Fuel Cloud Dispersion through Quiescent Atmosphere and under Lateral Wind Action

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1 Introduction

Liquid fuel spillage and its safe storage consist on major and well known problems of recurrent safety. Even under the later situation, it is frequent the occurrence of leakage of the liquid fuel and or its vapor. In the case of the existence of an evaporating surface of a liquid fuel one can model its vapor behavior, i.e., the evolution of its diffusion through the atmosphere and, in the instance of an existing lateral wind, its convective propagation through it. Learning the gaseous fuel cloud evolution behavior allows accident prevention or at least its minimization. This may lead to better safety standards for the transport, storage and use of these fuels. Therefore this work discusses the modeling of the atmospheric dispersion of flammable vapors generated by liquid fuel spills. This is done under quiescent atmosphere conditions using the well known model developed by Bird et al. [1] and extended to include the occurrence of existing lateral winds. A case study has been included simulating a methanol spill during a ship to dock transfer under both conditions: quiescent atmosphere and lateral wind blowing. Finally proper safety procedures to be adopted for a general case of this kind of spill are recommended.

2 Methodology

The vapor concentration profile of methanol in air with time in order to verify the flammable cloud formation has been obtained using the model suggested Bird et al [1] for evaporation under conditions with no winds taking place.

This model assumes the evaporation of methanol in air taking place under constant temperature and pressure. Following evaporation, diffusion (as the methanol molecules propagate through the atmosphere due to the methanol concentration difference between the liquid separation surface and the surrounding air. Obviously, as the methanol migrates from its liquid phase into the air by evaporation it will occur an increase of volume around the liquid surface which push forward the molecules, triggering the convection process.

Following estimates of the diffusivity of methanol in air (using Lennard-Jones equation) and recalling that the flammability limits of methanol in air lie in the range from 6 to 36 % in volume), and also taking into account that in the liquid interface the concentration is linked to the vapor pressure, then the height of the flammable column should be estimated on a conservative basis in the lower flammability limit of 6%.

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3 Modeling methanol evaporation in quiescent air

Upon estimating the change of the mixture density, viscosity and the Schimidt Number with concentration [2], one obtains the results shown in Figure 1, which display the time for establishing a given height of the flammable column for different mixture temperatures:

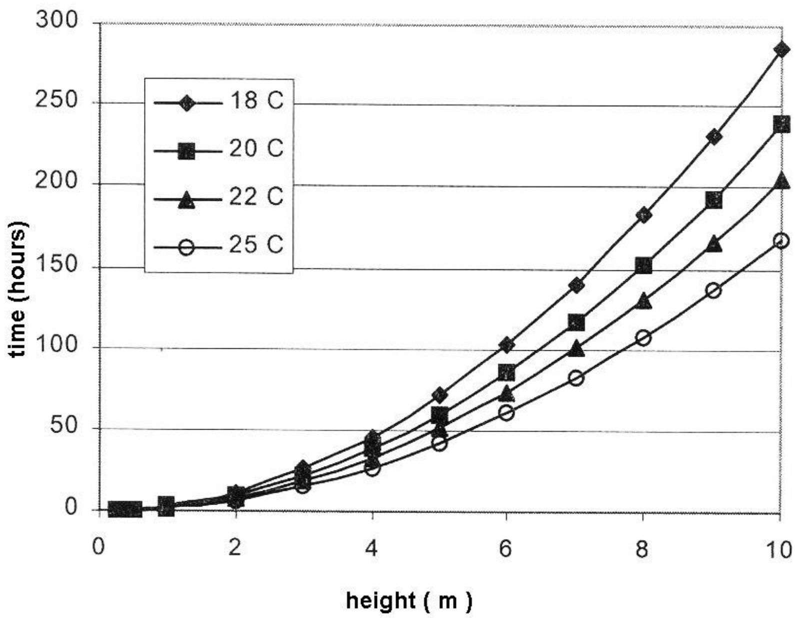

Figure 1 – Time for establishing a Flammable column as function of temperature

This points out the fact that the methanol vapor dispersion is quite slow for it depends mostly on diffusive phenomena.

In the case of compressed gases the decompression effect itself may trigger the motion and turbulence needed to quickly generate a flammable mixture. This way due to the long time needed for vapor dispersion to take place, flammable liquids tend to form explosive mixtures in poorly ventilated spots such as inside equipment and storage tanks

4 Modeling the fuel evaporation process considering wind dirpersion effect

To better study the build up of explosive atmospheres due to methanol evaporation, one considers the case of methanol dispersion in air in the presence of wind. To do so one assumes that methanol has been spilled on a ship main deck and that there is a side wind action as suggested in Figure 2 and apply the well known mass transfer boundary layer approach:

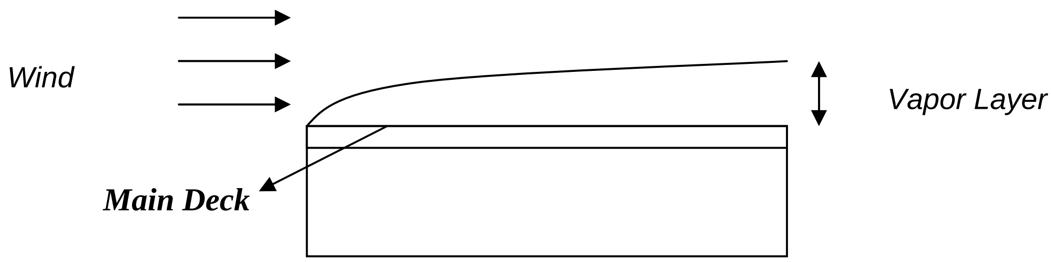

Figure 2: Sketch displaying vapor layer distribution under wind presence

5 Results and discussion

Figure 3 displays the behavior of the flammable vapor column height vs. the distance from the “pool” or “source” edge (as suggested in figure two) under a 1m/s side wind speed for ambient temperatures of 15, 20 and 25^{o}C, respectively and Figure 4 shows this column height distribution under lateral wind speeds of 0.5, 1.0 and 2.0 m/s respectively, for an ambient temperature of 20^{o}C.

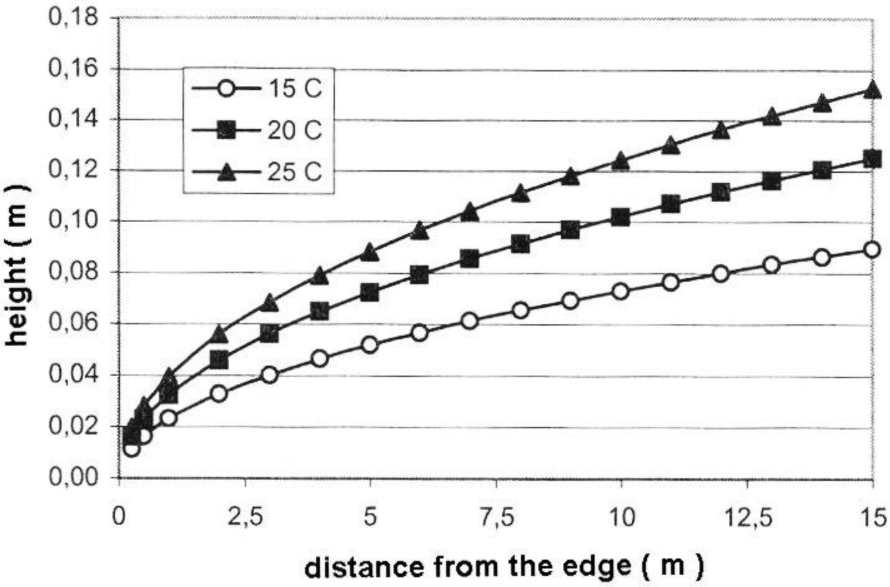

Figure 3 Flammable vapor column behavior under a 1 m/s side wind speed for environment temperatures of 15, 20 and 25 ^{o}C, respectively

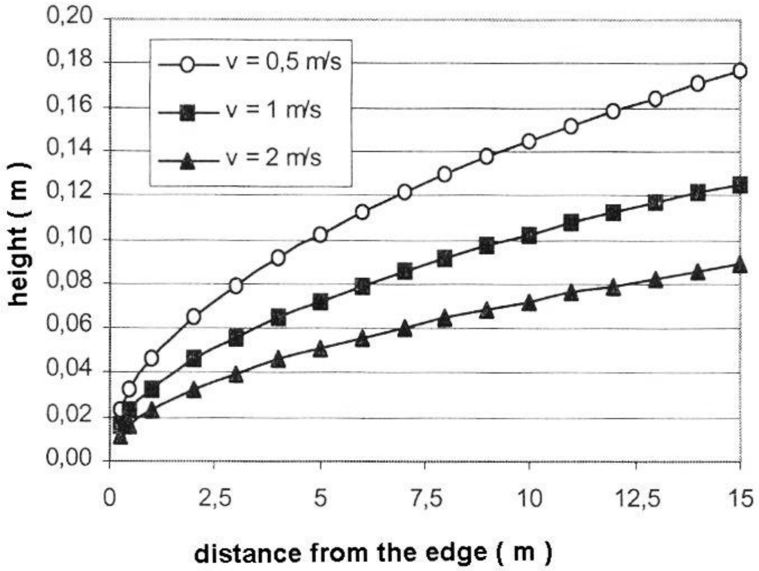

Figure 4 Flammable vapor column height distribution under lateral wind speeds of 0,5, 1,0 and 2,0 m/s respectively in an environment at 20 °C

According to the figures above it is obvious that open spaces such as ships main deck and common gas stations surroundings are well ventilated to guarantee the proper dispersion of methanol vapors and gasoline or other like fuels vapors, if the fuel layer does not exceed 20 cm height. It is worth mentioning that in this case study it was considered a methanol spillage capable to flood an open area close to $100m^2$.

6 Conclusions and recommendations

Through the use of mass transfer models based on diffusion processes it has been verified the time needed to build up a column of flammable gases in confined and in open, well ventilated environments. As the process is one of slow kinetics, it has been noticed that there would be no chance to generate a flammable cloud higher than 20 cm in an area of nearly 100 m^2 flooded with methanol, even if the leakage were not detected for more than 15 hours. Fuel storage tanks in maritime or air terminals as well as in drilling platforms (either “on shore” or “off shore”) and refineries, should have as a safety norm, available fans to disperse gases originating from leakage and / or fuel evaporation. In the case of ships with relief pressure vents such as tankers and chemical carriers, these vents should incorporate holes with diameter smaller than the flame quenching distance. This procedure, besides alleviating the tank internal pressure, will not allow any external flame penetration.

References

[1] Bird, RB et al. (1990). Transport Phenomena. Wiley International Edition, Singapure; p 594

[2] Reid, RC et al. (1988). The properties of gas and liquids,. Mc Graw-Hill International Editions, 4th Edition, New York, p 242