ELECTROSTATIC IGNITION RISKS AND TANK WASHING OPERATIONS

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Sparks of static electricity can ignite flammable gas mixtures. This has been responsible for a number of major explosions and fires – in large tankers and on-shore tanks. The article explains how static electricity can give rise to ignition risks and how risks can be assessed and controlled.

INTRODUCTION

Explosions severely damaged a number of VLCCs (very large crude oil carriers) in the late 1960s [1,2,3]. These explosions were attributed to the ignition of flammable vapours created in the cargo tanks in tank washing operations by spark discharges of static electricity. These sparks occurred because a) the impact of the high pressure water jets created a fine electrostatically charged mist in the tank space, b) lumps (slugs) of wash water moving across the tank space became electrostatically charged, and c) spark discharges occurred when these contacted projections into the tank space – girders, bulkheads, washing machines, etc. In the words of the official report it was considered that 'water slugs were the least unlikely cause of the explosions'!

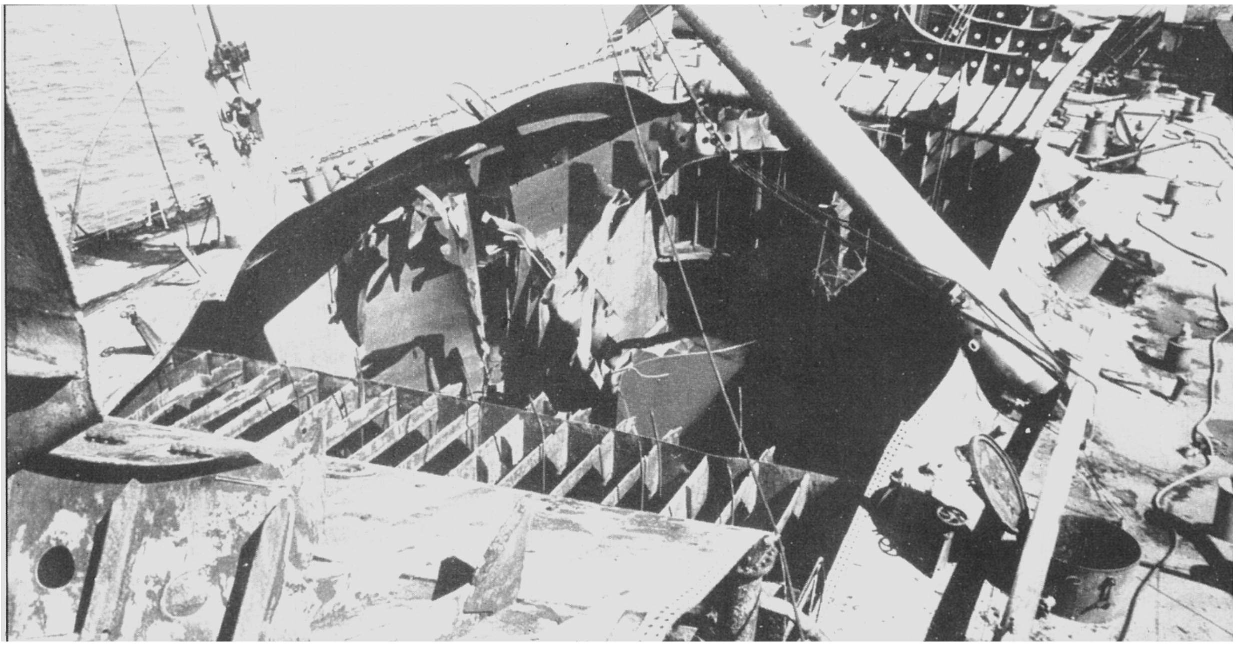

Figure 1: Example of tanker explosion damage

The risk of vapour ignitions by electrostatic sparks is greatest with the very large volumes available in large crude oil tankers and combination carriers (OBOs) – for example 25x25x25m. This is because the electric fields at the structure boundary will be higher for the larger volume for a given density of charge in the mist. The same mechanisms could, in principle, arise in many other situations where high pressure water jets are used for cleaning where flammable gas mixtures could be present or be created.

It needs to be noted that ignition risks can arise in a variety of ways – and static electricity in tank washing is just one way. It is hence important to appreciate the various ways risks can arise and the precaution needed to ensure safety.

TANK WASHING

The impact of a high pressure water jet on a surface generates an electrostatically charged mist [2,4,5]. The density of electrostatic charge in the mist varies with the force of impact and with contamination in the wash water. A large amount of work was done on the way electrostatic ignition risks can occur during tank washing operations [1,2,3,4]. The avoidance of risks in tankers has, however, been achieved not by controlling electrostatic risks but by back filling the tank space with inert gas (spent flue gas) during cargo discharge operations.

The way electrostatic ignition risks arise during tank washing is:

a) the impact of the washing jet on the tank walls generates an electrostatically charged mist
b) the charged mist creates electric fields at the edges of all projections into the tank volume
c) 'lumps' or 'slugs' of wash water either leaving such a projection in a high field and moving to a surface in a low field, or vice versa, can give an electrostatic spark discharge
d) if the quantity of electrostatic energy discharged is above the minimum ignition energy for the gas atmosphere present and if the speed of approach between the surfaces is not too high then an incendiary spark discharge can occur

Risks of ignition depends primarily on the electric fields created at projections, the size of lump/slugs of water available and the speeds of their movement.

With densities of charge in the mists created by impact of the washing jets space potentials up to 40kV can arise towards the centre of tank volumes [2]. The time for relaxation of such charged mists can be several hours. Such potentials sound high, but in fact are quite inadequate to cause occurrence of lightning type electrostatic discharges. Shipboard studies have shown that sparks do occur, and in large numbers, during tank washing [3]; and that they are associated with particular patterns of interactions of the washing jets with the internal structure of the tanks (bulkheads, girder-work, etc). Triggered flash photography showed the presence of sizeable bodies of wash water at the time of occurrence of sparks [3,4,5]. It was however not possible to identify the location of the sparks or the size of the lumps of water responsible. Computer modelling studies suggested that football size lumps of water would be needed for spark discharges to have sufficient energy for ignition. Other studies indicated that ignitions would only occur if the approach velocity of the discharging surfaces was less than a few metres per second [3]. This would probably rule out discharges from lumps of water falling to the bottom of large tanks.

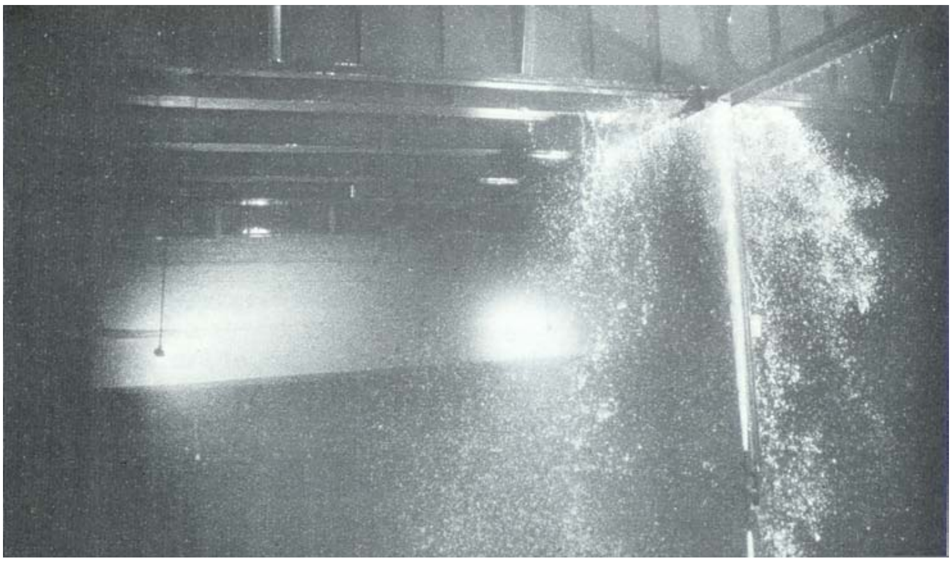

Figure 2: Example flash photograph of water cascade during tank washing

While risks of electrostatic ignitions during tank washing on large crude oil tankers has been effectively controlled by the use of inert gas the question remains about risks in perhaps smaller tanks with uncontrolled atmospheres.

There are several factors to be considered in assessing the possibility of risk in smaller tanks:

1) maximum values of electrostatic charge density likely in mists
2) maximum free dimensions within the tank volume
3) maximum sizes of lumps of water likely to arise

Studies have shown that charge densities vary greatly as wash water is contaminated with crude oil [1]. Charge densities in the mist could be up to 300nC m^{-3}.

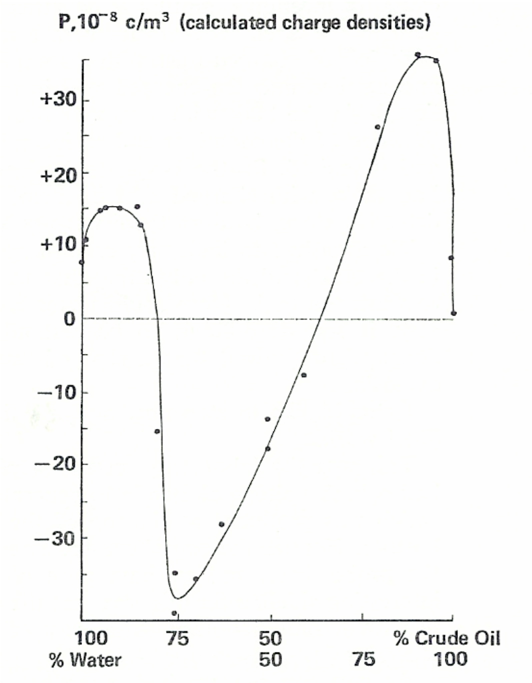

Figure 3: Graph of variation of mist charge density with crude oil contamination

The maximum electric fields that will arise at projections into the tank space cannot easily be estimated, but will relate to the maximum space potential in the tank space. This maximum space potential V_{max} (V) can be estimated from the space charge density and the radius of the maximum size sphere that can be fitted within the main structural boundaries of the tank. The relation is:

$$V_{max} = \rho r^2 / (6 \varepsilon_0)$$

- where ρ is the density of charge (C m^{-3}) , r the radius in m and ε_0 the permittivity of free space, 8.854 10^{-12}.

There are a number of practical factors worthy of note:

a) Although it has been shown that crude oil contamination can have a strong effect on charge density in the mist it may be that other oils or other materials will give different levels of maximum charge density
b) Water surfaces will not support high values of local electric field [6] except very briefly. If the electric field gets too high then the water surface will create a spray discharge that will tend to neutralise the space charge.
c) Large lumps of water are difficult to create. It would seem they are only likely to arise if a sufficient volume can be held together on elements of tank structure and then released appropriately. This is less likely in tanks with only small section webs on roof structures or horizontal girder structures.

d) The break up of the water column in the washing jet may create quite long isolated lumps of water, but these are moving at high velocity and so are not likely to be a risk for ignition [3].

The above discussion does not allow a definitive decision on whether electrostatic risks will arise during tank washing but does provide some indications. Software modelling calculations can be made to assess risks in relation to expected values of charge density and possible sizes of water lumps interaction with various likely items of tank structure [4,5]. Measurements can also be made to find out the electrostatic charge density of mists in the tank during the progress of washing operations [2,4,5]. However, neither of these approaches is simple or without cost!

PERSONNEL CREATED RISKS

In addition to the electrostatic risks that can arise in tank washing, it needs to be remembered that risks can also arise from equipment or metalwork lowered into the tank space that is not properly bonded to earth. The 'Shell Safety Guide' gives a good overview of the control of static risks in handling petroleum products [7].

Care needs to be taken by personnel when working in situations where flammable gas mixtures may arise. Two particular points worth noting: first, that paint layers may insulate a person's body from earth. The rubbing of footwear and garments against surfaces may then charge the body. If the body voltage is above the level at which a spark is felt (around 4kV) then there is sufficient energy available to cause an ignition. Second, in dipping and sampling tanks that may contain charged liquids or mists the line and person may become charged and create risk of spark ignition at contacting the side of the entry aperture. This can be avoided by earthing the person and using an insulating line and sampling vessel.

INERTING

It needs to be noted that 'inerting' a tank containing a flammable gas to try to make it safe may itself create risk of ignition! There have been two serious explosion incidents caused by preventative inerting with carbon dioxide – the Bitberg fuel tank incident in 1954 and the Alva Cape in 1974 [8,9,10].

WATER SETTLING

Where an immiscible component settles out in an insulating liquid (for example water in oil) then high potentials can arise. If these are over about 45kV there is a risk that incendive electrostatic discharges could occur.

CONCLUSIONS

Flammable gases in large volume tanks can be ignited by electrostatic discharges in a variety of ways. There is a large amount of experience available on risks from static electricity and how to control them. It is hoped the present notes will improve awareness of ignition risks mechanisms and give an appreciation of control strategies.

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