

MIE TALK - October 2015

HAZARDOUS AREA CLASSIFICATION

LIQUID DISPERSIONS

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Abstract

The classification of hazardous areas forms part of legislation and provides a process to ensure a safe working environment for the operations. Hazardous Area Classification (HAC) is therefore an important part of the design of a plant and needs to be completed before the selection of equipment is done. HAC can be done by direct example, source of release, risk studies or a combination of the three methods.

Introduction

HAC is normally done for all flammable environments and the flammability of the environment is defined by the flammability of the chemical products by their physical properties. Liquids that are operated below their flashpoint are in general perceived as non-flammable.

A product like Ethylene Glycol which is basically antifreeze has a flashpoint of 115 °C. This makes it non-flammable unless it is operated at or above the flashpoint temperature where significant vaporization will occur. There are other however scenarios where the product may become flammable as well.

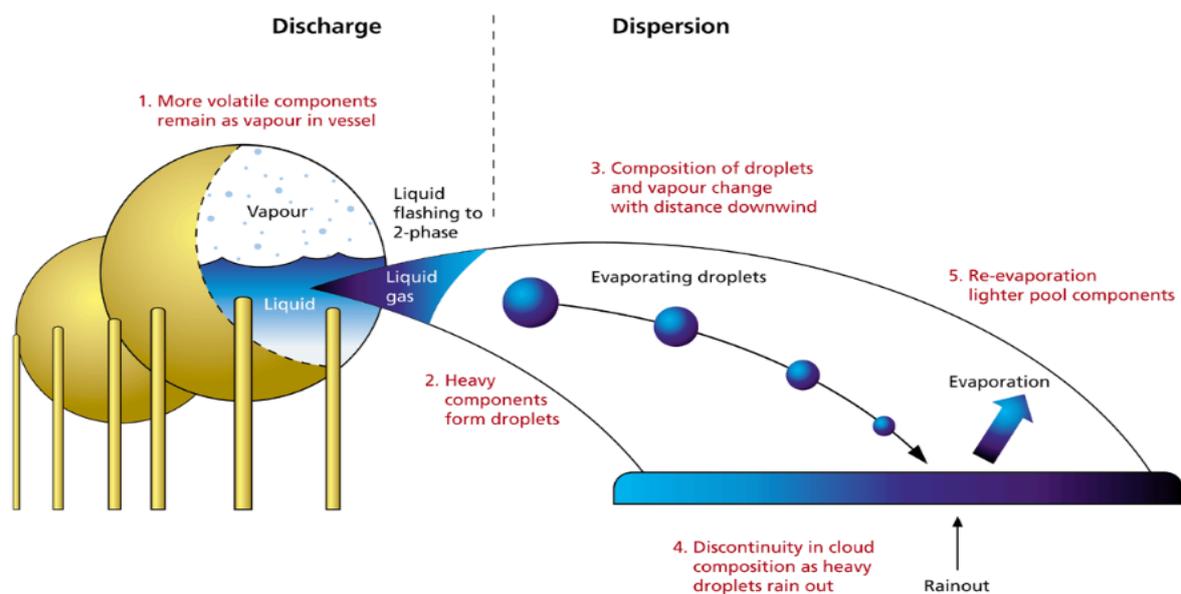


Figure 1: Liquid leak

Liquid Environments

Introduction

Liquid spill consists of a spill/ spray and then the resultant evaporation of the liquid into a gas. The flammable environment is created by the evaporation where mixing with oxygen occurs. In many cases the liquid is presented in ambient pressure as two phased i.e. liquid and gas release due to the sudden reduction in pressure.

Liquids handled above the flash point and released under pressure may create smaller droplets. Various names have been used related to the droplet size:

Aerosol: The term “aerosol” is used generically here to describe a mist of fine droplets. It is defined more formally in BS EN 60079-10 (BSI, 2009c) as small (sub 50 μm) particles suspended in the atmosphere.

Fog: A cloud of droplets usually produced by condensation of saturated vapour. Normally, most of the droplets have diameters less than 10 μm (Lees, 2005), whilst meteorological fog (or cloud) droplets have typically a diameter of between 10 μm and 15 μm (Lefebvre, 1989).

Spray: A momentum driven collection of droplets usually produced by atomisation of liquid through mechanical forces, e.g. a pressurized release through a nozzle. Typically, most of the droplets in spray have diameter greater than 100 μm (Lees, 2005).

Mist: The term “mist” is used generically here to describe a collection of droplets of liquid suspended in a gas medium. It is usually distinguished from sprays in having lower momentum and behaving more as a quiescent cloud. In the context of fire suppression, water mists are generally assumed to be composed of smaller droplets than water sprays.

What is important to note is that the droplet size needs to be smaller than 50 μm to create a flammable atmosphere. This can only happen if the liquid is atomised. Atomisation will only happen in the second wind-induced and atomisation regimes (see Figure 3: Change in jet break-up regime and length of solid liquid core with exit velocity below). The regime or possibility of atomisation must therefore first be accessed.

Minimum Ignition Energy per Droplet Size

The minimum ignition energy (MIE) necessary to produce a self-propagating flame in a mist is affected by a number of factors. The most significant of these is the droplet size, but the fuel concentration, volatility, air velocity and the presence of any fuel vapour (in addition to the droplets) are also important. These factors were studied in detail and models were developed for the ignition energy and quenching distance that were shown to be in good agreement with experimental data for a range of mists and sprays of various substances.

For a given mist concentration (in terms of mass of liquid within a given volume of air), as the droplet size decreases, the effective surface area available for evaporation increases and therefore the MIE decreases. For monodisperse mists, the optimum droplet diameter which requires the minimum MIE appears to be between 10 μm and 30 μm . Within this size range, the droplets seem to be sufficiently large to still create some wrinkling of the flame front (and enhance combustion), whilst being sufficiently small to evaporate quickly.

The energy required to ignite the droplets have been tested by a number of authors. The figure below shows the correlation for tetralin aerosol.

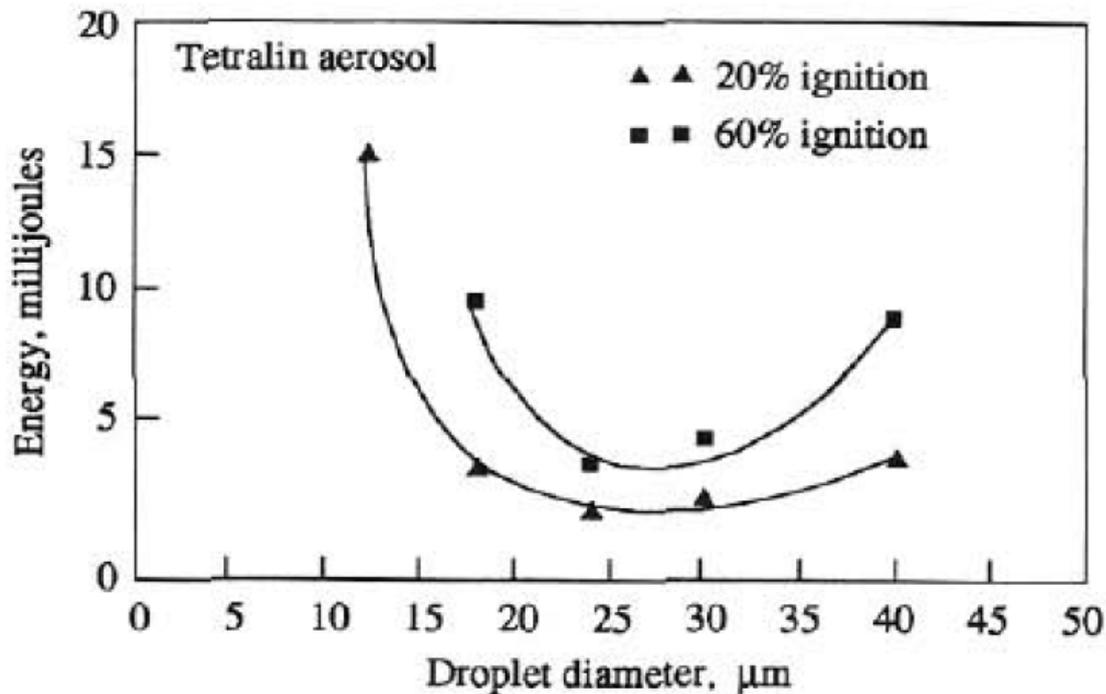


Figure 2: Variation of minimum ignition energy with droplet size

Heavy fuel oil, diesel oil and gas oil aerosols are predicted to have minimum ignition energies of a few milli-joules for systems with Sauter Mean Diameters (SMD) of about 30 μm, over a wide range of equivalence ratios.

Liquid Velocity

The practical variables characterising the release conditions for a particular liquid are considered to be the containment pressure of the liquid, P_L , and the hole or orifice diameter, d_o . In order to interpret relevant studies to date, the containment pressure is related to the liquid exit velocity using the simplistic, 1-dimensional relationship:

Equation 1: Liquid velocity

$$U = C_d \left(\frac{2\Delta P}{\rho_l} \right)^{0.5}$$

C_d = Discharge coefficient

ρ_L = Liquid Density (kg/m³)

ΔP = Pressure difference across orifice ($\Delta P_L - \Delta P_a$) (N/m²)

Quenching Distance

Flames cannot propagate through very small spaces due to the heat losses to the surrounding solid surfaces. The quenching distance is the limiting size of opening through which a flame can only just pass. This is larger than the Maximum Experimental Safe Gap (MESG), as the MESG allows for re-ignition of the gas by hot combustion products or chemical radicals even if the flame is temporarily quenched.

Sauter Medium Droplet Size (SMD)

For most systems, for example, the smaller the initial 'average' droplet size, the easier it will be to ignite at a fixed fuel concentration. Thus, it is considered relevant to draw upon the various formulae quoted in the literature to give a guide to the initial quality or fineness of atomisation in the case of an unobstructed jet.

Six different mechanisms were identified that was involved in secondary breakup of spray droplets. Each mechanism was found to be characteristic of a particular Weber number range. Below a critical Weber number, W_{ec} , secondary droplet breakup does not occur and the droplet size remains stable. An empirical correlation describing how this critical Weber number varies as a function of the Ohnesorge number was developed.

Jet Break-up Regimes

The hole size range where results appear to be valid for jet-break-up prediction, covers two orders of magnitude: between 0.1 mm and 10 mm. Pressure differentials applicable are considered to be between 0.1 bar and 60 bar; liquid densities, 700 to 1 000 kg/m³; liquid zero-shear viscosity, 5×10^{-4} to 5×10^{-1} kg/ms; liquid surface tension, 20×10^{-3} to 73×10^{-3} N/m. These ranges should cover a large proportion of the cases likely to be encountered in the industrial environment, but should not be considered absolute; they are included as guidelines only.

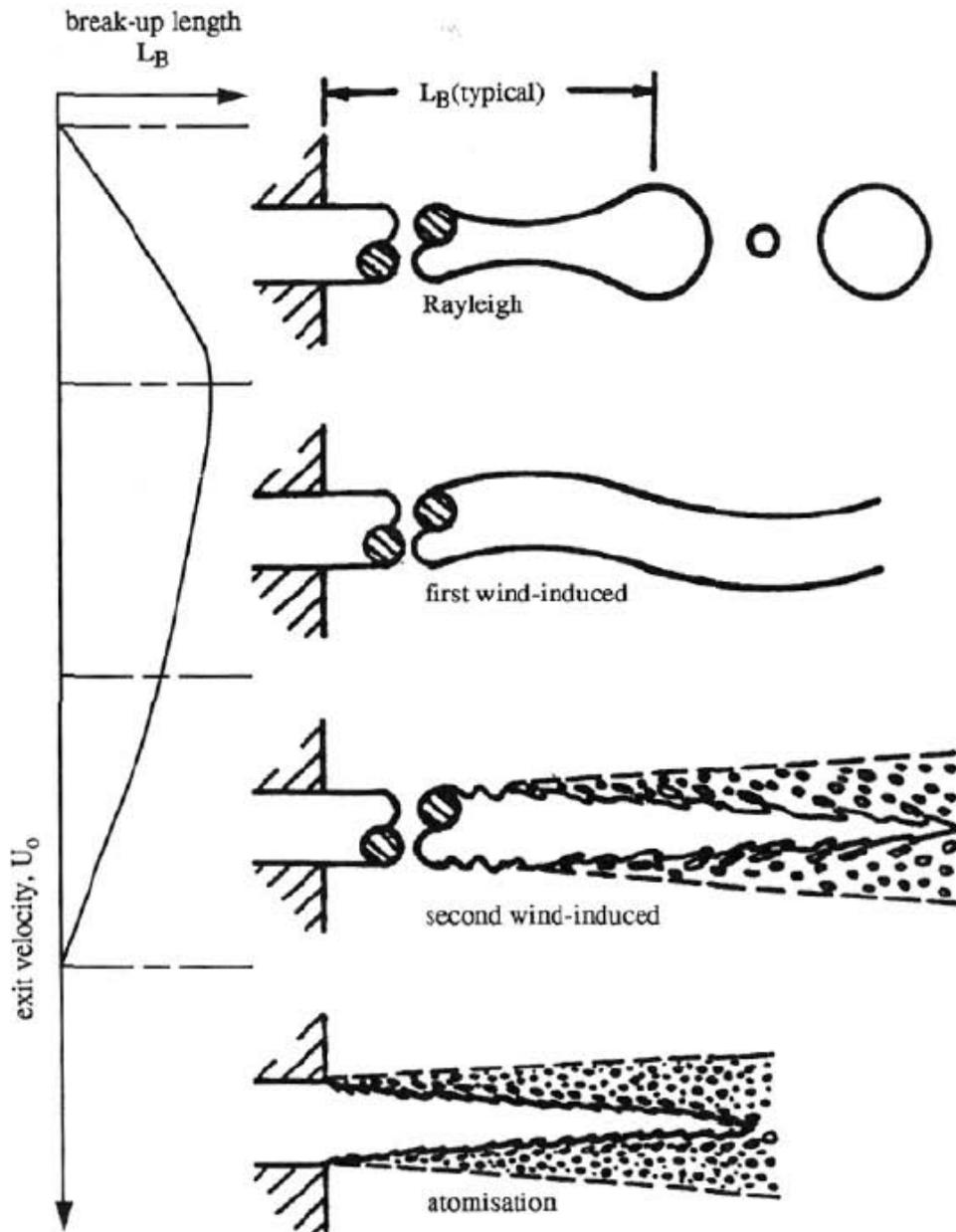


Figure 3: Change in jet break-up regime and length of solid liquid core with exit velocity

Hazardous Regimes

The figure below shows the hazardous regimes i.e. second-wind and atomization regions.

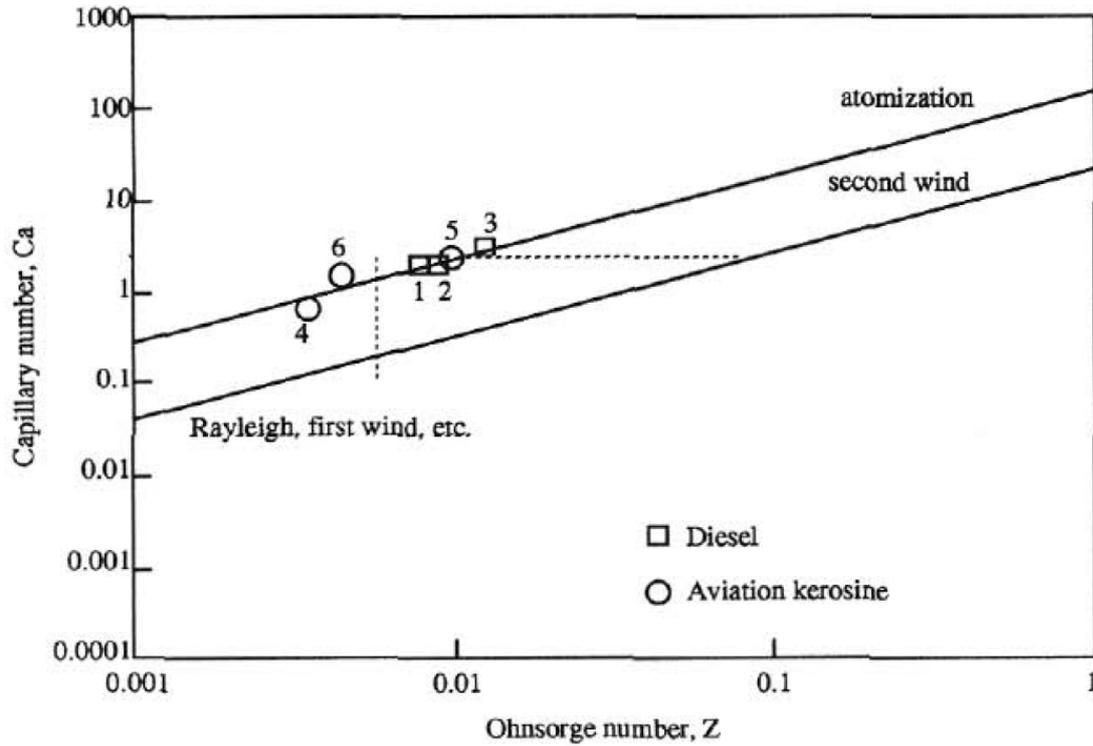


Figure 4: Transition curves for jet break-up, Ca to Z

Ohnsorge introduced the Ohnsorge or stability number which determines the ratio of viscosity force to the square root of the product, surface tension force x inertial force.

Points lying above this curve in Figure 4: Transition curves for jet break-up, where $Ca > (17.8) \cdot Z^{0.91}$ are considered to represent potentially hazardous conditions.

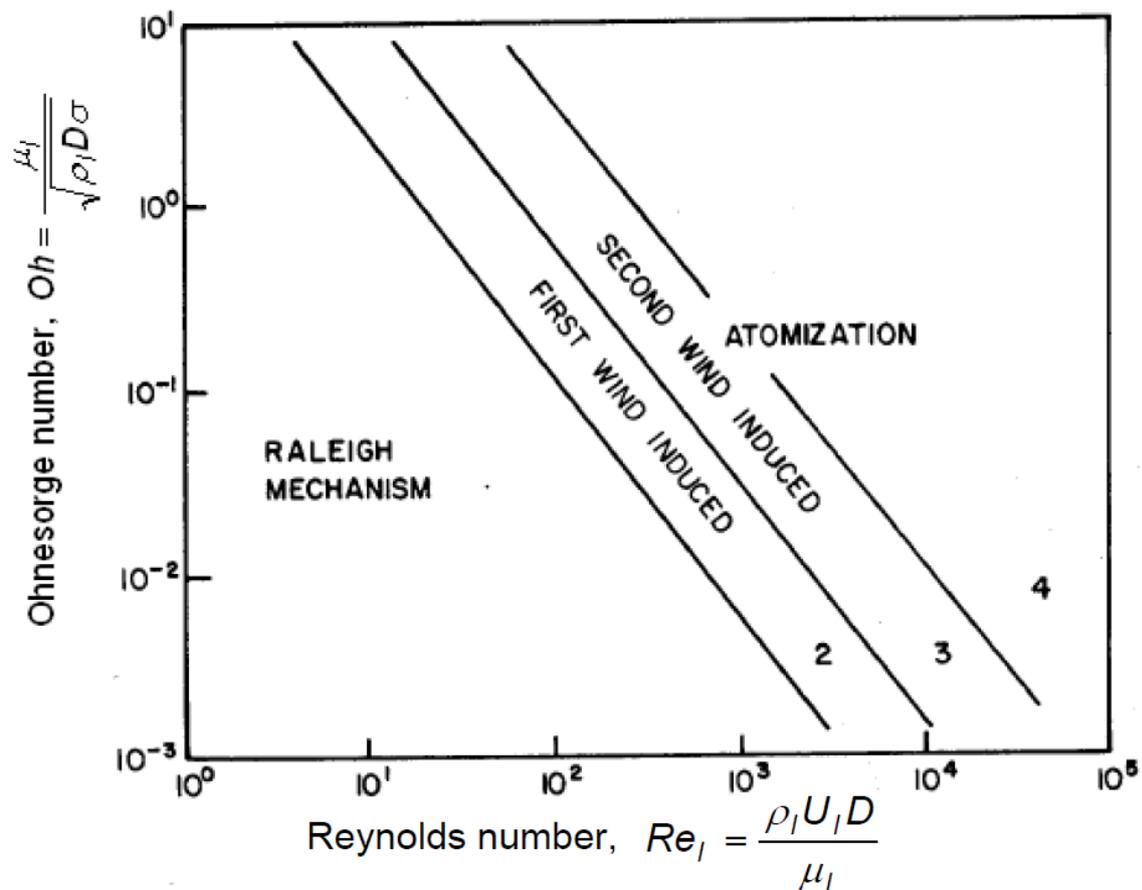


Figure 5: Transition curves for jet break-up, Z to Re_1

The figure above shows the atomization zone above line 4 or in region 4 based on the Reynolds and Ohnesorge number. Area 3 will already provide significant droplets.

Conclusion

It is of significance that any Hazardous Area Classification must be done by a Subject Matter Expert. There are too many variables that may produce a flammable atmosphere that is not readily understood. The above shows that even a liquid that is non-flammable due to its flashpoint may very easily create a flammable atmosphere if released under pressure even if it is processed at below flashpoint temperature.

The released liquid will cool down and rain out into a liquid pool that is not flammable under normal atmospheric conditions.

A mist that has a droplet size of below 20um responds much like a gas.