

A NEW TYPE FIELD TEST INSTRUMENT FOR SPECIFIC RESISTIVITY OF FLY ASH

YUAN YONGTAO, QI LIQIANG, YUAN ZONGHUI AND YANG QIAN

North China Electric Power University

qi_liqiang@sohu.com

ABSTRACT

The probe of this instrument can be inserted into the flue directly for testing the specific resistivity of fly ash. It adopts the ceramic filtration catcher and iso-speed sampling based on static pressure balance technique with parallel short-tube. The collection efficiency of ceramic filtration catcher (η) can reach even exceed 99.9%, and the error of sampling in different velocities is less than or equal to 5%. All these make the sameness between samples and the actual fly ash in many facets, including size distribution, carbon content, element compositions, etc. The coefficient of optimizing ringed electrode for concentric circles k is 14.6, which can adapt all kinds of fly ash whose specific resistivity is in the range from 10^4 to $10^{13} \Omega \cdot \text{cm}$. In addition, the ceramic filtration catcher made of white corundum powder can endure high temperature, high voltage, and acid cauterization. So this test instrument can work well under the conditions in which the flue temperature is from room temperature to 300°C and in the caustic gas. Ceramic filtration catcher also has many excellences, such as avoiding disassembly, cleaning ash easily, repeating use for long time. This instrument has obtained the invention patent in China and applied widely in the domestic range.

INTRODUCTION

There are some ordinary test instruments using different electrodes, such as comb-tooth electrode, pole-plate electrode, etc. While the theory of these instruments is based on the theory of high voltage and electrostatic collection, therefore the particles with different resistivity have different collection efficiency. As a result, the typicality and the authenticity of samples are dubitable. The BDL portable resistivity tester adopts other method. The probe inserted directly into the flue is installed a ceramic filtration catcher and concentric cirques electrodes, and synchronously the probe has the function of iso-speed sampling in order to make the suspend particles in flue gas enter the sampling nozzle of the probe placidly and equably on the intrinsic flow state. And ceramic filtration catcher can collect all the fly ash in the sampling nozzle with high efficiency. The two pivotal techniques above lead to the sameness in many facets between samples and the actual fly ash, such as particle size, element compositions, etc. Thereby, the test data is more authentic.

This instrument is a unique field resistivity tester adopted ceramic filtration and iso-speed sampling technique in the world at present. It has applied to ESP widely in many power plants and cement factories in China.

1 TEST SYSTEM

Figure1 shows that the BDL portable resistivity tester is made of test probe (1), high-resistance test apparatus (2), deflating facility (3) and micro-differential piezometer.

The test probe is the hard core, and there are a catcher and test electrodes in it. The probe is inserted into the flue directly for collecting fly ash and for inputting or outputting the voltage semaphore and current semaphore. The high-resistance test appearance supplies the rated volts d.c. for ash in the probe and synchronously it can show the data of the resistivity. The vacuum pump is the power source of the test system and it can imbibe fly ash into the catcher. The micro-differential piezometer has the function of controlling and adjusting the deflating flux, and it can also maintain the pressure balance between inside and outside of the sampling nozzle in order to sample with iso-speed.

2 TEST PROBE

Figure2 shows the structure of the test probe. The current with particles flows into the ceramic filtration catcher (3) through the sample nozzle (2) under the condition of iso-speed sampling, and then the particles sink into the annular narrow between the outer (4) and the inner (5) electrodes of the concentric cirques. The two electrodes above connect the high-voltage fan-out and the micro-current input-end of the high-resistance test apparatus (9) by high temperature leads. The inner electrical source of the high-resistance apparatus can bring some adjusted pressure based on demand to the fly ash in the catcher, and the specific resistivity of fly ash will be showed.

2.1 Ceramic filtration catcher

The ceramic filtration catcher in the probe has the highest collection efficiency among all the field resistivity instruments. And this instrument isn't any restrictive to fly ash. That is, all the

fly ash can be collected whether specific resistivity is high or low, whether particle is coarse or fine, whether glutinosity is great or less.

Some people had ever studied the catcher whose filtration membrane is made of paper before. Although this kind of catcher has the high collection efficiency, the membranes are too attrited easily to use again. As a result, the new membrane should be installed before testing, and the electrodes should often be renewed. While in the ceramic filter catcher, the electrodes are installed permanently and can be used repeatedly for a long time, the electrodes and the catcher are integrative, and they needn't dismantle.

2.2 Electrode

The test electrodes are concentric circles, and involve inner and outer electrodes and accessorial electrodes. The test electrodes are installed in the ceramic filter catcher and fixed closely in the stainless steel probe permanently in order that they needn't be dismantled or replaced when operating.

The ash layer sunk on the concentric circles is cylindraceous. Based on the ohm law, when the current is being into the ash layer there is a connection to the resistance R with the specific resistivity ρ , the inner surface acreage F of outer electrode and the ash thickness L (That is narrow width) as follows:

$$R = \frac{L}{F} r \quad (1)$$

To the cylindraceous ash layer, the resistance of random tiny-unit is:

$$dR = r \frac{1}{2\rho hr} dr \quad (2)$$

In the formula, h is the effective height of ash layer and it is equal to the electrode height. Then, the total resistance of ringed ash layer is:

$$R = r \int_{r_1}^{r_2} \frac{1}{2\rho hr} dr \quad (3)$$

In the formula, r_1, r_2 are the inner and outer radiuses of the ash layer respectively.

And then the specific resistivity of ash layer can be elicited:

$$r = \frac{2\rho h}{\ln \frac{r_2}{r_1}} R \quad / \Omega \cdot \text{cm} \quad (4)$$

If

$$k = \frac{2ph}{\ln \frac{r_2}{r_1}} \quad (5)$$

Then the specific resistivity of fly ash is:

$$r = kR \quad (6)$$

k is the electrode coefficient.

The electrode coefficient k of the BDL portable resistivity tester is equal to 14.6. From formula (5), k is only connected with the geometry parameters of inner and outer electrodes, which are confirmed through a series of experiments according to the different physical chemistry characteristic of industry dust, such as r_1, r_2, h . Therefore, the electrodes adapt to test the dust whose resistivity is in the range from 10^4 to $10^{13} \Omega \cdot \text{cm}$.

2.3 Iso-speed sampling

The size and composition of fly ash are the importance factors to affect the specific resistivity. For keeping the sameness between test ash in the catcher and the actual ash in flue, the velocity of flue flow entered sampling nozzle must be the same to the velocity of flow near the sampling nozzle, and that is iso-speed sampling. If the velocity of flue flow entered sampling nozzle is less than the actual velocity at measuring point, and then the sample particles will be coarse, the carbon content will be higher than the right, and the particles with greater real density will manifold. On the contrary, if the velocity of flue flow entered sampling nozzle is greater than the actual velocity at measuring point, and then the sample particles will be fine, the carbon content will be lower than the right, and the particles with lower real density will manifold. In order to prevent this situation, the static pressure balance iso-speed sampling instrument with parallel short-tube is installed on the test probe according to the theoretical calculation and the wind tunnel experiments. This installation improves the facticity of the samples.

The iso-speed sampling of this instrument is realized through adjusting the static pressure between inside and outside of the sampling nozzle. The iso-speed sampling can be realized when balancing between the inner static pressure and the outer static pressure through adjusting the sampling flux.

2.4 Capability

Collection efficiency The collection efficiency of the catcher is connected with the particle size. After testing the samples whose median diameter d_{50} is $19.6\mu\text{m}$ and whose screen-down accumulative total distribution ratio is $3.8\mu\text{m}$ (that is $D_{3.8}$), the filtration efficiency of the

catcher isn't less than 99.9%. So it adapts all kinds of industry boilers and kilns.

Enduring-temperature capability The ceramic filtration catcher is made by white corundum powder fired at 1300°C, and it has the perfect enduring-temperature capability in order to adapt the test conditions of different ESP involved high-temperature electrostatic precipitator.

Insulation capability White corundum powder is a sort of insulated material and its specific resistivity isn't less than $10^{15} \Omega \cdot \text{cm}$. For keeping its perfect insulation capability even in damp, PTFE insulated ring (quartz ring in especial instance) should be installed between inner the electrode (high-voltage electrode) and the catcher.

3. FIELD APPLIANCE

Table1 show that the field data on specific resistivity of fly ash in power plants in China by the BDL portable resistivity tester.

The specific resistivity of fly ash in the lab is tested under the condition of contained air in the room, and it is only connected with the element composition and mineral composition of the solid particle. It is only the dielectric characteristic of fly ash itself, and independent of the gas and the liquid inside the particles or on the surface of the particles. So it is called the cubage specific resistivity of fly ash. The cubage resistivity is affected only with the physical chemistry characteristic of fly ash, such as element composition, mineral composition, size distribution, etc. While the field specific resistivity is tested under the flue state, and it is not only connected with the solid particle itself, but also with the flue gas characteristic, such as humidity of flue gas, SO₂ content, etc. Therefore, the field resistivity is less than the resistivity in the lab, and the downtrend is not disproportionate. Table1 show that the extent is different from severalfold to 3 orders of magnitude.

Table1 shows that the resistivity of fly ash is different with the difference of the flue temperature. The curve on flue temperature and specific resistivity ($\rho \sim ?$) shows that this instrument is sensitive and reasonable with the change of test status, and the difference of the specific resistivity is slight under the hardly different temperature. So this instrument has the perfect repeated-operation capability.

4. CONCLUSION

It is the first time to adopt the ceramic filtration catcher and iso-speed sampling technique in the BDL portable resistivity tester, and the efficiency can be greater than 99.9%, so the samples are representative on many facets, such as particle size, carbon content, element composition, etc. Therefore, the test value of specific resistivity by this instrument is the same to the real value. The optimization design to the concentric cirque electrode can adapt the fly ash whose specific resistivity is in the range from 10^4 to $10^{13} \Omega \cdot \text{cm}$. In addition, it can work well in the conditions that the flue temperature is from room temperature to 300°C even in the caustic gas because of its special material and technic.

The collection method is filtration collection and it needn't the high-voltage electrical source with direct current. So it is portable and safe, the test is rapid, and the cost is low. In addition, the dapper probe gives some advice on testing the resistivity on line.

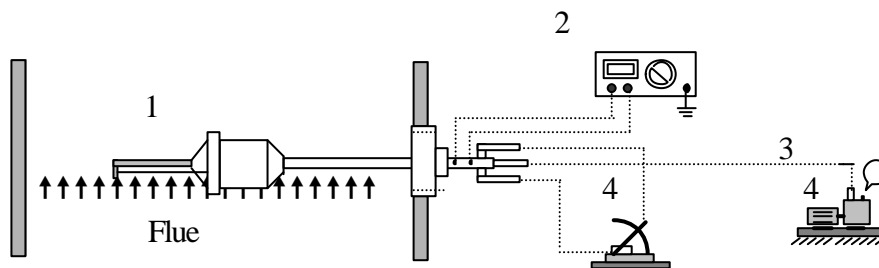


Fig. 1 The field test system for specific resistivity of fly ash
 1. Test probe 2. High-resistance test apparatus
 3. Deflating facility 4. Micro-differential piezometer

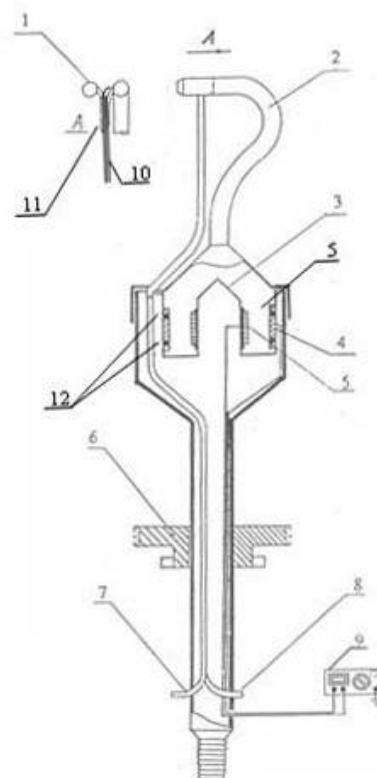


Fig.2 The structure of the test probe
 1. Outer sense static pressure head 2. Sampling nozzle 3. Ceramic filtration catcher 4. Outer electrode 5. Inner electrode 6. Hole plug 7.10. Inner static pressure-transfer tube 8.11. Outer static pressure-transfer tube 9. High-resistance test apparatus 12. PTFE insulated ring

Table.1 The field specific resistivity and the specific resistivity in the lab in power plants

Sample source	Test in the lab		Field test	
	Specific resistivity $\rho/O\text{-cm}$	Test temperature $t^{\circ}\text{C}$	Specific resistivity $\rho/O\text{-cm}$	Test temperature $t^{\circ}\text{C}$
Shijingshan Power Plant	2.2×10^{12}	160	3.2×10^9	160
Huozhou Power Plant	—	—	2.5×10^{10}	129
A Power Plant in northeast area	7.5×10^{12}	120	$2.9 \sim 5.5 \times 10^{12}$	155
	1.5×10^{13}	140		
	6.0×10^{12}	160		
	2.7×10^{12}	180		
B Power Plant in northeast area	1.8×10^{10}	120	2.0×10^8	
	2.9×10^{10}	140		
	1.5×10^{10}	160		
	3.0×10^{10}	180		
C Power Plant in northeast area	2.3×10^{12}	120	$2.3 \sim 3.6 \times 10^{12}$	153
	4.5×10^{12}	140		
	6.0×10^{12}	150		
	5.1×10^{12}	160		
	3.7×10^{12}	180		
D Power Plant in northeast area	1.2×10^{11}	120	$2.8 \sim 3.9 \times 10^{11}$	165
	4.2×10^{11}	140		
	5.2×10^{11}	160		
	4.2×10^{11}	170		
	3.0×10^{11}	180		
E Power Plant in northeast area	2.8×10^{11}	120	$5.5 \sim 8.2 \times 10^{10}$	168
	1.8×10^{11}	140		
	4.0×10^{11}	160		
	6.1×10^{11}	170		
	8.2×10^{11}	180		
Shimen Power Plant	8.58×10^{10}	126	2.9×10^{12}	120
	8.91×10^{10}	130	6.7×10^{12}	130
	8.51×10^{10}	135	9.8×10^{12}	140
	9.24×10^{10}	139	9.1×10^{12}	150
	7.30×10^{10}	144	5.2×10^{12}	160
	—	—	1.2×10^{12}	180
Hancheng Power Plant	4.4×10^{10}	160	—	—
	3.6×10^{10}			
	5.1×10^{10}			

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