The electrostatic properties of Fiber-Reinforced-Plastics double wall underground storage gasoline tanks

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Abstract. At present Fiber Reinforced Plastics (FRP) double wall underground storage gasoline tanks are wildly used. An FRP product with a resistance of more than $10^{11}$ $\Omega$ is a static non-conductor, so it is difficult for the static electricity in the FRP product to decay into the earth. In this paper an experimental system was built to simulate an automobile gasoline filling station. Some electrostatic parameters of the gasoline, including volume charge density, were tested when gasoline was unloaded into a FRP double wall underground storage tank. Measurements were taken to make sure the volume charge density in the oil-outlet was similar to the volume charge density in the tank. In most cases the volume charge density of the gasoline was more than $22.7 \mu C \, m^{-3}$, which is likely to cause electrostatic discharge in FRP double wall underground storage gasoline tanks. On the other hand, it would be hard to ignite the vapor by electrostatic discharge since the vapor pressure in the tanks is over the explosion limit. But when the tank is repaired or re-used, the operators must pay attention to the static electricity and some measurements should be taken to avoid electrostatic accident. Besides the relaxation time of charge in the FRP double wall gasoline storage tanks should be longer.

1. Introduction
In the last few years, oil leakage accidents in the automobile gasoline filling station have taken place for many times. These accidents take pollution to the environment and sometimes may cause explosion accidents [1]. FRP double wall underground storage gasoline tanks have been used in foreign countries to avoid these accidents. This kind of storage gasoline tanks can alarm us when there is an oil leakage accident. So something can be done to avoid environmental pollution. But the FRP product is static non-conductor and its electrostatic characteristic should be noticed. In this paper an experimental system was built to simulate the automobile gasoline filling station. Gasoline in this system was unloaded into a FRP double wall underground storage gasoline tank, and at the same time some electrostatic parameters of the gasoline were tested.

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According to the true automobile gasoline filling station an experimental system was built. This system was built by a FRP double wall underground storage gasoline tank, a tank truck, gasoline, an oil drum, gasoline dispenser, test equipment, and so on.

The tank was buried in an impermeable pool, and the diameter of the tank was 2.5 m, the length of the tank was 6.7 m. The diameter of sucker was 80 mm, and the distance between the terminal of the sucker and the bottom of the tank was 200 mm. The diameter of oil-outlet was 40 mm. In order to dissipate the electrostatic accumulation, there were two metal plates and each plate’s acreage was 0.8 m², they located at the bottom of the tank and they were bonded to the external ground [2].

Because the existing liquid potential measures are severely influenced by the environment [3], the volume charge density was chosen to be tested and analyzed. The way of gathering volume charge density data was as follows. A meter was installed in the oil-outlet, the name of the meter was DQJ-4A and it was used for testing the volume charge density of the pipe. When the gasoline was unloaded into the tank, the operators run the gasoline dispenser and tested the volume charge density of the pipe. The meter was closed to the tank and the pipe between the meter and the tank didn’t bond to the earth. So the volume charge density of the pipe was nearly equal to the volume charge density of the gasoline in the tank.

### 2.3. The experimental process

The volume of the gasoline was 27000 L, before operation the gasoline had been reposed for 12 hours. The temperature of the environment was 26 (±2) °C, and the relative humidity was 50 (±5) %RH. Under the gravitational effect gasoline was unloaded into the Double Wall FRP underground storage gasoline tank through the sucker and the data of the volume charge density was tested at the same time. The experiment had been done for many times and one group of the test data of the volume charge density of the gasoline is in table 1. Some data in other groups was close to 22.7 μC·m⁻³, but all less than 22.7 μC·m⁻³.

| filling rate | volume charge density (μC·m⁻³) | filling rate | volume charge density (μC·m⁻³) |
|--------------|---------------------------------|--------------|---------------------------------|
| 40%          | 17.4                            | 60%          | 14.9                            |
| 42%          | 22                              | 65%          | 16.2                            |
| 45%          | 22.7                            | 70%          | 15.8                            |
| 48%          | 18.9                            | 75%          | 14.6                            |
| 50%          | 16.9                            | 78%          | 15.3                            |
| 55%          | 13.4                            | 80%          | 16.8                            |

After the test mentioned above, the gasoline was pumped from the Double Wall FRP underground storage gasoline tank into the tank truck, until the filling rate of the Double Wall FRP underground storage gasoline tank was 40%. After this operates for 20 minutes, under the gravitational effect, the
gasoline was unloaded into the Double Wall FRP underground storage gasoline tanks again. One group of the test data of the volume charge density of the gasoline is in table 2.

| filling rate | volume charge density (μC • m⁻³) | filling rate | volume charge density (μC • m⁻³) |
|--------------|-----------------------------------|--------------|-----------------------------------|
| 50%          | 25.3                              | 65%          | 35.6                              |
| 52%          | 27.1                              | 68%          | 33.3                              |
| 55%          | 29.8                              | 70%          | 31.2                              |
| 58%          | 37.1                              | 72%          | 29.6                              |
| 60%          | 36.4                              | 76%          | 30.7                              |
| 62%          | 33.9                              | 80%          | 29.4                              |

3. The electrostatic risk analysis of the Double Wall FRP underground storage gasoline tank

3.1. Oil surface potential

When the volume charge density of the tank is given, the oil surface potential of the tank can be calculated by special formula [6].

\[ V = \frac{\rho r^2}{4\varepsilon} \]  

Where \( V \) is oil surface potential, \( \rho \) is volume charge density, \( \varepsilon \) is dielectric constant.

In this experiment, the diameter of the tank was 1.25 m, the relative dielectric constant of the gasoline was 2.2. When the relaxation time of charge was enough, the maximal number of the volume charge density was 22.7 μC • m⁻³. Assuming the charge in the tank was well distributed, it could be calculated that the maximal oil surface potential of the tank was 455 kV in theory. If the relaxation time of charge was not enough, the maximal number of the volume charge density was 37.1 μC • m⁻³; it can be calculated that the maximal oil surface potential of the tank was 705 kV in theory. The calculation of the oil surface potential shows that it has big probability to cause electrostatic discharge in the tank [7].

3.2. Time of repose of the gasoline

The relaxation time of charge of the gasoline can be calculated by special formula [8].

\[ t = \frac{\varepsilon}{\sigma} \]  

Where \( t \) is relaxation time of charge, \( \sigma \) is conductivity, \( \varepsilon \) is dielectric constant.

The conductivity of the gasoline was 16 pS • m⁻¹, the relative dielectric constant was 2.2. The time of repose is three times of the relaxation time of charge, it could be calculated that the relaxation time of charge of the gasoline was more than 3.65 s. When the conductivity was 16 pS • m⁻¹, the volume of the tank was 30 m³, according to some standards, for metal tank the time of repose was more than 3 minutes [4].

The experiment had been done for many times, sometimes the time of repose was more than 12 hours and sometimes the time of repose was more than 20 minutes. If the tank was metallic, the times of repose were all satisfied. But from the data of the volume charge density it could be concluded that, after the operation the Double Wall FRP underground storage gasoline tanks need more time to relax the charge.
3.3. The risk analysis of explosion accident causing by electrostatic discharge
From the results of some experiments we know that the volume ratio of oil gas in an underground storage gasoline tank is more than 10% when unloading gasoline into the tank, and the vapor would be hard to be ignited by discharge even the energy is larger than 10 J. Under the general circumstance the electrostatic discharge is less than 10 J, so the vapor in the Double Wall FRP underground storage gasoline tank would be hardly to be ignited by electrostatic discharge. The Double Wall FRP underground storage gasoline tanks have been used in North America for thirty years, their operation experience can prove that. But when the tank is repaired or re-used, some appropriate measurements should be taken to avoid the occurrence of accident.

4. Conclusion
In this paper, some electrostatic parameters of the Double Wall FRP underground storage gasoline tank were tested in an experimental system. Some related data showed that it has big probability to cause electrostatic discharge in the tank. But in normal condition it has low risk to cause explosion accident, and some appropriate measurements should be taken when the tank is repaired or re-used. Besides the Double Wall FRP underground storage gasoline tanks need more rest time after operation.

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