

**TECHNICAL AND ECONOMICAL COMPARISONS BETWEEN  
DIFFERENT KINDS OF MATERIALS AND DIFFERENT  
GEOMETRIES FOR ELECTROSTATIC PRECIPITATOR INSULATORS**

**LONG TAO, ZHOU BAOSHAN AND XU JIAN**

**Nanjing Tailong Special Ceramics Co., Ltd.**

**East End of Shennong Road, Jixiang'an, Nanjing 210038,**

**Jiangsu Province, China**

**Contact [longtao@nj-tailong.com](mailto:longtao@nj-tailong.com)**

**ABSTRACT**

Accompanying the fast development of power, cement and iron/steel industries recently, China have produced huge quantity of precipitators and its insulators. Different kinds of material were used for insulators, such as common electrical porcelain, high strength electrical porcelain, quartz (silicon glass), high polymer and high alumina porcelain, etc. A lot of successful and non-successful experiences were encountered. Of course there have different suitable material and geometrical choices for different industrial processes, yet it seemed for the same process there may have some different material requirements between European type and American type precipitators mainly because of their different type of electrode rapping.

This paper summarized the Chinese experiences and comparisons of material selection and insulator geometries for different processes and precipitators both technically and economically.

## **INTRODUCTION**

ESP insulators are different from other electrical insulators. Not only should they have big creep distance and dust-free shape, but also should their materials have good mechanical, electrical and thermal properties so that they can normally working in the high temperature, high humidity and dusty gas environment.

Although the insulators cost compare to that of total ESP is rather small, but they are key parts of ESP. Material selection and shape design should be considered carefully according to their functions and working conditions.

## **MATERIAL HAVE BEEN USED FOR ESPINSULATORS**

Materials for ESP insulators have been to be common electrical porcelain, high strength porcelain, quartz, high alumina porcelain and high polymer materials. At the initial stage, common standard electrical porcelain insulators were used directly as ESP insulators. Their working life has been short because of the grimmer environment, so fusion quartz and high strength porcelain materials are used instead of standard electrical porcelain in later time. Fusion quartz has very good insulation capability but has weaknesses of fragile and quick reducing of resistivity as temperature rises, hence seldom used today. High strength porcelain, such as alkali aluminum silicate and high strength bauxite porcelain, already instead of standard porcelain are used as the material of ESP insulators.

High polymer material has the advantageous of low price and non-fragile, so it has been widely used in common sense.

Special made high strength electric porcelain (such as 50% alumina porcelain) and high alumina porcelain (such as 85% alumina porcelain or 95% alumina porcelain) as a whole series, can satisfying all the usage of ESP under different and grim conditions with long working life of not less than 30 years, the same life as ESP.

The properties and economical comparisons between different insulation materials are shown in Table 1.

## **MATERIAL REQUIREMENT FOR DIFFERENT INSULATORS**

Firstly ESP insulator materials should have good electrical insulation capability under high voltage and the working temperature. Next are temperature endurance and high strength. Generally speaking, for ESP working below 170°C, standard electrical porcelain and 50% alumina can be used. For that of below 250°C, 50% c is suitable. For ESP working above 250°C, then 85% or 95% should be considered.

For insulators working in dust laden flue gas, it is better to select 85% or 95% alumina porcelain with surface polished but without glaze.

Table 1: Comparisons between different insulation materials

Material	Insulation properties			Anti-Heat shock property	Mechanical strength			Price	O&M cost
	Room temp.	200 8C	500 8C		Room temp.	200 8C	500 8C		
Common Electrical porcelain	Good	Bad	-----	Bad	OK	Slight lower	-----	Low	High
Quartz glass	Good	Bad	-----	OK	OK	Low	-----	Slight higher	High
High polymer	-----	-----	Good	Carbonized at 1300 8C	Non-fragile	-----	-----	Slight lower	High
Special high strength porcelain	Good	OK	Bad	OK	OK or High	OK	-----	Slight higher	Slight lower
High alumina porcelain	Good	Good	Good	Good	High	High	Slight higher	High	Low

The purposes of glazing are:

- Increase strength----- Usually compressive glaze are covered. It means the expansion coefficient of glaze is slight small than that of porcelain. If the blank and glaze match each other suitable, the products strength can be increased about 30%,
- Some surface defects can be covered by glazing,
- Increase capability of surface pollution prevention.

So, it is no doubt beneficial for insulators long time working in atmospheric environment. But it by no means the same thing for them working in gas with certain high temperature. In this case, glazing not only useless, but also harmful. As temperature increases, tensile stress in glaze surface increases also. We know glaze is a kind of brittle vitreous body without plastic strain, so moiré will occurs if tensile stress going higher. In this case, small particulates in the gas will enter into the crevices hardly to remove away, hence reducing resistivity and insulation level. Surface flash over will easily occur and expanding the moirés, conducting burst of insulator. This is the main reason of glazed support bushing of ESP bursting in China so far.

Table 2 lists the recommended material of different insulators commonly used in ESP.

Table 2: Recommended materials for different kinds of insulators

Insulators	Mechanical load and environment	Required properties other than electric insulation	Recommended materials
Support bushing	Weight	Mechanical Strength	50% Alumina porcelain, Electric porcelain
Pull rod	Weight	Mechanical Strength	85% or 95% Alumina porcelain
Rapping bar	Rapping impulse	Mechanical Strength	85% or 95% Alumina porcelain for important cases, High polymer
Rotating shaft	Torque	Mechanical Strength	50% Alumina porcelain (Temp.≈2008C), 85% or 95% Alumina porcelain (Temp.= 350~4508C)
Wall bushing	-----	-----	Different materials depending on working situations
Wall support bushing	Weight	Mechanical Strength	85% or 95% Alumina porcelain
Anti-swing Insulator in ESP shell	Temperature variation, Dusty gas	Anti-heat shock	95% Alumina porcelain

### SIZE AND SHAPE DESIGN

For insulators working outside of ESP shell, their shape and electrical creep distance can be designed similarly as the common electric insulators. For insulators working inside ESP shell, directly naked in the dusty gas, its electrical creep distance should be considered according to dust resistivity and its shape decided by dust angle of repose and stickiness.

High voltage ESP insulators can be divided into two classes. Break down class A include wall bushing and inner heating condensation-proof insulators. The other types of insulators belong to non break down class B.

The following factors should be considered in ESP insulators design from the electric and mechanical point of view.

### Mechanical Strength---Check Dangerous Cross Section

Insulator size and detailed dimensions of course should be considered for mechanical strength. Checking dangerous cross section strength is necessary with a safe factor of not less than 1.5.

### **Material Dielectric Strength---Check Insulator Thickness**

This factor has special importance to class A insulators. If electric field strength exceeds the endurance of dielectric material, breakdown occurs. The higher the resistivity and dielectric strength of the material has, the smaller thickness of insulator can be made economically. Generally ESP operated under voltages of 50-120 kV, for a 95% alumina porcelain insulator, thickness of 15-20 mm is enough for normally working.

### **Shape and Geometry---Enough Electric Creep Distance**

Make sure of the creep distance is the key point for a successful insulator design both for class A and class B. Necessary creep distance is depending on the resistivity of the dust covered on the insulator surface. Under dry state, for dusts with moderate high resistivities ( $10^6 \Omega\text{-cm}$ ), creep distance can be calculated from 0.3-0.4 inches/kV. If condensation appears or the surface pollutants are wet and sticky, longer creep distance should be designed. Hot dry air blowing is also necessary.

### **Umbrella---Necessary or Not ?**

Umbrella is necessary only in case of insufficient creep distance. For vertical insulators downward shape umbrella should be used and its inclined angle must be larger than the angle of repose of dust. Distance between umbrellas should be as large as possible provided the creep distance being enough. For horizontal insulators wave form umbrella is suitable with steep peak and wide bottom.

### **Enough Space Surrounding Insulator--- Avoid Corona Discharge or Flash Over**

The necessary space surrounding insulator is related to the dust concentration and the spacing between corona and collecting electrodes (distance S). Usually (1.1-1.5) S is acceptable. Larger distance is necessary for higher dust concentration.

### **Surface Conditions---Avoid Dust and Condensation**

Flat and smooth surface is beneficial to insulators that working in the dusty gas. Surface condensation prevention should be also mentioned. Heating and hot air blowing are used simultaneously or separately. Two methods of heating are used according to concrete conditions. Outer heating is realized by heating coil or/and heating box; 1-3 kW is consumed for one insulator heating. Inner heating is realized by inserting a heating plug into the insulator body, simple and energy saving (0.25 kW for one insulator).

## **APPLICATIONS OF HIGH ALUMINA PORCELAIN INSULATORS**

Based our experiences, we found the high alumina porcelain insulators have evident advantages of high insulation capability, long working life, high heat shock endurance, high performance/price ratio and giving practical possibility of producing the so-called “inner heating insulators”.

Table 3 lists the practical working life and unit price of different material insulators in different Chinese applications.

Table 3: Working life and economical comparisons of Different material insulators in different applications

Really application cases (Location)	Temp. 8C	Insulators type and materials have been used							Final Changed to 95% AO	
		Originally used				Have been changed to				
		Insulator	Material	Price RMB	Life	Material	Price RMB	Life	Price	Life
Phosphorus fertilizer (Nanjing)	300	Rotating Shaft (Imported)	75% AO	6000	1Year	CP	350	1~3 Day	3500	∃10 Years
Copper Smelt (Tongling)	350	Rotating Shaft	95% AO	3500	-----	-----	-----	-----	-----	∃10 Years
Copper Smelt (Yuyao)	350	Rotating Shaft	CP	350	40P/1Y	-----	-----	-----	3500	∃10 Years
Iron ore pellet (Nanjing)	150	Rotating Shaft	CP	600	30P/2.5Y	-----	-----	-----	3500	∃10 Years
		Support insulator	CP	375	12P/2.5Y	-----	-----	-----	950	∃10 Years
		Bushing	Q	5000	12P/2.5Y	-----	-----	-----	4000	∃10 Years
Cement (Dalian)	260	Bushing (Imported)	HP	5000	6P/9Y	-----	-----	-----	2000*	∃10 Years
Cement (Hailaer)	Explosive	Pull rod	CP	240	3 Months Average	PTFE	950	5—6 Months	1800	∃3 Years
Cement (Huogang)	150	Rapping bar (Imported)	PL	2000	18P/1Y	-----	-----	-----	2200	∃1 Year
Miscellaneous (Lingou)		Pull rod	CP	150	0.5—1 Month average	-----	-----	-----	1800	∃3 Years

CP-----Common electric porcelain

HP-----High strength electric porcelain

Q-----Quartz

AO-----Alumina porcelain

PL-----Polymer

P/Y-----How many Pieces destroyed in how many Years

\*-----Here 50%AO was used

It was shown that:

- Although 95% alumina porcelain (briefed as 95%AO, same as other percent) is expensive,

but it can be compensated by its much longer life. We have some of them worked already 12 years, while common electric porcelain insulators can work only 1-3 months,

- The price of alumina porcelain is approximately the same of quartz, but working life is 15-20 times that of quartz,
- Polymer is not suit for high temperature, easing carbonization once arc happened,

There are some engineering examples:

- Parallel test on a 30 m<sup>2</sup> ESP of Shandong Lingou Company shown that operating voltage and collecting efficiency increased 12-34kV and 0.2%-0.5% respectively when common electrical porcelain insulators were replaced by that of 95% alumina porcelain.
- It was proved that the operating voltage and collection efficiency for a 45 m<sup>2</sup> ESP for iron ore pellet calcining in Nanjing were increased 5-10kV and 0.5% respectively when common electrical porcelain insulators were replaced by that of 95% alumina porcelain. In five years, 75 thousands RMB insulators maintenance cost have been saved. ESP shut down loss was reduced by 36 thousands RMB. The value of more 1100 tons of iron ore mixture collected cost 220 thousands RMB. So, totally 330 thousands RMB benefits were created comparing to the insulator retrofit cost of 81 thousands RMB.
- It was proved that the operating voltage and collection efficiency for a 60 m<sup>2</sup> ESP for cement mill in Nanjing were increased 5-7kV and 0.8% respectively when common electrical porcelain insulators were replaced by that of 50% alumina porcelain.

### **INNER HEATING CONDENSATION-PROOF INSULATORS**

Because of high alumina porcelain have excellent heat shock endurance, it become really possible to design a kind of inner heating condensation- proof insulator. The Tailon produced such kind of 95% alumina porcelain pull rod insulator with 36V inner electric plug heating can keep its surface temperature always at 110-150°C with energy consumption only 0.1~0.2kW (Patent Application No. 01273156.0). Although some dust particulates and water may temporarily adhesive on it, but they drop down away as temperature rising. It can operation normally under big temperature fluctuation.

### **REFERENCES**

Bill Steinkuhler. *Design and Selection of Insulators for Electrostatic Precipitators*, Translated and published by the "Electrostatic Precipitation and Gas Cleaning"( Chinese), Vol.3, No.2, 29-37, 1997.

Hans iebermann. *Reliability of High Voltage Insulation Materials*, Electric Porcelain Lightning Arrester, 13-16, No.5, 1998.

Liu Houqi and Lin Hong. *Electrostatic Precipitator*, China Architectural Press, 1987.

Long Tao, Xu Jian and Zhou Baoshan. *Characteristics and Advantageous of Corundum Insulators for Electrostatic Precipitators*, Electrostatic Precipitation and Gas Cleaning (Chinese), Vol. 7, No2, 22-28, 2001.

Zheng Hongwu. *Corundum Porcelain Insulators Used for High Voltage Parallel Vertical Tube Electrostatic Precipitators*, Cement, **3**, 42, 2002.