Research on the minimum allowable values of energy efficiency and standard of energy efficiency grades for precipitator in power industries

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Abstract. This paper elaborates the necessity and the feasibility of the standard research on the minimum allowable values of energy efficiency and energy efficiency grades for precipitator in China’s power industries. It does a research on the energy efficiency grades, minimum allowable values of energy efficiency and its test methods for precipitator in power industries.

1. Overviews of the energy-efficiency standard for energy-using products in China
The term “energy efficiency”, also known as the “energy utilization efficiency”, indicates the efficiency and quality characteristics of the energy consumption by the products. the energy efficient is a scientific method for assessing the products’ energy-using performance and an effective tool for showing the products’ energy-using performance objectively and comparing the difference of energy-efficiency level among different products scientifically.

As the global economy develops rapidly, energy crisis and environmental impacts have become increasingly worse. The economic development can’t be sustained without the consumption of huge energy and natural resources, and without the destructive impacts to our environment. When faced by this harsh situation, all the countries have adopted the energy-efficiency standard as a policy instrument to enhance the energy efficiency of those energy-using products, conserve energy and protect environment. They have developed and implemented the energy-efficiency standards for those energy-using products. According to the related statistics, more than 50 countries and regions have successfully implemented their energy-efficiency standard systems. To be specific, the energy-efficiency standards and eco-design requirements as included in the U.S.’s Energy Star program and EU’s EuP/ErP (energy-using products/energy-related products) Directive are the highest energy-efficiency standard. Currently, the national energy-efficiency standards have seen a gradual shift of focus from the household electric appliances to the industry, commerce, construction and transportation[1-2].

China has developed a well-established the energy-efficiency standard system for the energy-using products, and designed over 60 national energy-efficiency standards for those key energy-using products, including household electric appliances, lighting equipment, commercial equipment, industrial equipment, IT products and means of transportation. They’re all the mandatory national
standards for evaluating the energy utilization efficiency of energy-using products. These standards have raised the market access requirements for China’s terminal energy-using products, and gradually eliminated those products with low cost efficiency and considerable waste of energy. When their mandatory and steering roles are exploited, these standards contribute much to popularizing the energy-efficient products, promoting the development of energy-saving technologies, raising the energy-conservation management level, accelerating the industrial restructuring, optimization and upgrading, boosting energy conservation and emission abatement, addressing the climate changes and attaining the goal of energy conservation and emission abatement.

2. Purpose and significance of designing the minimum allowable values of energy efficiency and standard of energy efficiency grades for precipitator in power industries

The industrial precipitators fall into the category of environmental protection equipment. Electric precipitators and bag precipitators are two main types of devices to deal with the industrial dust. The electric precipitators feature the substantial flue gas-handling capacity, efficient dust removal, high applicability, low resistance, simple and reliable use, low operation cost and avoidance of the secondary pollution. They’ve been the leading equipment in China’s power industry for removing flue gas and dust. However, their dust-removal efficiency tends to be swayed by the characteristics of flue gas and dusts. In contrast, the bag precipitators, as the efficient particles removers, can reduce the emission of flue gas (dust) noticeably, enjoy the strong capturing capacity for the fine particles with the diameter of less than PM2.5, and remove such toxic and harmful substances like mercury and dioxin. They’re widely used in the process of dust removal and raw materials and side products recovery in power, building material, metallurgical, chemical and light industry. As one of the important technological devices for solving China’s flue gas and dust emission problems, they have the advantages like low concentration at outlets and immunity to the dust characteristics, but are troubled by the disadvantages including large resistance to system and high energy consumption. The integrated precipitators achieve the effective combination between electrostatic dust removal and filtering dust removal and fully exploit the advantages of two dust-removal technologies. At first, they pre-charge the dusts and collect most dusts through the principle of electrostatic dust removal, and the dusts can have their filtering properties changed by the charging process. Then, they achieve the steady low-concentration emission through the principle of filtering dust removal. The related results show that the electrostatic-bag integrated precipitators have such advantages as long-term low emission, energy conservation, low operation and maintenance cost and high cost efficiency.

In recent years, China has introduced a series of more rigorous emission standard concerning the atmospheric pollution prevention and control. Since 2011, China has promulgated the Standard on the Emission of Atmospheric Pollutants in Thermal Power Plant, the National Standard Series for the Emission of Pollutants in Iron and Steel Industry, and the Standard on the Emission of Atmospheric Pollutants in Cement Industry to tighten the control over pollutants and pose a higher requirement for the performance and reliability of atmospheric pollution control equipment when it comes to the environmental protection.

Meanwhile, we’ve also noticed that the total energy consumption of different precipitators and its growth rate have deserved much of our attention due to their promotion and application on a large scale. It’s true that precipitators can perform the functions of environmental protection, but they’re the high energy consumers. In fact, their production, operation and maintenance consume an increasing amount of energy. Therefore, the energy-efficiency standard for those terminal energy-using products should consider not just the large production equipment, but the energy consumption of those significant or key environmental protection devices as well, so as to guarantee that the environmental protection devices are the energy-saving equipment. In this case, it’s an urgent task to design the mandatory energy-efficiency standard for these environmental protection devices so that their energy consumption can be regulated. Once the standard is implemented, the market will have the precipitators with reliable performance and efficient energy use. Only in this way can we regulate the market competition of precipitators in China. For one thing, we can raise the energy-efficiency access
threshold for precipitators; for another, we can support the implementation of energy-efficiency “pacesetter” and environmental protection “pacesetter” system.

3. Research on the energy-efficiency standard of precipitators in power industry

3.1. Scope of application of the energy-efficiency standard for precipitators

This standard applies to dry electrostatic precipitators, bag precipitators and electrostatic-bag integrated precipitators used for the purpose of flue gas and dust removal in the coal-fired power plants.

3.2. Basic investigation and analysis

According to the scope of application as defined in the energy-efficiency standard of precipitators, a field survey was conducted of three types of precipitators in terms of technology, energy consumption and pollutant emission, and the energy-efficiency data of precipitators were collected, summarized and analyzed after the information, standards and policies concerning the domestic energy-saving and emission-reducing monitoring and control technologies were examined.

3.3. Key terms and definitions

- Specific power consumption for precipitator: the power consumption when a precipitator copes with the volume of flue gas with dust contents per unit.
- Minimum allowable values of energy efficiency for precipitator: the maximum specific power consumption allowable for precipitator in the required testing conditions when the precipitator’s performance meets the design requirements.

3.4. Technical requirements

3.4.1. Basic requirements.

- The design, manufacturing and quality of electrostatic precipitators should conform to the provisions of JB/T 5910, JB/T 11267[3] or DL/T 514; The design, manufacturing and quality of bag precipitators should conform to the provisions of GB/T6719; the design, manufacturing and quality of electrostatic-bag integrated precipitators should conform to the provisions of GB/T27869.
- The dust contents in flue gas at the outlet of precipitator should meet the national and local standards and requirements for environmental protection and emission.
- The pressure drop, air leakage rate and other performance indicators of electrostatic precipitators should conform to the provisions of JB/T5910 and JB/T11267; the pressure drop, air leakage rate and other performance indicators of bag precipitators should conform to the provisions of GB/T6719; the pressure drop, air leakage rate and other performance indicators of electrostatic-bag integrated precipitators should conform to the provisions of GB/T27869.

3.4.2. Energy efficiency grade of precipitators. The energy efficiency grade is designed to implement the energy efficiency labelling system. Now China’s energy efficiency grade labels, as the part of information labels, are an important way for the government’s energy conservation management. When the customer service is treated as the guiding principle, these market-oriented labels can provide the necessary information for any purchasing decisions by users and consumers and encourage them to choose the high-efficiency and energy-saving products.

There’re three energy efficiency grades for precipitators. Grade 1 represents the highest energy efficiency. When the dust contents in flue gas at the inlet of electrostatic precipitators at all grades in the coal-fired boilers are no more than 30g/m3, the specific power consumption of electrostatic precipitators at all grades shall be no more than the level as defined in Table 1. For the corresponding dust contents in flue gas at the outlet of bag precipitators at all grades in the coal-fired boilers, the
specific power consumption shall not be more than the level as defined in Table 1. The specific power consumption of electrostatic-bag integrated precipitators at all grades in the coal-fired boilers shall be no more than the level as defined in Table 1.

3.4.3. Minimum allowable values of energy efficiency for precipitator. The minimum allowable values of energy efficiency are designed to implement the elimination system for those high energy-using products. As the mandatory indicators, they’re the national minimum values of energy value allowable for products and the basis for the national government to eliminate the high energy-using products. Those products whose energy efficiency is below the specified values should be categorized as the high energy-using and low energy-efficiency products, and should not be allowed to enter the market. The minimum allowable values of electrostatic precipitators are the Grade 3 energy efficiency as indicated in Table 1; the minimum allowable values of bag precipitators are Grade 3 energy efficiency as indicated in Table 2; the minimum allowable values of electrostatic-bag integrated precipitators are Grade 3 energy efficiency as indicated in Table 3.

- Specific power consumption of precipitator is calculated according to Formula (1):

\[ C = \frac{W}{Q} \]  

(1)

Where:

- \( C \) — Specific power consumption of precipitator, with kW·h/m³ as the unit;
- \( W \) — Power consumption of precipitator per unit time, with kW·h/h as the unit;
- \( Q \) — Volume of flue gas handled by precipitator per unit time, with m³/h as the unit.

The investigation and analysis show that the main power consumption of electrostatic precipitator per unit time includes the resistance power consumption of electrostatic precipitator, the power consumption of high-voltage power-using devices in electrostatic precipitator per unit time, and the power consumption of high-voltage power-using devices in electrostatic precipitator per unit time; the main power consumption of bag precipitator per unit time includes the resistance power consumption of bag precipitator and the bag power consumption of precipitator; the main power consumption of electrostatic-bag integrated precipitator per unit time includes the resistance power consumption of electrostatic-bag integrated precipitator, the unit-time power consumption of air compressor system, the unit-time power consumption of high-voltage power supply devices, and the unit-time power consumption of insulator heating devices.

| Energy efficiency grade | Electrostatic precipitator | Bag precipitator | Electrostatic-bag integrated precipitator |
|-------------------------|---------------------------|-----------------|------------------------------------------|
|                         | Dust contents in flue gas at outlet Cout (mg/m³) | Specific power consumption \((\times 10^3\) kW·h/m³) | Dust contents in flue gas at outlet Cout (mg/m³) | Specific power consumption \((\times 10^3\) kW·h/m³) | Dust contents in flue gas at inlet Cin (g/m³) | Specific power consumption \((\times 10^3\) kW·h/m³) |
|                         | Generation unit grade      |                  | Generation unit grade                     |                  | Cin≤30 | 30 < Cin≤60 | Cin > 60 |
| 300MW                   | 0.23                      | 0.22             | 0.21                                      | 20< Cout≤30      | 0.26   | 0.25         | 0.20 (0.22 0.23) |
| 600MW                   | 0.27                      | 0.26             | 0.25                                      | 10< Cout≤20      | 0.27   | 0.26         | 0.22 (0.24 0.25) |
| 1000MW                  | 0.33                      | 0.31             | 0.30                                      | Cout≤15          | 0.32   | 0.31         | 0.23 (0.25 0.26) |
| 1 20<Cout≤30            | 0.28                      | 0.27             | 0.26                                      | 10< Cout≤20      | 0.30   | 0.29         | 0.24 (0.26 0.27) |
| 15<Cout≤20              | 0.34                      | 0.32             | 0.31                                      | Cout≤10          | 0.32   | 0.31         | 0.26 (0.28 0.29) |
| 2 Cout≤15               | 0.40                      | 0.38             | 0.37                                      | Cout≤10          | 0.35   | 0.34         | 0.27 (0.29 0.30) |
The above-stated specific power consumption applies when coal dust removal difficulty is "ordinary" and the dust contents in flue gas at inlet C in ≤30 g/m³. When coal dust removal difficulty is "easy" or "difficult", specific power consumption shall be multiplied by the modified coefficient of 0.9 or 1.1. When the dust contents in flue gas at inlet are more than 30 g/m³, the specific power consumption should be multiplied by the modified coefficient of 1.1.

After the unit capacity is increased, assessment is still conducted according to the pre-expansion unit capacity. The unit size has a very small effect on specific power consumption, so specific power consumption is classified based on different dust contents at inlet.

### Resistance Power Consumption of Precipitator

The resistance power consumption of precipitator is calculated according to Formula (2).

\[
W_r = \frac{Q \times \Delta P}{1000 \times 3600 \times 0.85}
\]  

Where:
- \( W_r \) —— Resistance power consumption of precipitator per unit time, with kW·h/h as the unit;
- \( Q \) —— Volume of flue gas handled by precipitator per unit time, with m³/h as the unit.
- \( \Delta P \) —— Pressure drop of precipitator, with Pa as the unit;
- 0.85 —— Comprehensive efficiency coefficient of induced draft fan and transmission unit in electrostatic precipitator system.

### Dust-removal Power Consumption of Bag Precipitator

The dust-removal power consumption of bag precipitator is calculated according to Formula (3).

\[
W_{dc} = 60L_{bag}k \times \frac{n \times (t_w + t_i)}{m \times T}
\]  

Where:
- \( L_{bag} \) —— Dust-removal gas consumption of bag precipitator, with m³/min as the unit;
- \( k \) —— Power consumption of compressed air per m³, the calculation value is set as 0.115 kW·h/m³;
- \( n \) —— Number of pulse valves;
- \( m \) —— Number of pulse valves blowing at the same time;
- \( t_w \) —— Width of electric pulse, with second (s) as the unit;
- \( t_i \) —— Pulse interval, with second (s) as the unit;
- \( T \) —— Dust-removal cycle of bag precipitator, with second (s) as the unit.

### Power Consumption of Air Compressors in Electrostatic-bag Integrated Precipitators

The power consumption of air compressors in electrostatic-bag integrated precipitators per unit time is calculated according to Formula (4).

\[
W_{ac} = q \times L_{electrostatic-bag}
\]  

Where:
- \( q \) —— Input specific power consumption of air compressor unit, kW/(m³/min);
- \( L_{electrostatic-bag} \) —— Gas consumption of compressed air for the electrostatic-bag integrated precipitators per unit time, m³/min.

Note 1: The energy consumption of air compressors refer to the unit-time power consumption
generated by the production of dust-removal compressed air and the overcoming of air compressor’s own efficiency.

Note 2: The input specific power consumption of air compressor unit is based on the energy conservation evaluation value of GB 19153.

3.4.4. Testing method
- When the performance of precipitators is tested, they should keep the steady operation for three months when the design requirements are considered, and then their main load should be more than 90% rated load.
- For the dust contents in the flue gas at the outlet of electrostatic precipitators, pressure drop, power consumption of high-voltage powers supply units and power consumption of low-voltage power-using units, their testing methods should comply with the provisions of GB/T 13931[4]; for the dust contents in the flue gas at the outlet of bag precipitators, and pressure drop, their testing methods should comply with the provisions of GB/T 6719[5]; for the dust contents in the flue gas at the outlet of electrostatic-bag integrated precipitators, and pressure drop, their testing methods should comply with the provisions of GB/T 32154.
- The pressure drop is based on the actual data during the performance assessment of precipitators, and the power consumption of high-voltage power supply units and of low-voltage power-using units is based on the 7-day average testing value.

4. Discussion
- The energy-efficiency standard for precipitators is China’s first energy-efficiency standard in the special equipment designed for environmental pollution prevention and control. The development and implementation of the energy-efficiency standard for precipitators will help enhance the energy-efficiency level of environmental protection equipment, reduce the total particulate emission, guide the manufacturers’ technological progress, encourage the production and consumption of energy-saving and high-efficiency environmental protection equipment, and contribute to the implementation of energy-efficiency “pacesetter” and environmental protection “pacesetter” system.
- The energy-efficiency standard of precipitators maintains the satisfactory connection with the precipitators’ related product quality standard, performance testing method and standard, and safety standard to create a whole set of mutually supportive, organically connected and scientific standards, which will play a significant role in supervision and management of energy conservation and emission reduction in power industry.

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