Effectiveness of the Water Curtains used by the Firemen to Face Toxic Heavy Gases Leaks

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Abstract :
Some experiments have been carried out by the School of Mines, in collaboration with the firemen from Ales, at an airport located in Southern France. The aim was to verify the effectiveness of the water curtains used by the firemen in the case of hazardous material spillage, particularly on transportation accidents. The substance used was ammonia liquefied under pressure, released at a low discharge rate. Under the meteorological conditions encountered on the site on that day, the presence of the water curtain reduced the near-field ammonia concentrations by a factor of 10 and more.

Keywords : Water Curtain, Liquefied Ammonia, Atmospheric Dispersion.

Introduction

As a consequence of the development of transportation and storage of hazardous materials, technological risk has increased during the last past decades. The French firemen have various means to face such accidental situation. In particular they implement a water curtain, either to limit the thermal radiation effect on a hydrocarbon fire or to ameliorate the dilution of a toxic heavy gas cloud. The study carried out by the School of Mines aimed to verify the effectiveness of such devices in the case of hazardous material releases, particularly for a 2-phase ammonia discharge. This paper will present the experimental methods used to analyse the major features of water curtains applied to the release of heavier-than-air gaseous materials together with the preliminary results.

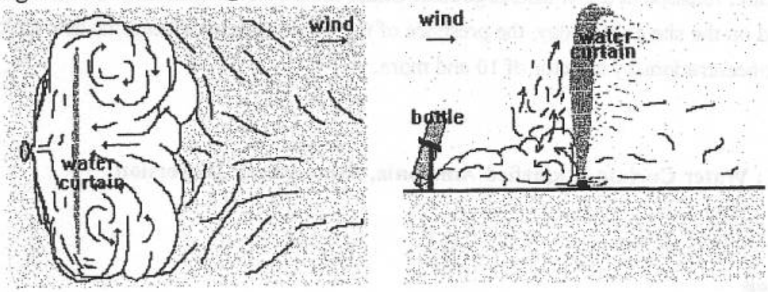
Heavier-than-air-gas releases and water curtains

When liquefied ammonia stored under its vapour pressure is released, a thermodynamical flash occurs : it is the instantaneous atomization of a fraction of the liquid phase. Some part of the material released gives also birth to an aerosol made of liquid ammonia droplets, which are formed due to the violent depressurization of the storage vessel. The remaining liquid phase is spread in the shape of a pool that evaporates under the effect of the ambient temperature and the heat conducted by the ground.

The resulting cloud is at the boiling temperature of ammonia, which, depending on the ambient humidity level, entails the condensation of the water vapor of the surrounding air. All these parameters contribute to give an average cloud density greater than that of the ambient air : the ammonia cloud, which has the aspect of a white dense mist, because of the presence of the aerosols [1] [2], behaves as a heavy gas.

Whereas the dispersion of a passive gas can not be influenced by the presence of a water curtain, since it is diluted and dispersed due to the only existence of natural turbulence in the ambient air, such a device can really affect the behavior of a heavy cloud.

Figure 1. Turbulences generated by a water curtain (above and side views).



Firstly, the water curtains can absorb the gas, particularly in the case of an ammonia cloud, which is a substance highly soluble in water. The turbulence generated by the upward water flow used in this experiment (see next paragraph) contributes to dilute the gas by dragging the surrounding air into the cloud [3]. It also elevates the plume. In addition, it acts as a barrier by accumulating the gas upstream and creating turbulence downstream. Different parameters influence the effectiveness of such a protecting device [4], like the drop size, the water pressure, the dimensions of the screen and the water flow rate. External factors can also play an important role : wind speed, discharge rate and ejection speed of the 2-phase ammonia... Some experiments have already been carried out on this subject [5] [6].

The experiments

These experiments were conducted in collaboration with the local firebrigade, at an airport located in southern France, that is to say on a large flat terrain. The hazardous material chosen was ammonia because of its relatively low toxicity compared to other heavy gas clouds and its dispersion properties, which depend on its storage conditions. Moreover, it allowed the firemen to experience situations equivalent to those which could be encountered in a transportation accident. Each experimental release had an average duration of 2 minutes. The experimental set-up included a liquefied ammonia storage vessel (44 kg - steel bottle of ammonia stored at its vapor pressure, so well above its boiling point) which was positioned to generate a 2-phase flow jet. The experimental discharge rate of ammonia was approximately 10 kg/min. A metallic pool contained the remaining liquid phase generated by the opening of the bottle sluice-gate.

Some meteorological measurements were made on the site, such as the determination of the ambient temperature, the humidity level in the air, the wind speed and the stability of the wind direction.

The ammonia concentrations were measured at different locations on the site, by trapping the gas into hydrochloric acid and dosing by the means of spectrophotometry with the Nessler reagent.

The water curtain was placed 6 metres downwind from the release point. The efficiency of the water curtain was determined by comparing the ammonia concentration measured with and without the protecting device. The water curtain was generated by means of a pressurized water jet thrown on a semi-elliptical plate which formed a semi-elliptical barrier in the vertical plane. Itsdimensions were approximately 15 meters width and 6 meters height. This barrier induces an upward water flow. The characteristics of the device were exactly the same as those commonly used by the firemen (10 bars and 500 l/min).

The following discussion is of the results of an experimenta on the 25th June 1996. The meteorological conditions on that day were as follows :

Meteorological Conditions	
Ambient Temperature	16°C
Humidity Level	58%
Wind Speed	4 m/s

Table 1. Meteorological conditions on the experimentation site

The ammonia concentrations were measured in the axis of the water curtain, corresponding to the axis of the cloud downwind displacement and for different distances in the near field :

Distance downwind from the release point (m)	**Gaseous ammonia concentration without the water curtain (ppm)**	**Gaseous ammonia concentration with the water curtain (ppm)**
13	2620	200
25	2000	150
35	860	100
50	70	50

Table 2. Concentrations measured on the site

The effectiveness of the water curtain is given by :

$$x\,\% = [\,1 - [NH3]_{\text{with water curtain}} / [NH3]_{\text{without curtain}}\,] \times 100$$

The results are collected in table 3 :

Distance downwind from the release point (m)	**Water curtain effectiveness (%)**
13	92 %
25	92 %
35	88 %
50	28 %

Table 3. Effectiveness of the water curtain

These values show that a water curtain certainly influences the dispersion of a heavy gas, particularly in the near field. Although it appears to become less significant at a distance of 50 metres from the release point, which seems to be related to the width of the water screen. At such a distance, these consequences are less important since the concentration of ammonia no longer presents danger to health or life. However, the results must be restricted to the special case studied here and must not be extended to other accidental situations, particularly for higher discharge rates or for other substances.

Some experimental deficiencies were noted from observing the cloud dispersion on the site: the water curtain did not subtend a 180° angle in the vertical plane, so that the gas could cross between the ground and the water barrier. As only one water curtain was implemented during the experiment, it has found not to be sufficient, as the cloud can go round the screen, which was not wide enough. However such technical deficiencies should be easily resolved for the next experiments.

Conclusion

The experiment studied in the present paper verifies the effectiveness of the water curtains used by the firemen in the case of an ammonia release, at a low discharge rate. Of course, more experiments are needed in order to collect significant results. This field is the subject of a Ph.D. Thesis being undertaken at the School of Mines at Ales.

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References

[1] Alp E., Matthias C.S., « COBRA : a heavy gas/liquid spill and dispersion modelling system », Journal of Loss Prevention in the Process Industries, 1991, 4, 71.

[2] Hodin A., « Modélisation du débit à la brèche et du jet généré par une fuite d'ammoniac en phase liquide : état des connaissances et modélisation des rejets diphasiques », Note d'Etude, Direction de l'Equipement EDF, Centre Lyonnais d'Ingénierie, 1996.

[3] St Georges M., Buchlin J.M., Riethmuller M.L., Lopez J.P., Lieto J., Griolet F., « Fundamental multidisciplinary study of liquid sprays for absorption of pollutant or toxic clouds », Trans I Chem E, 1992, 70 B, 205.

[4] Fthenakis V.M., Blewitt D.N., « Mitigation of hydrofluoric acid releases : simulation of the performance of water spraying systems », Journal of Loss Prevention in the Process Industries, 1993, 6, 209.

[5] Moodie K., « The use of water spray barriers to disperse spills of heavy gases - the performance characteristics of full-scale water-spray barriers when dispersing accidental spills of heavy gases », Plant/Operation Progress, 1985, 4, 234.

[6] Van Doorn M., « The control and dispersion of hazardous gas clouds with water sprays », Thesis of the Delft University of Technology, 1981.