An experimental study on anti-electrostatic gauge rulers

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Abstract. The process of oil filling will produce electrostatic phenomena which may cause fire accidents. There were no reports about research on the danger of static electricity generation in the process of gauging operation to date. This paper presents an experiment on charge transferring quantity of gauge rulers, and calculates the charge transferring quantity of an anti-electrostatic gauge ruler and a metal one, respectively. The results indicate that the charge transferring quantity can be more than 0.1 \(\mu\text{C}\) for a metal gauge ruler, while it is less than 0.1 \(\mu\text{C}\) for an antistatic gauge ruler. Therefore, this experimental research proves that using an anti-electrostatic gauge ruler is safer than using a metal one. This study also provides some theoretical and experimental evidence for making anti-electrostatic gauge rulers.

1. Introduction

In the process of filling, loading and shipping the oil products or in the monthly inventory checking at the end of every month, the operators must perform the manual measurement. Because the oil products are highly insulated, the oil surface is apt to accumulate charge in the filling process. At this moment, if the operator uses a steel gauge to perform the manual measurement, it may produce electrostatic discharge when the metal copper weight of the grounded gauge touches the charged oil surface, which may lead to an oil tank fire accident. For example, the oil tank caught fire in the process of dynamic manual measurement in an oilfield company in September, 2003. The oil tank caught fire in the process of dynamic manual measurement in another oilfield company in February, 2005.

The electrostatic danger of the manual measurement manifests itself mainly when it produces brush discharge as soon as the metal copper weight touches the charged oil surface. Generally speaking, the energy is not more than 4.0 \(\text{mJ}\), but charge transferring quantity is far beyond 0.1 \(\mu\text{C}\) [1], which is easy to a flash explosion in the oil tank in the process of manual measurement. In order to keep the process of manual measurement safe, the only way is to make sure the oil product standing time. Given that the first part to touch the oil surface is the metal weight in the manual measurement, it is necessary to limit the charge transferring quantity of the weight. Therefore, when we research on the material to be used in making the weight, we should make sure that the charge transferring quantity of this kind of material should be reduced to less than 0.1 \(\mu\text{C}\), and it should also make the weight not keep a high potential because of oil product electrostatic reaction.

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2. Selection of the material to make the anti-electrostatic weight

According to the requirements of the working situations which need to use an anti-electrostatic gauge weight, the following aspects should be considered.

2.1 Electrostatic conductivity

According to the rules defined in Section 6.3.7 in GB12158-2006 General Guideline for preventing electrostatic accidents [2], for the synthetic material for the sampler, thermoscope and gauge should be of electrostatic sub-conductive material, whose electrical resistance value per unit length should be \(1 \times 10^5 \text{--} 1 \times 10^7 \, \Omega \text{ m}^{-1}\), or whose area specific resistivity and volume resistivity should be less than \(1 \times 10^{10}\) or \(1 \times 10^8\, \Omega \text{ m}^{-1}\) respectively.

2.2 Oil resistance

The oil-measuring gauge should be checked every half year, during which the time of using the gauge may be about 20 h. If the material is soaked into some common gases with stronger solubility for 96 h without changing its appearance and texture, we may say it has good oil resistance.

2.3 High-temperature resistance

The temperature of the oil product in the tank may be very high, so the material used must have a certain high-temperature resistance. The requirement in the process is that the material must resist the high temperature of more than 80 °C.

2.4 Impact resistance

There may be some collisions in the manual measurement, so the material must have a certain impact resistance. If the finished weight is dropped freely from the height of 1.5 m and is not broken, we may say it has good impact resistance.

3. Research on the testing method of charge transferring quantity

Using a pump, the oil product is sent from the storage tank to the measuring tank by a filter. Use electrostatic potentiometer to test the surface potential of the oil product, and then test respectively the charge transferring quantity when using an anti-electrostatic gauge ruler or a common gauge ruler at different oil surface potentials and then the electrostatic dangers from the different kinds of gauge rulers can be determined. It is shown in figure 1.

![Figure 1. Block diagram of testing method of the charge transferring quantity.](image-url)
3.1 Research purpose for the testing equipment of charge transferring quantity of oil product

Using this testing device, the oil product will be charged. After the potential of the oil product in the testing tank reaches to a certain value, the test of charge transferring quantity of the gauge ruler will be carried out to determine the dangerous degree of charge transferring quantity of the weights with different electrical resistance value.

3.2 Testing method of oil surface potential

Figure 2 shows how to test the potential according to GB6951-86 safe surface voltage of light fuel oil in tank filling operation [3]. When an isolated copper ball is placed on the tested surface as a collecting electrode, the ground insulation resistance of the copper ball and the tested surface is more than $10^{14} \, \Omega$, and the ground capacitance is less than 100 pF, the copper ball’s potential is the potential of the oil surface where the ball is located.

![Figure 2. Diagram of the testing system of oil surface potential.](image)

3.3 Testing method of charge transferring quantity

Figure 3 shows the testing method of charge transferring quantity. At different oil surface potentials, the weight lowers to the oil surface. By the RC circuit the maximum $V_m$ of the RC discharge pulse is tested by an oscilloscope, based on $Q=C \times V_m$, we can get the max charge transferring quantity.

![Figure 3. Schematic diagram of the testing method of charge transferring quantity.](image)
3.4 Selection of oil surface potential in the testing tank
According to the definition in Section 7.2.5 of GB12158-2006 General guidelines for preventing electrostatic accidents, when loading the light oil product, the oil surface potential should be lower than 12 kV. So we should select the following oil surface potentials to carry out the test of charge transferring quantity:

\[ U < 12 \text{ kV}; \ 12 \text{ kV} \leq U \leq 30 \text{ kV}; \ 30 \text{ kV} < U \leq 40 \text{ kV}; \ 40 \text{ kV} < U \leq 50 \text{ kV}; \ 50 \text{ kV} < U \leq 60 \text{ kV} \]

3.5 Testing device
Figure 4 shows the testing device used for testing charge transferring quantity. Oil storages in 1# tank, flowing through valve 1, valve 2, pump, valve 5, valve 6, filter, valve 8, insulation flange 1, valve 9, pumped into 2# tank. The electrostatic generated during transportation is collected in 2# tank, and then tests the charge transferring quantity of gauging ruler at different potentials. To begin another test the oil flows through flange 2, valve 10, valve 4, pump, valve 3, valve 1, back to 1# tank.

![Figure 4. Schematic diagram of the testing device for charge transferring quantity.](image)

4. Experimental research on charge transferring quantity between ruler weight and the charged oil surface

4.1 Metal weight
Table 1 shows the experimental data. Figure 5 is the data graph. From the table 1 and figure 5, we can see that the charge transferring quantity of metal weight is more than 0.1 μC when the oil surface potential reaches 30 kV, so it is dangerous for gauging operation at this condition.

| No. | The surface potential of the discharge ball (kV) | Discharge potential (V) | Charge transferring quantity (μC) |
|-----|---------------------------------------------|------------------------|----------------------------------|
| 1   | 10                                          | 0.93                   | 0.0047                           |
| 2   | 15                                          | 5.17                   | 0.0259                           |
| 3   | 20                                          | 9.56                   | 0.0478                           |
| 4   | 25                                          | 15.07                  | 0.0754                           |
| 5   | 30                                          | 22.13                  | 0.1107                           |
4.2 Anti-electrostatic weight

Table 2 shows the experimental data. Figure 6 is the data graph. From the table 2 and figure 6, we can see that the charge transferring quantity of anti-electrostatic weight is still very low until the oil surface discharges itself, so it is safer using anti-electrostatic weight for gauging operation especially at high oil surface potential.

**Table 2.** Data of charge transferring quantity of anti-electrostatic weight.

| No. | Surface potential of discharge ball (kV) | Discharge potential (V) | Charge transfer (μC) | Weight potential (V) |
|-----|----------------------------------------|-------------------------|---------------------|---------------------|
| 1   | 10                                     | 0.012                   | 0.0001              | 0                   |
| 2   | 15                                     | 0.059                   | 0.0003              | 0                   |
| 3   | 20                                     | 0.096                   | 0.0005              | 0                   |
| 4   | 25                                     | 0.188                   | 0.0009              | 0                   |
| 5   | 30                                     | 0.469                   | 0.0023              | 0                   |
| 6   | 35                                     | 0.513                   | 0.0025              | 0                   |
| 7   | 40                                     | 0.678                   | 0.0034              | 0                   |
| 8   | 45                                     | 0.821                   | 0.0041              | 0                   |
| 9   | 50                                     | 0.922                   | 0.0046              | 0                   |
| 10  | 55                                     | 1.332                   | 0.0066              | 0                   |
| 11  | 59                                     | 2.730                   | 0.0137              | 0                   |
| 12  | 60                                     | The oil surface discharges itself. |                      |                     |
5. Conclusions

(1) The charge transferring quantity of the gauge ruler is related to its medium resistivity. The smaller the resistivity is, the larger the charge transferring quantity will be observed.

(2) The charge transferring quantity of the gauge weight of the same kind is related to the oil surface potential. The larger the oil surface potential is, the larger the charge transferring quantity will be.

(3) When the metal weight touches the oil product whose surface potential is 29.0 kV, the charge transferring quantity is 0.1001 μC, which is more than 0.1 μC. When the surface potential of charged oil product is more than 29.0 kV, all of the charge transferring quantities are more than 0.1 μC. So it is dangerous for the metal weight to touch the charged oil product.

(4) When anti-electrostatic weight touches the oil product whose surface potential is 59.0 kV, the charge transferring quantity is 0.0137 μC, which is much less than 0.1 μC. When the oil surface potential is up to 60 kV, the oil surface discharges itself and the oil surface potential descends rapidly. For this reason, the oil surface potential will not be over 60 kV. The experimental results indicate that it is very safe for the anti-electrostatic weight to touch the surface of the charged oil product and the weight will not be charged.

References

[1] Electrostatic Security Guidelines, Japan
[2] General guideline for preventing electrostatic accidents GB12158-2006
[3] Safe surface voltage of light fuel oil in tank filling operation GB6951-86