Application of electrostatic prevention technology on polyethylene silos

Hong Gong 1,2*, Quanzhen Liu 1,2, Fenggui Tan 1,2, Yunpeng Zhang 1,2
1. SINOPEC Research Institute of Safety Engineering, Yan’an 3rd road, Qingdao 266071, China
2. State Key Laboratory for Safety Control of Chemicals, Yan’an 3rd road, Qingdao 266071, China
E-mail: gh64@163.com

Abstract. The main reasons of static electric explosion accidents in polyolefin plant silos were analyzed in this paper, and the study finds that the reasons include control failure of flammable gas content in the feed, high electrification caused by the wind supply, and frequent electrostatic discharge in silos. The electrostatic-reducing technologies of polyolefin powder were introduced, and its application performance in polyolefin plant silos was also clarified. In addition, the methods including FDCS and DGES for evaluation of electrostatic explosion in polyolefin plant silo were proposed. In the end, the risk of electrostatic explosion in PE plant blended silo was evaluated before and after application of electrostatic reducing technology.

1. Introduction
Electrostatic explosion accidents abroad reached a peak during 1970s and 1980s, while the peak delayed a little later in China. From 1985 to 2008, more than 70 explosion accidents occurred in China, nearly 90% of the accidents were related to polyolefin silos. For example, 13 flash explosion accidents occurred in the powder silo of PE (Polyethylene) facilities in 1987-1998 after the expansion and reconstruction of factory, and similar accidents happened many times in another factory’s blending silo of PP(Polypropylene) facilities in 1989-1994. In other large-scale polyolefin production enterprises, these explosion accidents also took place occasionally. To solve these problems, the related administrative authorities have organized several security experts to investigate the explosion accidents in polyolefin powder silo for many times, and some common conclusions were acquired. Namely, most of these accidents were caused by the combination of powder, gas and static electricity; Inadequate ventilation design or process control errors including improper responses, devolatilization equipment failures or silo ventilation operational errors were also one of the important causes of explosion accidents; Large quantity of electrostatic charges caused by wind sending powder and frequent electrostatic discharge were produced frequently in polyolefin facilities silos, which plays a important role in explosion accidents. The investigation results of these accidents show that completely eliminating or avoiding the trigger sources related to processes was extremely difficult, which was affected by deficiencies or shortcomings of the current equipment design. For instance, according to a statistic of 68 accidents, there were 49 related to the deficiencies or shortcomings of equipment design. To enhance the prevention capability of electrostatic explosion in current silo

* To whom any correspondence should be addressed.
devices, the measures including elimination of static electricity caused by wind sending and enhancement of ventilation capacity in silos should be taken first. Therefore, a company cooperated with SINOPEC Research Institute of Safety Engineering to complete the program entitled “powder electrostatic prevention for mixing silo of PE devices” in 2011, and the expected results were acquired. The following will introduce the electrostatic elimination effect and silo explosion risk assessment.

2. Brief introduction of electrostatic prevention technology for wind sending powder in mixing silo of PE facilities

![Schematic of system layout.](image)

The PE plant employed density polyethylene reaction under low pressure gas-phase process, so the reaction period was short and the processing load was very heavy (30~33 t h⁻¹). But the content of volatile materials was also high and the devolatilization depended mainly on the degassing silo. Due to fast production, the reliability requirement for equipment maintenance and operating system was very strict. Once the system failure or inadequate devolatilization happened and the emergency was not handled properly, it will cause silo static flash explosion accidents (similar cases occurred many times domestically). For the above reasons, the company installed a set of ion wind powder static eliminator / monitor system in 12 blending silos of PE (A / B / C line) devices.

This system consisted of operation control cabinet, on-site electrical control box, sub-control box, eliminating electrical body and monitoring body. Using the most advanced non-equilibrium bipolar ion wind static elimination technology, electrostatic parameters (μC kg⁻¹) provided by electrostatic charge sensor on the monitor, the charge transmitter - the current controller of the electronic control
box, the I/O module - master cabinet PLC signal processing unit, the touch screen system and others can be employed to randomly adjust the electrical positive and negative ion current of discharge needle in the electrostatic eliminator to neutralize material charge in the pipeline to achieve the designed effect. Positive and negative ions flow regulation was implemented by the following system, which was formed by master cabinet touch-screen communication unit, the PLC digital-analog processing unit - electronic control box I/O modules, the voltage controller-electrostatic eliminator body positive and negative high voltage control module, positive and negative discharge needle air current jet components. The schematic system layout was shown in figure 1.

3. Record of electrostatic prevention of wind sending powder in mixing silo of PE facility

The static electrification and static elimination record of wind sending material in silos of PE facilities were shown in Table 1 - Table 3.

| Table 1. The static elimination record for PE(Line A) (unit: µc kg⁻¹). |
|-----------------|----------------|----------------|----------------|
| Silo number     | TK451A         | TK451B         | TK451C         | TK451D         |
| static electrification range of material | -2.62 ~ -3.26 | -4.4 ~ -4.96 | -2.97 ~ -3.40 | -7.19 ~ -7.99 |
| Average         | -3.07          | -4.78          | -3.16          | -7.34          |
| Average after static elimination | 0.11           | -0.06          | -0.09          | 0.03           |
| Static elimination efficiency | > 96%         | > 98%          | > 97%          | > 99%          |

| Table 2. The static elimination record for PE(Line B) (unit: µc kg⁻¹). |
|-----------------|----------------|----------------|----------------|
| Silo number     | TK2451A         | TK2451B         | TK2451C         | TK2451D         |
| static electrification range of material | -1.67 ~ -1.83 | -4.41 ~ -5.10 | -3.28 ~ -3.59 | -3.24 ~ -3.64 |
| Average         | -1.74          | -4.77          | -3.44          | -3.48          |
| Average after static elimination | -0.02          | -0.13          | 0.04           | -0.08          |
| Static elimination efficiency | > 98%         | > 97%          | > 98%          | > 97%          |

| Table 3. The static elimination record for PE(Line C) (unit: µc kg⁻¹). |
|-----------------|----------------|----------------|----------------|
| Silo number     | TK2451A         | TK2451B         | TK2451C         | TK2451D         |
| Average         | -2.77          | -1.88          | -2.64          | -1.27          |
| Average after static elimination | -0.05          | -0.15          | -0.11          | -0.08          |
| Static elimination efficiency | > 98%         | > 92%          | > 95%          | > 93%          |

Static elimination records of PE facilities’ (Line A/B/C) silos in Table 1-table 3 show that the static eliminator reduced the static electricity of wind sending material from 1-8 µc kg⁻¹ to less than 0.1 µc kg⁻¹. The probability of discharge on stockpile surface and the electrostatic risk in silo was significantly reduced.
To analyze the silo electrostatic explosion risk, two main methods were used. One was silo field diagnosis and counting for static electricity (FDCS), and the other was silo dust electrostatic explosion danger grading (DGES). The following described the practical effect employing the above assessment methods accordingly when the PE plant equipped with electrostatic eliminator.

4. Risk assessment of static electricity in polyolefin silos

Table 4. Basic data of PE plant mixing silo.

| Silo number | Line A                  | Line B                  | Line C                  |
|-------------|-------------------------|-------------------------|-------------------------|
| Size of silo| Φ 5500×23450            | Φ 5500×17500            | Φ 6000×17000            |
| Dielectric constant($\varepsilon_r$) of material | 2                        | 2                        | 2                        |
| Charge-mass ratio(µc/kg)  | -1.74~ -7.34  | -1.27~ -2.77  | -0.7~ -1.18  |
| Resistivity of material(Ω.m) | 10$^{14}$       | 10$^{14}$       | 10$^{14}$       |

Basic data of PE plant mixing silo was listed in Table 5 and data of silo electric field acquired by using FDCS method was analyzed as follows:

(1) When the charge-mass ratio “q” was -0.11 µc kg$^{-1}$, the electric field distribution condition on the material surface was shown in figure 2. The electric field close to tank shell approached the critical discharge electric field(3 MV m$^{-1}$), which may cause brush discharge (discharge energy < 3.6 mJ).

Figure 2. Silo of PE plant electric field distribution (-0.11 µc kg$^{-1}$).

(2) When the charge-mass ratio “q” was -0.11 < q ≤ -0.24 µc kg$^{-1}$, the material surface electric field was 3~6.7 MV m$^{-1}$ (as shown in figure 3). In this case, conical discharge may take place (discharge energy ≤ 10 mJ).
(3) With simulating experiments (as shown in figure 4), it can be concluded that the surface of materials will be $\geq 40$ kV (powder ignition risk potential) when the charge-mass ratio “q” was $\geq 1.65 \mu\text{c kg}^{-1}$, 170 mm away from tank wall, the potential on the stockpile. If there was metal protrusion above the stockpile surface, igniting discharge may take place.

(4) When the charge-mass ratio “q” was $\leq 0.25 \mu\text{c kg}^{-1}$, within 400 mm from the tank shell, the surface potential was $<10$ kV, which met the requirements of “$<10$ kV static electricity safety management target”[3].

From the above analysis, it can be conclude that:

① Wind sending systems of PE plants generated a great amount of static electricity, which was greatly beyond the charge-mass range of conical discharge (-0.11~0.24 $\mu\text{c kg}^{-1}$) and the risk limit of metal protrusion discharge (1.65 $\mu\text{c kg}^{-1}$). When the Hexane gas volume in the silo was more than 0.5% wt, conical discharge may cause explosion of mixed miscellaneous dust; when material dust concentration exceeded the explosion limit (20 g $\text{m}^{-3}$), the discharge of material level sensors or mixing tube holder may ignite the silo dust and cause explosions.

② When the ion wind powder static eliminator was installed, the static electricity of wind
sending material in PE lines was reduced to less than 0.1 µc kg⁻¹. As a result, conical discharge will not happen on the stockpile surface in the silo and ignitable discharge will not take place within 400 mm from tank shell, so the safety performance of material static electricity was improved dramatically.

4.2. Assessment of explosion risk grading for dust static electricity in mixing silos of PE facilities
The DGES method was used to calculate composite index of electrostatic explosion. The main data were shown in table 6 and table 7.

Table 5. Calculation factor

|                          | Before elimination | After elimination |
|--------------------------|--------------------|-------------------|
| Dust factor D            | 55                 | 55                |
| Gas factor G             | 150                | 150               |
| Electrostatic discharge factor E | 370              | 10                |
| Second blast factor S    | 70                 | 70                |
| Coefficient of correction K | 1                | 1                 |
| Risk factor H            | 645                | 285               |

Table 6. Danger grading and recommended measures

| Risk factor H          | Recommended measures                                      |
|------------------------|-----------------------------------------------------------|
| Very serious (>350)    | Comprehensive management of dust, gas, static electricity  |
| Serious (300-350)      | To focus on the management static electricity, taking dust and gas into account |
| Moderate (200-300)     | Mainly to manage the dust and gas                         |
| Slight (<200)          | Mainly to manage the technology of dust and gas            |

5. Conclusion
Before the application of the static elimination measures, the risk factor of PE facility blending silo was 645, which was a severe danger exposure frequency grade. When the measures were taken, the risk factor dropped to 285, which was a moderate danger exposure frequency grade. So the silo electrostatic risk was significantly reduced.

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