimate where a flammable mist atmosphere could occur. However, it still appears difficult to determine what the extent of such an atmosphere could be.