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The risk of static electricity at handling diesel fuel

Mihaela Părăian[1,*], *Emilian* Ghicioi[1], *Niculina* Vătavu[1], *Dan* Gabor[1], and *Sorin Iuliu* Mangu[2]

[1]INCD INSEMEX Petroşani, Romania
[2]Universitatea Petroşani, Romania

Abstract. Diesel fuel in motion when is transporting by pipes when is mixing, pumping, filtering, agitating or by pouring them from one vessel to another can generate static charges. Also, static electricity may occur if the liquid is splashes and forms a mist inside the tank. Accumulation of static electricity can, under certain conditions, be discharge and ignite the flammable/explosive atmosphere. Ignition hazards from static discharges can be eliminated by controlling the generation or accumulation of static charges or by eliminating a flammable mixture where static electricity may be discharged. Factors that need to be considered to reduce the risk of ignition sunt flammability characteristics of explosive atmosphere (the vapor pressure, flash point, temperature, and pressure) and the factors that determine the charging of static electricity (fuel type, electrical conductivity, sulfur content, viscosity, vehicle process: flow rate, pipe diameter, filters, pumps, spark promoters). In this paper are presented some aspects regarding the technical, organizational requirements and responsibilities of the personnel designated to prevent the formation and accumulation of static electricity when loading diesel fuel tanks, starting from a case study, respectively some explosions which occurred to a company during the loading operation.

1 Introduction

Flammable liquids, such as liquid hydrocarbons (e.g., gasoline, diesel fuel) may generate an explosive atmosphere if they are handled at a temperature higher than their flash point. The flash point is defined as "the lowest liquid temperature at which, under certain standardized conditions, a liquid gives off vapours in a quantity such as to be capable of forming an ignitable vapour/air mixture" (SR EN 60079-10-1). Each type of liquid has a specific flash point. For example, diesel fuel has a relatively high flash point of 55° C as compared to gasoline, which has a very low flash point of -23° C. This means that the risk of explosion is reduced when handling diesel fuel, given that diesel fuel is safer than gasoline. Nevertheless, a series of incidents occurred when road tankers were being loaded with diesel fuel.

* Corresponding author: mihaela.paraian@insemex.ro

It was proven, however, that in most cases the flammable atmosphere was not generated by the diesel fuel, but rather by residues of gasoline or gasoline vapors as a result of gasoline having been previously handled with the same equipment. This procedure is called switch-loading. Investigations have shown that, when incidents occurred, the ignition source was static electricity which was generated and accumulated in the liquid because of the liquid's reduced conductivity combined with facilitating factors such as high filling flow, low residence time after filters, splash filling and improper bonding and grounding.

In order to prevent such accidents, the appropriate precautions must be taken. According to the Directive 1999/92/CE, the employer must perform an assessment of the explosion risk in order to establish the appropriate protective measures [1,2,3].

2 Static electricity

2.1 Charge Accumulation and Relaxation

During the handling of liquid hydrocarbons and the tank operations, static charges may be generated and accumulated in the relevant product and, in certain circumstances, these could be suddenly released in static discharges with sufficient energy to ignite flammable mixtures of hydrocarbons gas and air.

Immediately after the static charges are generated, a process commences which dissipates them to the ground on reduced conductivity ways, namely through the liquid itself, the container and the devices for connectivity to the ground. In a grounded conductive container, the static charges dissipation depends upon the conductivity of the handled liquid. It is a known fact that liquids with conductivity greater than 50 pS/m (50 C.U.) do not accumulate static charges.

The charges accumulated in the liquid loaded in the tanks, under certain conditions, can be discharged with enough energy to ignite an explosive mixture if such mixture is present. When loading fuels in tanks, two types of discharges can occur: Spark Discharge and Brush Discharge.

Spark Discharge

Between two conductive objects at different voltages, there can be spark discharges. This may occur, for example, between a metal can floating on a surface of a non-conductive liquid and the wall of a tank (fig.1). To prevent these static discharges, all conductive objects must be grounded and bonded to each other.

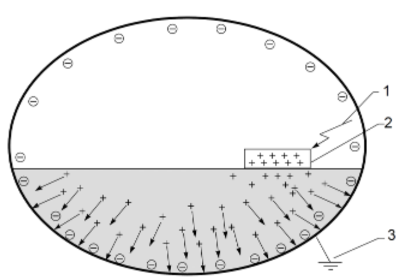

Fig. 1. Spark discharge.
1-Spark discharge; 2- Floating object (spark promoter); 3- Ground

Brush Discharge

Between a grounded conductive object and a charged low conductivity material, brush discharges may occur. This may occur, for example, between the bottom of a filling arm and the surface of the charged product (fig. 2).

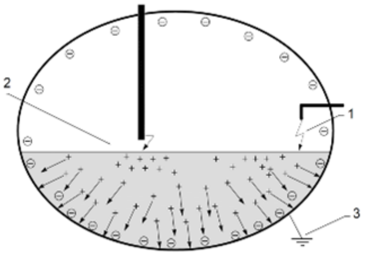

Fig. 2. Brush Discharge
1,2 – Brush Discharge; 3- Ground

When filling tank trucks, static charge may be generated by the following mechanisms:
• product flow through piping;
• product flow through filters and screens;
• splash loading; and
• multiphase flow.

According to IEC TS 60079-32-1:2017 [5] and API RECOMMENDED PRACTICE 2003 [6], the level of charge accumulation in a particular liquid, and therefore the electrostatic hazard that can be created, are strongly dependent upon the liquid's electrical conductivity and dielectric constant (relative permittivity), ε_r.

Hydrocarbons, which have a dielectric constant of around 2, are classified as follows:
• high conductivity > 10 000 pS/m;
• medium conductivity between 50 pS/m and 10 000 pS/m;
• low conductivity < 50 pS/m.

2.2 Bonding and Grounding

In order to prevent dangerous electrostatic sparks from igniting the explosive atmosphere, the Bonding and Grounding of all conductive objects: the tanker-trailer, pump, piping, and storage tank must be ensured. [4]

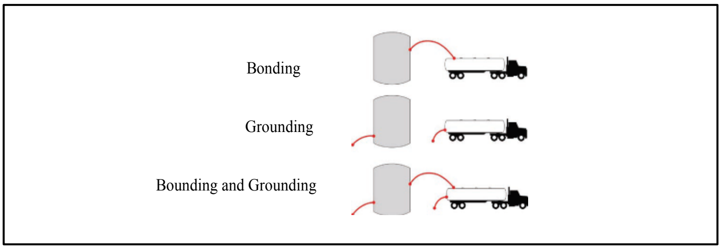

Fig. 3. Bounding and Grounding

A maximum bonding resistance of 1 MΩ is required among the chassis, the tank and the associated pipes and fittings on the truck. A maximum resistance of 10 Ω is required for wholly metallic systems. If the maximum resistance exceeds 10 Ω, the possible causes are corrosion or loose connection [5].

2.3 Flow-through Filters and Screens

High quantities of static charges may be generated if fine filters are installed on pipes adjacent to a tank. The risk of explosion is high for products with conductivity levels lower than 50pS/m if the size of the pores of the filters are lower than 150 microns. In these situations, a residence time of more than 30 seconds is necessary.

2.4 Splash Loading

Static charges may be generated when splash loading. In order to avoid dangerous splashing, the loading speed must be no higher than 1m/sec until the end of the loading pipe is submerged in liquid.

2.5 Flow through piping

The static charge generated by the flow of liquids through pipes depends on the liquid's characteristic and the rate of the liquid's flow. The regulatory requirements for reducing the static charge when loading tank trucks are determined based on the loading arm diameter, as follows [5,6]:

$$vd < 0.5 \text{ m}^2/\text{s} \tag{1}$$

where:

v is velocity in m/s;
d is inside diameter of the downspout in meters.

In addition, linear flow velocity should never exceed 7 m/s. These restrictions apply to all piping segments from 0 to 30 seconds (minimum) upstream of the tank fill opening, including the piping segment on the tank vehicle itself. When calculating the *vd* value in each segment, any flow contributions from other loading arms should be included.

The 0.5 m^2/s limit greatly reduces the probability of ignition. Industry experience loading ULSD has indicated that the historical limit of 0.5 m^2/s may not be adequately protective. For tank trucks loading ULSD and Gas oil the maximum flow rate should never exceed 7 m/s or 0.38m^2/s whichever is greater.

The main parameter that must be controlled when loading tanks trucks is the loading flow, respectively the speed that must be limited to non-dangerous values corresponding to the fuel conductivity. In the first phase of loading the speed of the liquid in the filling line must be limited to about 1 m/s until the outlet is immersed in liquid at a height twice the outlet diameter to prevent splashing / spraying and to minimize surface turbulence. Furthermore, the speed must be limited depending on the conductivity of the fuel and the sulfur content to the maximum values resulting from the tables below.

Table 1. Influence of the Sulphur content on middle distillate *vd* limits for road tankers.

Product class	Conductivity pS/m		
	> 50	> 10	< 10 or unknown
Diesel or gas oil with > 50 ppm sulphur and all other middle distillate fuels	$vd \leq 0{,}5$ m²/s	$vd \leq 0{,}5$ m²/s	$vd \leq 0{,}38$ m²/s ($vd \leq 0{,}5$ m²/s)
Diesel or gasoil with ≤ 50 ppm sulphur	$vd \leq 0{,}5$ m²/s	$vd \leq 0{,}38$ m²/s ($vd \leq 0{,}5$ m²/s)	$vd \leq 0{,}25$ m²/s ($vd \leq 0{,}35$ m²/s)

Table 2. Velocity and filling rate limits for road tankers.

Pipe size*			***vd* = 0,25 m^2/s**		***vd* = 0,35 m^2/s**		***vd* = 0,38 m^2/s**		***vd* = 0,5 m^2/s**	
NPS	**DN**	**ID, mm**	Flow velocity m/s	Filling rate m^3/min	Flow velocity m/s	Filling rate m^3/min	Flow velocity m/s	Filling rate m^3/min	Flow velocity m/s	Filling rate m^3/min
2,5	**65**	**62,7**	4,0	0,74	5,6	1,03	6,1	1,1	7,0	1,3
3	**80**	**77,9**	3,2	0,92	4,5	1,3	4,9	1,4	6,4	1,8
4	**100**	**102**	**2,4**	1,20	**3,4**	1,7	3,7	1,8	**4,9**	2,4
6	**150**	**154**	1,6	1,81	2,3	2,5	2,5	2,7	3,2	3,6
* *based on diameter of critical pipe section*										

3 INSEMEX - Case study

INCD-INSEMEX Petroşani, as an independent national body charged with investigating industrial fire and explosion produced at the end of the last year at a loading ramp for car fuels while loading diesel fuel in compartment 4 of a tanker. It is mentioned that the company has faced such incidents in the past, including one with the several months before [7].

3.1 Description of the circumstances in which the event occurred

According to the recordings (videos, logs), during the loading of diesel fuel with a conductivity of 9.1 pS/m and with a low sulfur content (< 50 ppm sulfur) in compartment 4 of the tanker truck, an explosion took place, captured on the cameras.

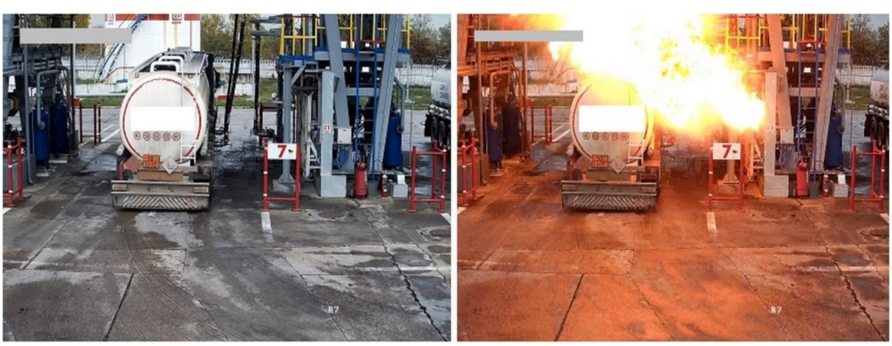

Fig. 4. a - Road tanker loading; b - Road tanker in flames

The fire could not be extinguished in the early stages and burned the entire amount of comb in the tank. The consequences of the event were the following:
- complete destruction of the road tanker;
- destruction of the loading ramp no. 7.

The effects found were due to exposure to thermal effects following the ignition and spillage of fuel in compartment 4 of the road tank involved in the event.

Fig. 5. Heavily damaged loading station

Fig. 6. The road tanker destroyed

3.2 Characterization of the explosive atmosphere

Following the analysis and application of specialized technical-scientific reasoning, it was established that the explosive atmosphere consisted of a mixture of air - gasoline vapors, remnants of the previous day's transport, in compartment no. 4 of the tanker, in which diesel fuel is loaded at the time of the event.

According to the registrations received, one day before the event, in compartment 4 was loaded amount of approx. 100 l of gasoline, after which the diesel loading was continued.
Consequently, the Switch Loading, the process of loading diesel in a compartment that previously carried gasoline, favored the formation of the explosive mixture of gasoline vapors inside compartment 4 [8].

According to bibliographic data, Switch loading or splashing (or both) represent 80% of the explosions initiated by static electricity.

Whenever a tank is filled with a product other than the one it previously contained, the operator / carrier must ensure that the compartment has been cleaned before filling. This is especially important for low-sulfur diesel.

3.3 Calculation of the flow rate of diesel in the tank

Based on the photo, video and documents provided, it was possible to determine the exact value of the diesel delivery flow, make the mass flow diagram as a function of time below and calculate the flow rate of diesel fuel, from starting the pump to the occurrence of the event. The result was a speed Vf = 3.92 m/s through the pipe with a diameter of 100 mm.

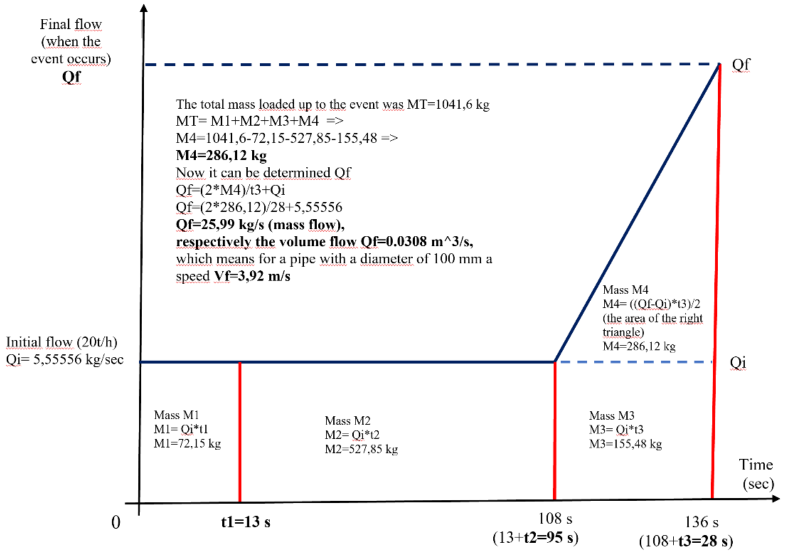

Fig. 7. Mass flow diagram as a function of time.

3.4 Hypotheses regarding the sources of initiation of the explosive mixture and their analysis

Among the sources of initiation of the explosive atmosphere, the following were analyzed: flames and hot gases, mechanically generated sparks, static electricity and chemical self-ignition. Following the analysis, it was retained as the source of the explosion - Static electricity - Discharge of accumulated static charges.

Given the low conductivity of diesel fuel (9.1 pS / m), low sulfur content (< 50 ppm sulfur) and high loading speed in compartment no. 4 in the last seconds before the occurrence of the event (3.92 m/s), it is estimated that there was a strong electrostatic charge when the liquid flowed, so that the electrostatic charges accumulated in the fuel could be discharged through a phenomenon of brush discharge and ignited the explosive atmosphere in the compartment due to gasoline vapors remaining in the compartment from the previous day's transport.

Favoring factors of the event:

- Existence of gasoline vapors inside the compartment where diesel fuel is loaded;
- Not cleaning of compartments contaminated with vapors sensitive to electrostatic discharges;
- Fluid flow rates above the limit value characteristic of types of fluids with low sulfur content and low conductivity.

3.5 Measures and recommendations to prevent similar events

- Ensuring an initial loading speed of max 1m/s until the outlet is immersed in liquid at a height twice the outlet diameter to prevent splashing / spraying and to minimize surface turbulence.
- Reducing the speed of circulation of petroleum products to the maximum threshold value in table no. 1 and 2 taking into account the specific conductivity and sulfur content for each product transported. It is necessary to determine the conductivity parameter for each batch of

product stored in the tanks of the park. Particular attention will also be paid to the properties of the additives used which may influence the above parameters.
• It will be forbidden to fill the tank compartments with diesel (switch loading), in which previously petrol was transported, without applying inertia and / or cleaning measures.
• Ensuring a sufficient residence time downstream of pumps and filters;
• Bounding and grounding of conductive parts to prevent potential differences between them (eg in flow, casting, steaming and sandblasting);
• Add, where appropriate, SDA (static dissipater additives) to low conductivity fuels to increase conductivity, preventing load build-up in grounded equipment.
• Removal or equipotentialization of spark promoters in the container;
• Ensuring a sufficient waiting period before sampling or measurement.
• Review procedures and instructions to establish all applicable technical and organizational measures to prevent explosions when loading autostatic tanks with electrostatically charged fuels in accordance with the requirements of applicable norms and standards

4 Conclusions

With the advent of new types of fuels, ULSD (Ultra Low Sulfur Diesel), as a result of the implementation of environmental legislation, has increased the risk of explosion, because these types of diesel are easily charged with static electricity and discharges with sufficient energy can occur. to ignite an explosive atmosphere. Therefore, oil companies need to review their working procedures with additional measures to prevent explosions. These procedures must implement measures to prevent switch loading and eliminate initiation sources. In order to achieve this, a cooperation arrangement between the road tanker operator and the site operator is indispensable for purposes of implementing safe loading and unloading procedures with the goal of mitigating the risk of explosion.

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