INVESTIGATION ON A LPG GAS RELEASE

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Abstract
An LPG ("liquefied petroleum gas") gas release from a storage was analysed to point out technical and managing factors useful to avoid similar accidents to happen again. The event has happened in Bassano (Italy) on September 2001 in an LPG underground storage, constituted of four cylindrical horizontal tanks (300 m3 capacity) and three cylindrical horizontal tanks (200 m3 capacity). Therefore the total capacity is 1800 m3 of LPG. The stored substances were propane, butane and mixture of propane and butane. The release occurred during the inspection and maintenance of safety relief valves installed on a tank containing butane. These operations required the valve to be shut off by means of a deviation box, then disconnected and checked. While being displaced, the valve was ejected and an LPG gas jet formed from the pipe where the safety device was connected, at about 6 m height from the ground. After the intervention of the fire-fighters together with the storage operators, the gas outflow stopped, and the emergency ended. The dynamics of the event were reconstructed after the examination of safety valve and the inspection of the tank where some missing components were found. Moreover, some technical and managing factors were suggested to prevent similar accident to happen. Finally, the possible consequences due to an hypothetical negative evolution of the event were simulated by means of simulation models (ALOHA, SIGEM Simma, STAR): the effluent flowrate, the distance at which the LFL concentration were reached and the radiation due to the jet fire in case of ignition were calculated.

The Accident Description
The accident happened during the inspection and maintenance of safety relief valves installed on a tank containing butane. These operations required one of the two safety valves on the tank to be shut off by means of a deviation box, then disconnected and checked.

Having shifted the obturator to shut off the valve, the operator was displacing the apparatus when it was ejected by a LPG gas jet together with the vent pipe.

An LPG gas release take place from the vent pipe at 6 meters above the ground with a 6 bar initial pressure. After the intervention of the fire-fighters, in collaboration with the plant operators, the gas outflow was stopped.

During the event, the traffic was stopped along the streets close by and the LPG lee-ward concentrations at the ground level were measured by means of an LFL gauge so that it was pointed out that dangerous concentrations for inflammability weren't reached.

To stop the release from the tank, a ball valve was placed to plug the vent pipe, while the fire-fighters were ready to pull down possible gas releases with an appropriate water flow.

The LPG mass outflow released was calculated to be about 20.000 L, while the initial (decreasing) flowrate was estimated to be 180 L/min.

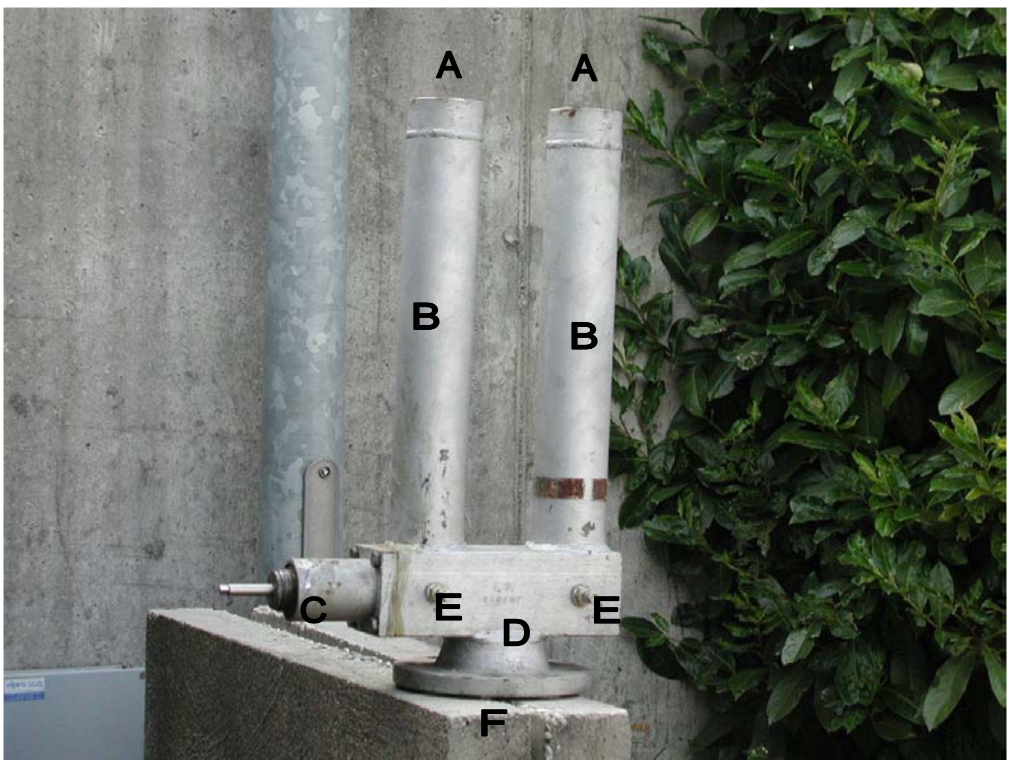
Afterwards, the LPG lee-ward concentrations at the ground level continued to be measured, up to 3 p.m. at each 15 minutes, to check the absence of inflammability conditions all over the plant areas and the surroundings as well, with a special regard to the depressed areas such as underpasses, basements, gully-holes. After then, having checked no dangerous conditions, the traffic was restored. Then the plant was placed under distress and the tank emptied as precautionary measure.

The valve apparatus

The valve apparatus consisted of (Fig. 1):

A. two safety valves set at 18 bar (not shown in the photo);
B. two pipes lodging the valves;
C. one deviation box upstream the valves;
D. one shaft, its lodging device and cover and a PTFE packing;
E. two degassing valves;
F. one flange allowing connection to the tank

Figure. 1



The investigation upon the accident

An investigation was carried out to reconstruct the accident dynamic.

From the comparison between the assembly of the valve apparatus and the components found nearby the tank, it was pointed out that some components such as a washer, a packing and a bolt were missing. So it was decided to carry on an internal inspection: an inert gas was first blown into the tank (previously emptied), then air to create adequate conditions for an operator to enter. As a consequence, two packings were found inside, while the bolt was still missing so that it was thought to have been ejected by the LPG gas jet.

The accident dynamic

The proper operations to be undertaken for a safe check of the valve apparatus are the following ones (Fig. 2):

1. check that the obturator shaft can moves without difficulties so that the obturator can reach the stroke end till the closing position for the "B" side;
2. move back the shaft till the operative position;
3. open the degassing valve for checking that the gas blows from the tank, then close it;
4. move the obturator shaft till the closing position for the B side;
5. open the degassing valve slowly to make the remainder gas blow out, then check that the gas blowing stops as an evidence that the tank has been shut off;
6. dislodge the valve to be checked, while leaving the vent pipe open so to check that the tank continues to be shut off or to operate if it is not true to avoid further releases;
7. screw down a substitutive valve;
8. lodge again the safety valve after the checking;
9. close the degassing valve;
10. move back the shaft till the operative position (in the middle of A and B position)

Figure. 2

It was clear from some technical surveys and interviews that the ejection of the valve apparatus was produced by the loosening of the obturator not noticed by the operator as a consequence of a lack of attention or an inappropriate control. Moreover, the loosening of the obturator was probably favoured by the rapid venting through the degassing valve (operation 5). So it was made evident the lack of a proper device to control the sealing properties of the obturator as well as a device to quickly stop up an emergency.

Simulation of possible effects by models

Finally, the possible consequences of an hypothetical negative evolution of the event were simulated by means of the following simulation models:

- ALOHA (Areal Location of Hazardous Atmospheres) US-EPA
- SIGEM Simma owned by the National Fire Department, developed by TEMA S.p.A.
- STAR (Safety Techniques for Assessment of Risk) release 3.1

Input conditions and parameters were:

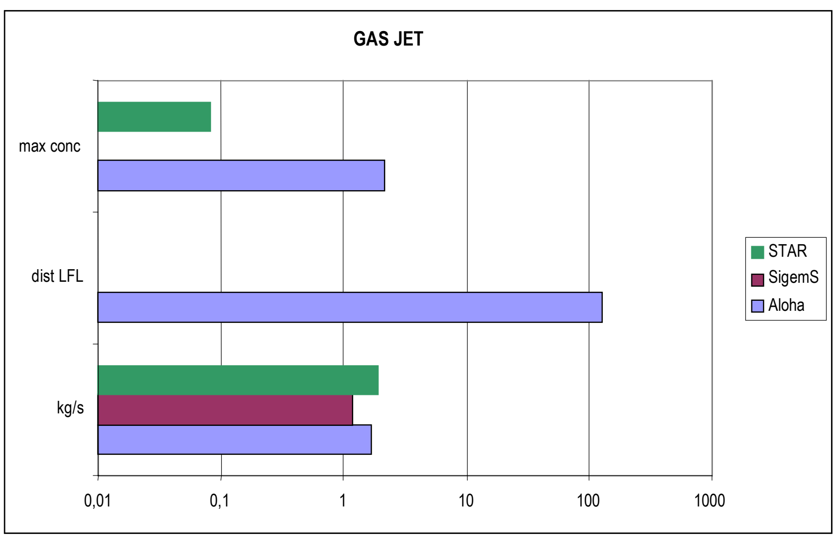
Table .1

Substance		Butane
Pressure	bar(a)	6
Temperature	K	293
Vent pipe diameter	m	0,05
Wind speed	m/s	1
Stability Class	-	C
Roughness	m	0,1

The ALOHA model calculates the gas jet flowrate and simulates the gas release from a pipe. Otherwise it is possible to introduce the flowrate value. For the application of the first case, a pipe length 200 times longer than the diameter is required, that is not our case (for a 0.05 m vent pipe diameter we need a 10 m pipe length, while it was 1 m). The results from the application of the ALOHA model were a 1.7 kg/s flowrate and a 129 m distance at which the LFL concentration is reached (2,1% volume of gas in air).
From the application of the SIGEM Simma model we obtained a 1.16 kg/s flowrate while both the LFL and the 50% LFL concentrations weren't reached at 1.5 m height above the ground level.

The STAR model provided a 1.87 kg/s value for the flowrate at sonic speed (242 m/s). Using this value together with the Ooms theory model (for a vertical gas jet) 0.078% concentration was found at 1.5 m height above the ground level.
Such results from the above models are displayed in Fig. 3:

Figure. 3



The results from the SIGEM Simma and STAR models agree with the measurements in field more than those from ALOHA model, for the 50% LFL were never reached.

To estimate the extension of the area able to be affected by the effects of a possible jet fire, the jet fire irradiation was calculated by means of the SIGEM Simma and STAR models and of a simplified model from a guideline contained in an Italian law (Environmental Ministry Decree 15/05/1996, in the following called, in abbreviated form, "DMA").

The results are displayed in Fig. 4 and 5:

Figure 4

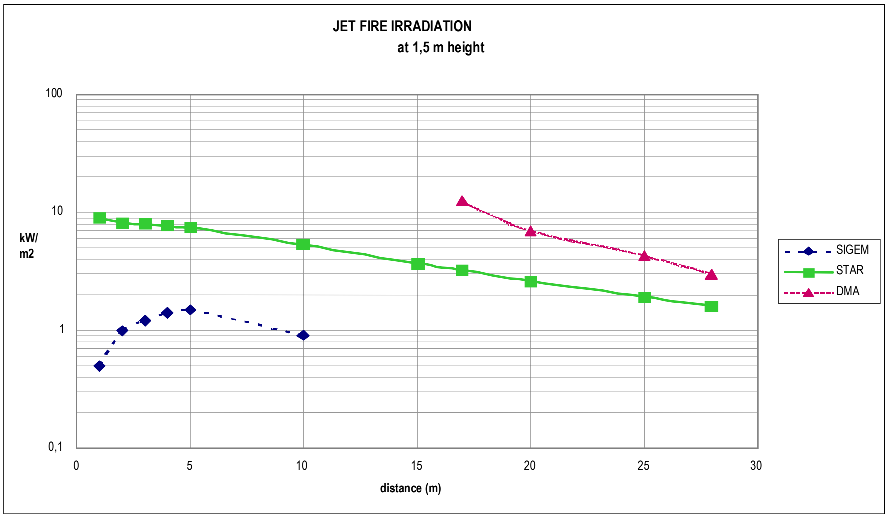
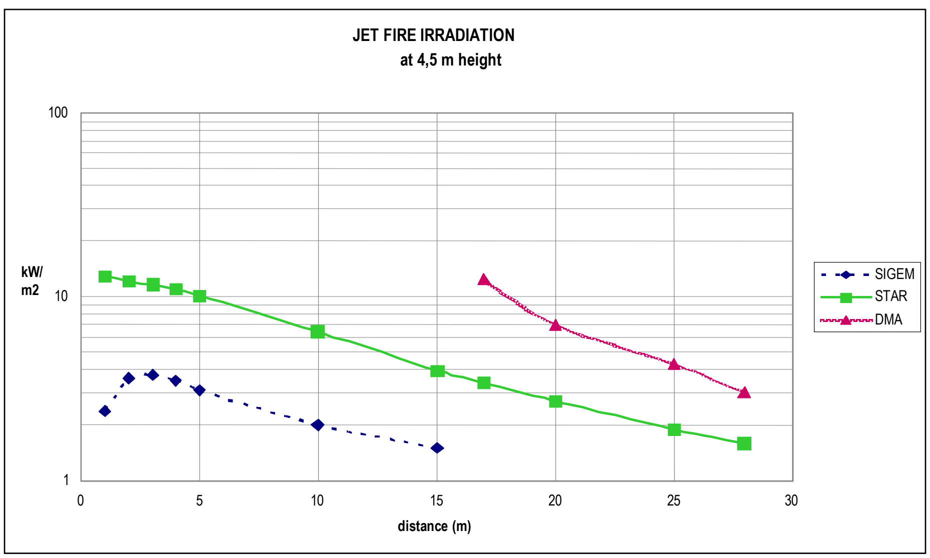


Figure 5



The method from DMA gives a jet flowrate referred to a liquid phase and equal to 15 kg/sec (for a pipe with a 2'' diameter). Since it isn't our case, we have applied such model using the flowrate value resulting from the application of the other ones (1.9 kg/s).

With regard to the jet fire irradiation, the DMA method doesn't give the height at which the irradiation value is referred. On the other hand, the SIGEM Simma method gives values for irradiation at 4.5 m (the height at which we find the vent pipe base) lower than those calculated by the STAR model: the former being 3.7 kW/m^2 at 3 m distance, the latter being 11 kW/m^2 at the same distance. This leads that the DMA method doesn't fit gas jet releases.

Conclusions

Finally some proposals to improve the safety conditions of the apparatus were given, that is:
to install a manual globe valve, locked open and upstream the deviation box, by the controller authority;
to install devices to check and block the obturator position and to control the actual depression.
Further safety conditions are assured by the application of Safety Management System procedures which give instructions about the operations for a correct and safe control of critical components and about the proper behaviour to face an emergency.

Authors Biography

Dott. Ing. Fabio Dattilo is in the National Fire Department from 1984. Till 1995, he has carried out operative and managerial jobs in the Fire Brigade of Padova. Also, as a component of the Fire Fighters Inspectorate of Veneto and Trentino Regions, he has carried out audits and checks of industrial activities with regard to Major-Accident Hazards. He is currently the Fire Fighters Chief in Vicenza.
He also is a member of the National Major Risk Commission, takes part in conferences, seminars and courses as a teacher in fire and major accident prevention and collaborates with the Universities of Padova and Venice for researches in the fields above.

Dott. Ing. Agatino Carrolo is the Deputy Fire Fighters Chief in Vicenza, Italy. Since 1st of March he has assumed the role of Chief in charge of the Fire Fighting Department of Belluno.

Fausto Zenier carried out (from 1991 to 1994) some jobs in the field of environmental pollution (emissions, writing of technical relations). In 1994 he began to collaborate with ARTES srl company (Risks Analysis & Ecology and Safety Technologies) developing or modernising software programs for operability analysis and calculation models for risk analysis. From 1997 he began to work on risk and reliability analysis (Hazop, fault-trees and events-trees), continuing the development, verification and validations of mathematical models and performing risk assessment and reliability analysis on several plants.

Cristina Balducci has a degree in Environmental Science. From 1999 to 2002 she worked in the field of waste management and quality management systems as well. In 2002 she began to collaborate with ARTES srl working on safety management systems and risk assessment.

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