Control of Static Electricity during the Fuel Tanker Delivery Process

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Abstract

Caltex Australia and the petroleum industry have experienced a number of incidents on retail sites, resulting in the ignition of fuel vapour during the delivery process. Static electricity is a known risk in the industry and these incidents are potentially related to the generation of static electricity in the delivery process. Though the likelihood of static related incidents is small with the existing control measures across the industry, the consequences can be severe. In order to support the identification of the likely cause of these incidents and further mitigate the possibility of them occurring in the future, there is a need to better understand the levels of static electricity generated at various stages of the fuel loading and delivery processes. Although subsequent investigations have identified static electricity as a potential cause of these workplace incidents, it is still not clear the levels of static electricity generated or the effects of changing conditions on static generation during the delivery process. Therefore, this project will focus on identifying the risk of ignition during the fuel delivery process and attempt to better understand through modelling techniques the level of static electricity generated at various stages of this process.

1. Introduction

1.1 Background information

In Western Australia most notably, a high percentage of incidents resulting in the ignition of fuel vapour during the delivery process have occurred, in comparison to other regions of Australia. The control of Static electricity has been identified as a major focus area in risk management strategies across the petroleum industry. To mitigate the risks associated with static electricity, Caltex Australia and the industry have incorporated many precautions in its operating procedures. These include:

1. Mixing the petroleum product with additives to increase its conductivity, which in turn minimises the build-up of electrostatic charges;
2. Grounding the trucks using earth wires and hoses when they are at both terminals and petrol stations;
3. Advising the drivers to ground themselves continuously by touching the truck or barrel (tanker)
4. Having all drivers wear insulated gloves during the majority of the loading and delivery procedures;

5. Bonding the bucket with the truck when the driver discharges the remaining hydrocarbon fluid in order to avoid any potential difference between the bucket and the truck.

Despite having adopted all these measures, incidents have still occurred and the specific part of the operation which generates ignition is still unknown.

1.2   Key findings of literature review

In order to get a better understanding of static discharge build-up, some professionals have attempted to model the electric field within the tanker. They assume that the tanker was full of petroleum product carrying a uniform charge density, which could be determined by the velocity of the hydrocarbon fluid in the pipeline and the properties of the hydrocarbon fluid itself. Because the electric charge density of the hydrocarbon fluid within the tanker is known, the electric field was calculated using Poisson's equation. By visualising the electric field, many eco-potential lines were identified within the tanker and the maximum voltage value was located and used to calculate the energy stored within the tanker. The amount of energy stored in the tanker is equivalent to the maximum energy released by static discharging between the tanker and any other object or person. Ignition occurs when the released energy is more than minimum ignition energy. Therefore, the risk of ignition could be identified by comparing the energy stored in the tanker with the minimum ignition energy (Butterworth, 1982). The methodology used in previous research papers has provided this project with a clear and basic idea of how to identify the risk of ignition. However, the tanker modelled in these papers did not contain any compartment and only one kind of hydrocarbon fluid was in the tanker, which is different from the Caltex's tankers. The tankers of Caltex contain many compartments and the petroleum products in different compartments are different. So how to describe the tanker with many compartments and model the electric field considering the effects from adjacent compartments will be one challenge addressed by this project.

Apart from modelling, some researchers also use measurements with a static field meter to investigate this issue. For example, a small fire accident occurred at a Snax service station in the manhole chamber during discharging of unleaded petrol from a tanker to an underground tank. The manhole has four filling pipelines made of plastics and a metal transition fitting at the top. An aluminium cap is used to seal the transition fittings of the filling pipes when the pipelines are not in use. Usually, two hoses are used to discharge the petrol to the underground tank. When the incident occurred, the driver just finished filling one tank and started discharging the petrol to another tank. More specifically, the driver connected the fittings of a hose to another pipe and then placed the metal cap onto the pipe that he had just finished discharging. This is when the fire incident happened. In addition, a bonding wire was usually used to connect the metal cap and the terminal fittings of pipes to avoid any potential difference between them, but the bonding wire was not used before the fire accident happened (Hearn, 2001).

The whole operating procedure was re-enacted for an investigation into the fire incident and several measurements were performed by the investigators. Initially, in order to calculate the relaxation time for the static charge on the fittings to dissipate, two values were measured, namely, the resistance and capacitance between termination fittings and the ground. Although the relaxation time of one termination fitting is notably bigger than those of other termination fittings, all the relaxation values of the terminal fittings are extremely low. Additionally, the investigators have used some instruments to measure the amount of static charge on the

terminal fittings and the pipes during discharging procedure. In the course of the measurements, the flow rate of the petrol within pipes was monitored at about 1000 litres per minute, which is equivalent to 2 meters per second. The terminal fittings of both the hoses and the pipes which were connected to underground tanks have been monitored during the discharging procedure. Furthermore, a small part of the plastic pipe in the manhole was also measured. After finishing discharging and disconnecting the terminal fittings, the measurements of static charge on the terminal fittings have also been taken. During filling the underground tank, all the terminal fittings had zero electric potential and an insignificant potential was detected by the instrument on the pipe in the manhole, which was less than 200 Volts. The explanation of these results given by the investigator was that the relaxation time of these terminal fittings was so small that no electric potential could be detected by the instrument. Finally, a measurement of the resistance between the body of the tanker and ground has been taken. The value of that resistance was around 8 MΩ, so the body of the tanker was conductive to static electricity (Hearn, 2001).

Based on the above measurements, several conclusions have been achieved by the investigators. Firstly, the investigators did not find out how the ignition was caused by static electricity. Secondly, the investigators suggested the static charge on drivers' bodies was a possible source of ignition but they did not measure the electric potential on drivers' bodies (Hearn, 2001).

1.3   Project objectives

The three primary sources of static electricity considered in this project are: i) the friction between the petroleum fluid and pipelines during filling tankers at terminals; ii) the friction between the fluid and the hose when the truck is at the petrol station discharging the hydrocarbon fluid into an underground tank; iii) the drivers' activities during the whole delivery procedure. In relation to the first two sources of static electricity, this project will endeavour to gain a better understanding of how static electricity builds up within tankers in order to determine whether it can cause ignition. Furthermore, regarding the third source of the electrostatics, this project will focus on identifying how much static electricity is generated by the drivers' activities and accumulated on drivers' bodies. Based on the outcomes of these investigations, some recommendations on operating procedures will be made to further minimise the risk of ignition. More specifically, the primary objectives will be defined as:

1. To investigate how the static charge density carried by the hydrocarbon fluid can be calculated;
2. To determine the static electric field within the tanker and how the electric field in different compartments affects each other by modelling it using software Ansys ®;
3. To investigate the amount of static charge on the surface of the tankers, terminal fittings and drivers' bodies by measurement;
4. To investigate how the amount of energy stored in the tanker can be calculated in order to compare it with the minimum ignition energy;
5. To identify some possible risk factors of ignition based on the outcomes of the first four objectives;
6. To make some recommendations to further mitigate the risk of ignition during the delivery system.

2.   Process

The project executive plan is demonstrated in Figure 1 below. The modelling work in Step 3 will be conducted with software Ansys ® and the measurments in Step 4 will be taken by Electromagnetic field meter.

1. Measuring the velocity v of the fluid in the pipe connected to a tanker.

2. Calculating the static charge density ρ_V caused by the friction between the fluid and the pipes using the equation:
$$\rho_V = \beta \times v \times \pi$$
(Butterworth, 1982).

3. Modelling the electric field due to the static charge in the fluid in tankers and hoses with Ansys ®:
  ➢ Inputs:
     (1) Static charge density ρ_V;
     (2) Relative permittivity of the fluid;
  ➢ Boundary conditions:
     The electric potential on boundaries of the tanker is zero since tanker is earthed;
  ➢ Results:
     (1) The electric field due to static charge in tankers and hoses;
     (2) The electric potential due to static charge in tankers and hoses.

4. Measuring the electric potential due to the static charge on the surface of tankers and hoses with Static field meter.
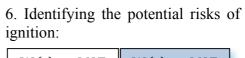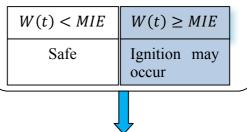
5. Calculating the amount of energy which can be released on discharge by the equation:
$$W(t) = \frac{1}{2} \times V(t) \times Q(t)$$
$V(t)$ is the potential difference between two objectives;
$Q(t)$ is the amount of charge which will be transferred from one object to another object during discharge (Udoetok, 2011).

6. Identifying the potential risks of ignition:

$W(t) < MIE$	$W(t) \geq MIE$
Safe	Ignition may occur

7. Making recommendations

Figure 1: Schematic of the project procedure
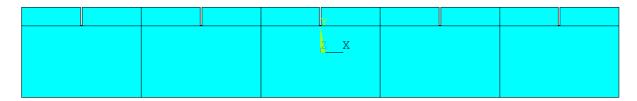
3.   Results and Discussion

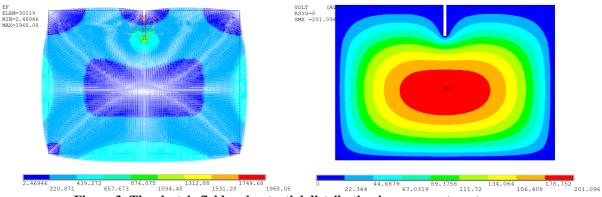**Figure 2: A cross sectional representation passing through nozzle tips of a tanker with five compartments.**

Figure 3: The electric field and potential distribution in a compartment.
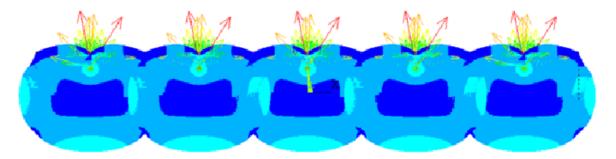

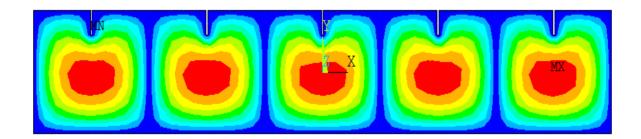**Figure 4: The electric field in a tanker with five compartments.**

Figure 5: The electric potential distribution in a tanker with five compartments.

The interior structure of a tanker with five compartments is shown in Figure 2. In each compartment, there is a nozzle tip for a washing machine. To investigate the potential difference between the fluid and the nozzle tip, it is assumed that the level of charged fluid in the tanker is one cm apart from the nozzle tip. The left plot in Figure 3 demonstrates the form

of electric field in a single compartment and the right plot in Figure 3 shows the electric potential distribution due to static charge in the compartment. Figure 4 and Figure 5 illustrate the form of electric field and electric potential caused by static charge in a tanker with five compartments.

The electric potential difference $V(t)$ between the suface of the charged fluid in tankers and the nozzle tip, which is needed for calculating the amount of potential released energy $W(t)$ on discharge, can be obtained from the models. Therefore, some potential risks of ignition within tankers can be identified by comparing $W(t)$ with the minimum ignition energy. In addition, the model results can help better understand how the electric field due to static charge exists in a compartment and how the electric field in adjacent compartments affects each other.

4.   Conclusions and Future Work

The project is still in progress, so there is no final conclusion on identifying any potential risk of ignition at this stage. However, the results from modelling have helped better understand this issue in terms of the form of electric field and electric potential distribution in a tanker with five compartments. Theoretically, the electric field in one compartment will be independent of the one in the adjacent compartments and the model results have confirmed the previous theoretical analysis. In addition, when the tanker is full of charged fluid, the maximum electric potential caused by static charge is near the center of each compartment and the electric potential of the fluid near the inner surface of compartments is zero.

Apart from interpreting the results from modelling, ongoing work also includes: taking measurements on the static charge on the surface of tankers and hoses; calculating the amount of potential released energy on discharge using the results from modelling and measurements; identifying potential risks of ignition and making some recommendations to further mitigate the risk of ignition as illustrated in the progress section of this paper.

6. References

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