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Determination of Ignition Voltage in Tank Vehicles Carrying Gasoline and LPG in Electric Field Zone

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ABSTRACT

This study has been conducted through computer simulations of ignition voltages, and opened-voltage on fuel tank vehicles consisted of gasoline and LPG, which is caused by the intensity of the electric field. This study reported the condition when tank vehicles consist of 5,000 liters of gasoline was passing through the electric field zone then it showed the ignition voltages was 3014.15 Volts, for tanks consist of 16,000 liters gasoline showed 2818.66 Volts. Other conditions among tanks consist of 9500 kg LPG showed ignition voltage as much as 2773.93 Volts while in the critical fields were 4040.42 Volts/meters, 2396.82 Volts/meters and 2040.55 Volts/meters, respectively. By knowing the ignition voltage result among the conditions as mentioned above, this study concluded that the tank on vehicles consisted of 5,000 liters gasoline had the most sensitivity to fire, followed by the tank on vehicles consisted of 16,000-liter gasoline and 9,500 kg LPG.

Key words: ignition voltage, open voltage, electric field intensity, critical electric field

1. Introduction

1.1 Background

The distribution system of fuel oil and until now is even predicted that for the next few decades, it will still use tank cars. When the vehicle passes under an extra-high-voltage air line network (SUTET) then in the metal of the tank the vehicle will accumulate an electric charge that is induced by an electric field that is under the SUTET network.

The driving factor why this research needs to be done is that most liquid fuel transport tank vehicles (including liquid, premium, Pertamax etc.) are cylindrical and space inside has the same electrical properties as a capacitor so that if there is an electric field present inside it will potentially cause capacitive spark discharge.

1.2 Literature Review

A study conducted by Epri (1975) in Ultra High Voltage (UHV) transmission research project p-68, said that a fuel tank vehicle with all its skeletons could be presented as a capacitor. Thus it can be concluded that there is a relationship between the electric field (E) and the ignition voltage value owned by the tank and the liquid fuel in the tank. An electric area can trigger the ignition of liquid fuel inside the liquid fuel tank (McKinney, 1962 as quoted by Epri, 1975)

McKinney (1962) has generalized an equation model for the ignition voltage from an experimental model which displayed the relationship between the ignition voltage and the capacitance of the object. The model obtained by this experiment can determine the ignition voltage number through the magnitude of the capacitance of the object in question.

1.3 Basic theory

1.3.1 Calculation of capacity value

The fuel tank model was represented by a horizontal-cylindrical electrode as shown below (Maruvada & Cavallius, 1975):

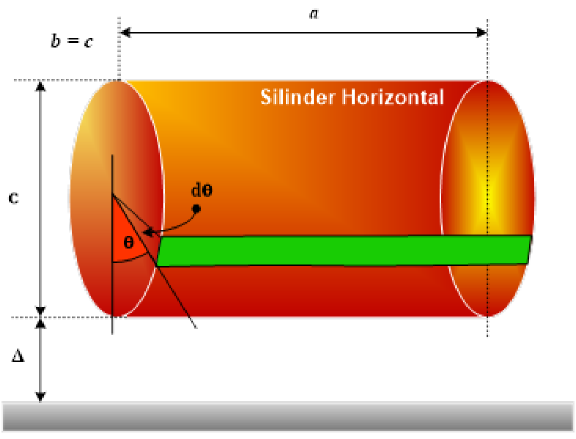

Fig. 1: Representation of Fuel vehicle tank and Cp Value Calculation for horizontal cylindrical surfaces (Marupada and Cavallius, 1975}

This configuration is characterized by four main dimensions:

- *a* is the horizontal length of the fuel tank.
- *b* is the horizontal width of the fuel tank
- *c* fuel tank height
- Δ the smallest gap between the fuel tank and the ground

More precise way to validate the ground influence among all values and configurations as follows. C capacitance of any object is considered as being composed of two capacitance values.

$$C = C_{\infty} + C_P \tag{1}$$

Where C is the capacitance value of the object above the ground surface, the CP value is obtained as an estimate as

$$C_P = \varepsilon_0 . \int_S^b \frac{dA}{h} \tag{2}$$

dA is the elementary surface area, and h is the height above the ground. Integration is carried out on the surface area of the ground or tilted at an angle of 900 or smaller. Calculation of the value of C for horizontal cylinders,

$$C_P = 2 \cdot \varepsilon_0 \cdot \int_0^{\frac{\pi}{2}} \frac{\left(\frac{c}{2}\right) \cdot a \cdot d\theta}{\Delta + \left(\frac{c}{2}\right) \cdot (1 - \cos\theta)} \tag{3}$$

And then in the next step is obtained,

$$C_P = 2 \cdot \varepsilon_0 \cdot a \cdot \frac{\left\{\pi - \text{arc } \cos\left(\frac{1}{1+a}\right)\right\}}{\sqrt{(1+\alpha)^2 - 1}} \tag{4}$$

with $\alpha = 2 \cdot \Delta / C$

1.3.2 Calculation of ignition voltage of liquid fuel in the tank

The electric spark between two conductive bodies can ignite a mixture of flammable hydrocarbon vapour air (Mc Kinney, 1962 in Epri, 1975). Three methods cause ignition, which was reviewed by McKinney (1962) in his review.

- Ignition by discharging capacitance circuit between particular electrodes as well as the closing process.
- Ignition by interference with the inductive sequence between the opening of contacts.
- Ignition by hot wire

A series of tests using real objects according to different capacitance values in the electrostatic field induced by high voltage air conductors. A fuel tank vehicle is simulated with a spout with an open container filled with liquid oline (oline). The data shown by Figure 2 below:

A straight line was drawn through points that represent the minimum ignition voltage for a spout (which contains) oline. The formula for minimum ignition voltage:

$$\mathrm{V}_p = 4.6 \times \mathrm{C}^{-0.3} \quad \text{(Volt)} \tag{5}$$

The actual ignition voltage is obtained in the range of values from 1 to 2 times the minimum value. The rms (root means square) value for ac voltage is converted through ($1 / \sqrt{2} = 0.707$).

1.4 Problem Identification

A liquid fuel carrier tank object has an oval-cylindrical tank that has a capacitance value for ground level, air space gap in the tank, loose bolt slit gap, and slab plate gap between the tank holder and its frame. When this vehicle enters the area SUTET, the terrain will be cut off by the presence of this vehicle.

1.5 Problem Formulation

Based on the description as mentioned before also by observing the electric field that is in around the SUTET-500 kV, 50 Hz network line, this study question can be described as how much the ignition voltage can be accumulated in the fuel tank installed on the vehicle and how the relationship between the electricity zone located below SUTET area and the accumulated voltage inside the fuel tank on the vehicles.

1.6 Research Objectives and Benefits

The objectives of this research are:

- To find out the ignition voltage for each size of the fuel tank placed on the chassis of the liquid fuel carrier.
- To know the intensity of critical electric field that is able to cause the ignition voltage in each tank with its dimensions.

2. **Research methods**

1.1 Research Methods

Modelled horizontal cylindrical tank truck. Modelling, as shown in Figure 3. The extra-high voltage air duct space to the ground surface is modelled as a capacitor with a dielectric medium in the form of air while the car object is modelled as a rectangular plate having an area of S.

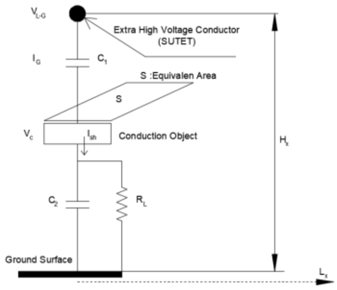

Fig. 2: One line transmission line model which has a conduction object on the below part

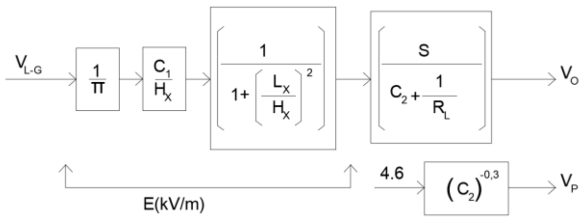

Fig. 3: The relationship between the study variables and the independent variables

Information:

- Vo = open voltage on the object against the ground
- Vp = object ignition voltage = 4.6x (C2) 2, the variable under research
- C_2 = Cog = value of the object's capacity to the ground
- S = the surface area of the charge collector on the object
- Hx = height of conductor SUTET above ground level, in meters
- VL-G = Voltage between one phase to neutral (to ground) in kilo-volts.
- Rog = RL in Ohms

Between SUTET conductor and the vehicle object which has an equivalent area of the charge collector (S), there is an air gap that can be modelled with a capacitor C1 with a dielectric constant of relative air ($\varepsilon_r = 1$). While between the object of the vehicle and the surface of the earth, a capacitor appears again, which is modelled with capacitor C2. These capacitors represent all material vehicles that are capable and have the potential to store electric charges when passing through the area under SUTET. Capacitor C2 will discharge (discharge) the charge when the voltage gradient has reached its breakdown value. The increase in the value of the gradient is triggered by the electric field generated by the conductor SUTET, which is voltage-acting against the ground by VLG. RL prisoners model the condition of material objects that are resistant, including the condition of the tires of the fuel tank vehicle. This RL resistivity model is usually considered to be infinitely large which shows modelling of the physical form of a vehicle's (rubber) tires when dry (not wet).

1.2 Research Steps

The research was conducted as the following diagram:

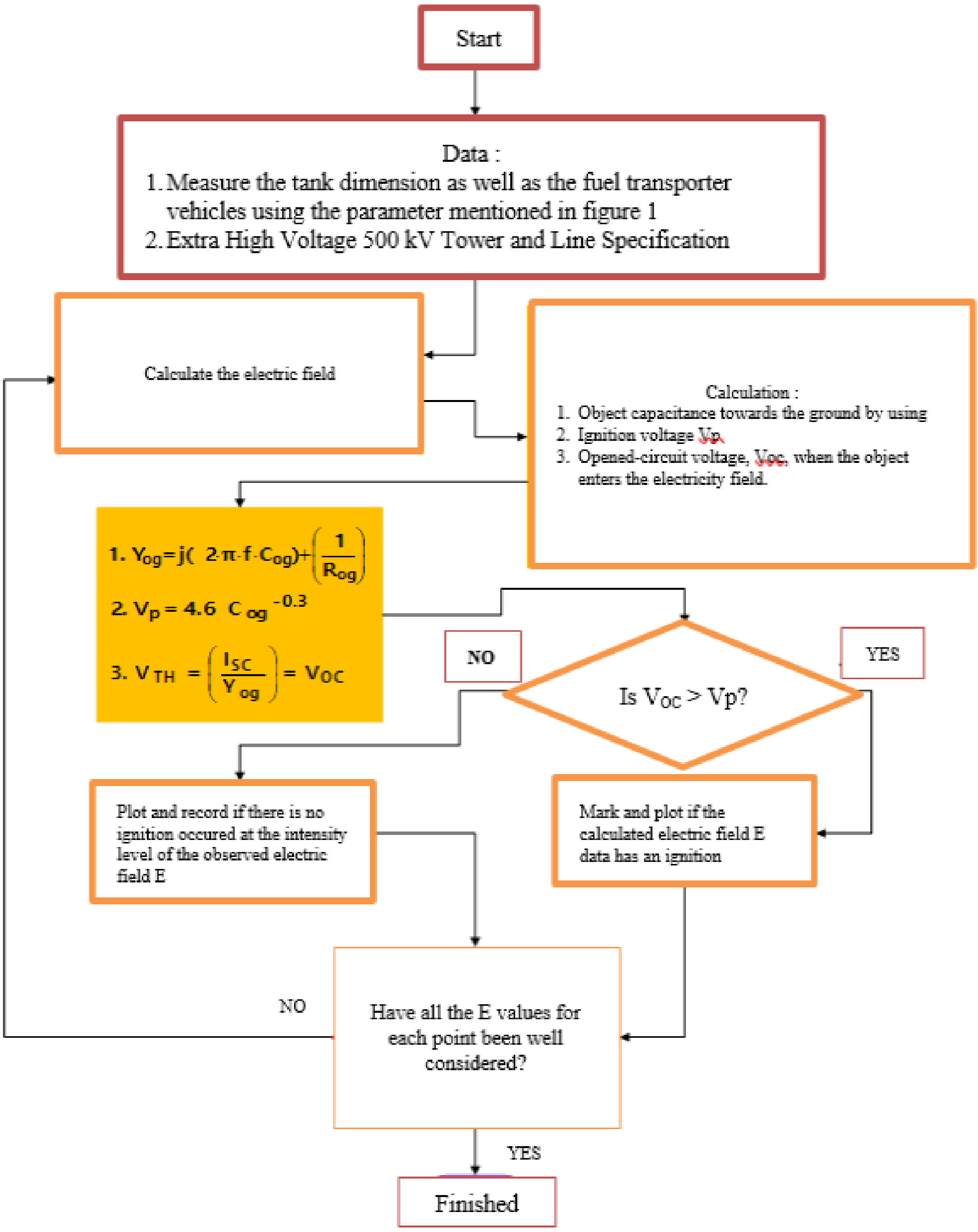

Fig. 4: Research Flow Chart

3. Results and analysis

The object of this research consists of three types of tank truck sizes, namely: 5000-litre premium oline tank, 9500 kg LPG tank and 16,000-litre premium petrol tank.

3.1. The Relationship between Opened-Voltage and Electric Field

The results of the calculation of the open-circuit voltage for the three types of armoured vehicles when entering the electric field caused by SUTET are tabulated as the table below (computer simulation results),

Table: 1 Opened-circuit voltage (Voc) for each vehicle tank consist of 5000 litre, 16000 liter gasoline and 9500 kg LPG

the electric field intensity (Kv/m)	*Voc Cog 5000 (Farad)*	*Voc Cog 16000 (Farad)*	*Voc Cog 9500 kg (Farad)*
1,528	1,140	1,796	2,075
1,618	1,207	1,902	2,198
1,715	1,279	2,016	2,329
1,820	1,357	2,138	2,471
1,932	1,440	2,270	2,623
2,053	1,530	2,412	2,787
2,182	1,627	2,565	2,963
2,322	1,731	2,728	3,152
2,471	1,842	2,904	3,355
2,630	1,961	3,091	3,571
2,799	2,087	3,290	3,801
2,979	2,221	3,501	4,045
3,168	2,362	3,723	4,302
3,366	2,510	3,956	4,571
3,572	2,663	4,198	4,850
3,782	2,820	4,445	5,136
3,996	2,979	4,696	5,426
4,208	3,137	4,945	5,714
4,415	3,292	5,188	5,995
4,611	3,438	5,419	6,262
4,792	3,573	5,632	6,507
4,950	3,691	5,818	6,722
5,081	3,789	5,972	6,900
5,179	3,862	6,086	7,032
5,239	3,907	6,157	7,114
5,260	3,922	6,182	7,142

Ignation voltage on tank consist of 5000 litre premium : 3014.15 Volt
Ignation voltage on tank consist of 16000 litre : 2818.66 Volt
Ignation voltage on tank consist of 9500 kg LPG : 2773.93 Volt

The relationship between the opened-voltage (opened-circuit) and the electric field that is under SUTET to the tank vehicle that is speeding in the region of the motor and electricity is shown in the curve below.

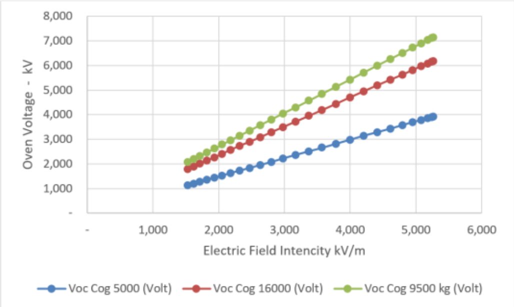

Fig. 6: Combined graph of the three fuel tank vehicles connecting the values Open voltage (Voc) with electric fields (E) with different graph steepness.

5000 litters tank. The curve (straight line) in blue has the equation of an open voltage circuit: Voc5 = 0.746 E, the ignition voltage is = 3014.15 Volts (see table: 1) and the electric field intensity is = (3014.15 / 0.746) = 4 040.42 V / m. Thus, the critical electric field experienced by the tank is 4.04042 kV / m so that if the value of this electric field exceeds 4040.12 V / m (E> 4040.12), then the tank has the potential to cause an electric spark or spark.

The 9500 kg tank contains LPG . The curve (straight line) in red has an open voltage equation: Voc95 = 1,358 E, ignition voltage of: 2773.93 Volts (table 4-1). and the intensity of the electric field equal to = (2773.93 / 1,358) = 2042.66 V / m. Thus the critical electric field experienced by the tank is 2042.66 V / m so that if the value of this electric field exceeds 2042 V / m (E> 2042.66), then the space in the tank has the potential to cause an electric spark or spark capacitive.

16000 litters tank. The curve (straight line) in green has an open voltage equation: Voc16 = 1.176 E. This vehicle with a 16000 kg tank has a rated voltage value of 2818.66 Volts (table 4-1), and the intensity of the electric field corresponding to this price is = (2818.66 / 1,176) = 2396.82 V / m. Thus the critical electric field experienced by the tank is 2396.82 V / m so that if the value of this electric field exceeds 2396.82 V / m (E> 2396.82), then the space in the tank has the potential to cause an electric spark or spark capacitive.

Fig. 6 shows that the LPG tank has the highest relative ignition voltage value (safer) compared to the other two tank vehicles for the number of intensity the same electric field.

4. Conclusion

1. The ignition voltage for tank vehicles with a capacity of 5000 litres, 16000 litres (contents of premium gasoline) and 9500 kg (contents of LPG) are 3014.15 Volt, 2818.66 Volts, and 2773.93 Volt
2. The intensity of critical electric fields that can cause the ignition voltage values above are as follows:
   - for the ignition voltage 3014.15 Volts at 4040.42 (Volts / m)
   - for the ignition voltage of 2818.66 Volts of 2396.82 (Volts / m)
   - for the ignition voltage of 2773.93 Volts of 2042.66 (Volts / m)
3. In point 1 it is revealed that the lowest ignition voltage is an LPG tank of 2773.93 Volts with the critical electric field intensity of 2042.66 (Volt / m) = 2.04 (kV / m).

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