Electrostatic Precipitator: The Next Generation

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Abstract: The Electrostatic Precipitator has become known for it efficiency and reliability but there are disadvantages. Described will be Patent No 323806 which describes new developments in EP design.

Keywords: Corona discharge, induction, single stage precipitator, electrostatic precipitator

1 INTRODUCTION

The Electrostatic Precipitator (EP) was designed to overcome the problems with the mechanical filter and be as, or more efficient. Electrostatic Precipitators have been growing in popularity since the 1950's. Among the advantages was that as the EP collected the particulate the pressure drop remained stable and the filter could be cleaned insitu. There are however some disadvantages to the EP. It was decided to investigate the disadvantages and design a filter system which would overcome the disadvantages.

2 OBJECTIVE

The object of the study was to develop an Electrostatic Precipitator Filter system which has a higher efficiency against velocity, is electrically more stable than any other systems and would not collapse if the collector section of the filter cell was short circuited. All the filter systems presently available were susceptible to the latter. It was determined that the method of testing to be used should be either EUROVENT 4/9 or ASHRAE 72. The method should determine the weight efficiency for a single Electrostatic precipitator cell. The method should also be able give a particle count to determine the efficiency for varying particle sizes.

3 METHOD

Electrostatic precipitators have changed over the years. The original precipitators had wires in the ionizing section to generate the corona discharge which is necessary for the precipitator to work. The problem with using wires was that they could break due to the high voltage vibrating the wires. Other disadvantages are that if the collector cell is short circuited for what ever reason that cell and any other connected to it also fails. We wanted to address all these problems and design a filter which could be adjusted for efficiency without the need to increase the cells dimensions.

To do this we had to analyze the way that electrostatic precipitators worked and how to improve them. A system was devised to test the filter system and to determine the disadvantages of the present filters. The test system comprised of outdoor air mixed with particles from a particle generator (diesel generator), a duct system, a filter housing which could take different sizes of filter and a fan with adjustable air flow. The duct was equipped with sensors before and after the filter to measure the air flow and particle weight and particle counting instruments (fig 1).

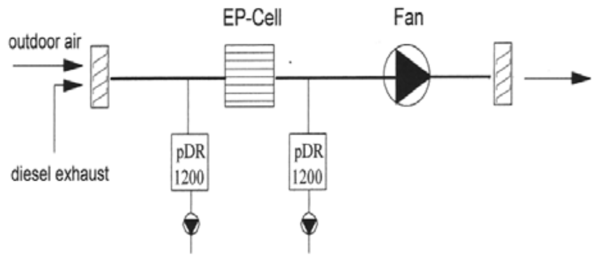


Fig. 1 The filter test rig prepared for weight efficiency test based on particle mass

Filter arrestance (A) is calculated by the following equation:

$$A = 100 \times (1 - \frac{W_d}{W_u})[\%]$$

W_d — weight of dust downstream of the filter [μg/m³]

W_u — weight of dust upstream of the filter [μg/m³]

A fluke particle counter was used in conjunction with the pDR 1200 to ascertain the particle size and the efficiency against particle size.

The EUROVENT 4/9 fractional efficiency method uses a laser particle counter to count particles within specified ranges upstream and downstream the test device. A given particle size range means all particles between two specified diameter values. The number of ranges is equipment specific, for instant the Fluke counters have 6 ranges, (0.3 μm–0.5 μm, 0.5 μm–1.0 μm, 1.0 μm–2.0 μm, 2.0 μm–5.0 μm, 5.0 μm–10 μm and >10 μm).

The basic expression of the fractional efficiency for a given particle size range, is the ratio of the number of particles retained by the filter to the number of particles fed upstream of the filter. The efficiency measurement is done by a series of 12 counts of one minute, conducted successively upstream and downstream of the test device. Between each count transfer lines are purged for one minute. The fractional efficiency (E1) for one repetition is calculated by equation (2)

$$E = (1 - \frac{2N_2}{N_1 + N_3}) \times 100[\%] \tag{2}$$

N_1 — downstream count at time 1,

N_2 — upstream count at time 2,

N_3 — downstream count at time 3.

Results showed that for a standard filter which is charged on the ionizer and collector the efficiency varies with the air velocity this is the known and used to determine the efficiency of a system used in industry. The filter systems of today are designed so that they are very close to arcing. This gives the highest efficiency. The problem with this is that with the system where more than one cell is power with the same power supply when a cell discharges the power is lost in that cell for a fraction of a second. The situation is that there will be other cells connected to the cell either directly or indirectly through the power supply. Therefore when an arc occurs, the other cells connected will also loose power. This is a big disadvantage especially if one cell has a short circuit. If this happens, the total system shuts down. To improve the filter system this is perhaps the one main area where the efficiency and filter cost could be improved.

We went back to basics and realized that the collector was a big capacitor. And that the EP was a capacitor which had a controlled discharge. We then thought about charging the capacitor. We know that the ionizer charges the particle but we wanted to quantify the effect of the ionizer with a varying velocity and a constant collector voltage. Normally due to the way the power generator is designed as the ionizer voltage is increased so the collector voltage also increases. We used a generator for the ionizer and a separate generator for the collector and had the results as shown in Table 1.

Table 1

Air Flow	0.3–0.5μm	0.5–1.0μm	1.0–2.0μm	2.0–5.0μm
4m/s	93.39%	96.03%	97.70%	96.91%
6m/s	88.80%	93.73%	96.38%	95.86%
8m/s	84.20%	93.13%	96.77%	95.75%

As can be seen the velocity affects the efficiency. The higher the velocity the lower the efficiency.

The Ionizing Voltage was varied with a constant air flow in: Table 2.

Table 2

Voltage	0.3–0.5μm	0.5–1.0μm	1.0–2.0μm	2.0–5.0μm
15kV	90.01%	94.94%	98.56%	98.12%
14kV	86.1%	92.1%	97.5%	98.4%
12kV	83.6%	88.9%	96.4%	97.8%

As can be seen to increase the ionising voltage we increase the efficiency and we can have a higher velocity with a high efficiency.

The collector voltage was varied with the ionising and the air flow constant (see Table 3).

Table 3

Voltage	0.3-0.5μm	0.5-1.0μm	1.0-2.0μm	2.0-5.0μm
6.5kV	90.4%	95.6%	98.0%	98.3%
4.6kV	84.1%	90.9%	97.4%	98.5%

As can be seen with at lower collector voltage the efficiency was lower but due to the high ionising voltage the collection efficiency was not dramatically decreased. Below 3 kV however the efficiency dropped dramatically.

The results showed that if we had a high collector voltage the collector could arc which caused a drop in efficiency. We then looked at the design of the ioniser and found that we could cause the collector to accept a charge without having a power connection. The principle we used was that of inducing a voltage in the collector. The faraday cage uses this principle. The final stage was to design an ioniser and test the filter with varying voltages and air speed. The INDUCTION ELECTROSTATIC FILTER was borne. The principle is shown in Fig. 2.

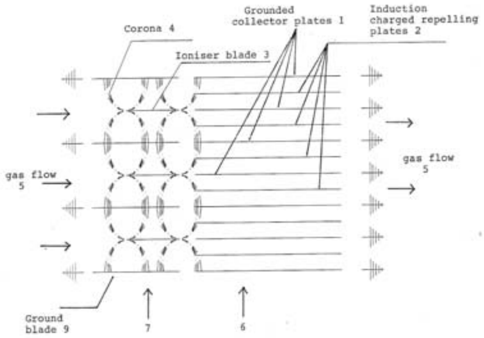


Fig. 2

The new filter was tested for efficiency and general performance. The filter had to be better than other filters available. The filter efficiency was compared with the standard filter it was seen to be of a magnitude higher (see Table 4).

Table 4

Particle size	0.3–0.5μm	0.5–1.0μm	1.0–-2.0μm	2.0–5.0μm
Efficiency	93.6%	95.9%	97.2%	98.3%

4. COST SAVINGS

The Induction Electrostatic precipitator (IEP) gave many financial advantages. The IEP requires only the ioniser to be powered therefore the cost of the power generator is lowered. Cable is only required for the ioniser thus cutting the cost of the installation.

5 CONCLUSIONS

The tests highlighted that the efficiency of the system was much higher than the existing filters and used less energy to attain the same efficiency. The IEP system showed other advantages.

5.1 Operational Advantages

In the old system if one cell was shorted then all the cells connected to that filter will shut down. With the IEP should one cell short circuit, only that filter cell will be affected. The IEP system allows the shorted filter cell to collect particulate but at a lower efficiency, when the cause of the short is removed the cell immediately attains full efficiency. The IEP system was less prone to arcing even when operating at a higher voltage.

5.2 Other Advantages

It was found that during testing the amount of ozone could be adjusted. The ozone could be increased, if required, which when the filter is used in conjunction with a carbon filter in a road tunnel the ozone converted NO to NO_2. The carbon filter collects NO_2 easier than NO.

5.3 Application

The IEP system has been installed in Korea to replaced existing cells. The result was an increase in efficiency with a reduction in power consumption. In a test carried out on the IEP cell in the test rig the efficiency by weight was 98% at 7 m/s.

REFERENCES

1. Norwegian Patent number 323806.
2. Chinese Patent (applied for) International application No. PCT/NO 2006/00378 refers to the IEP.

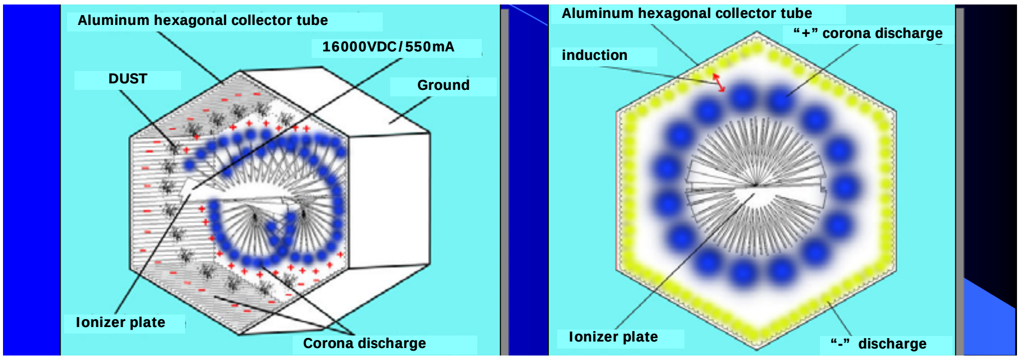
FURTHER ELECTROSTATIC PRECIPITATOR DEVELOPMENT

High Speed EP

Developed by KGD/RITCO to achieve a velocity of 30 m/s with an efficiency of greater than 80% this filter can be fitted directly to the Fan. It is believed to be the highest velocity filter available and was especially designed for road tunnels which have existing jet fans installed and the tunnel requires air cleaning to be installed.

The heart of the precipitator is the ionizer which was designed to spin the air and ionize the particulate. The precipitator also removes smoke should a fire occur in the tunnel. The precipitator can be installed in a short period of time and is 100% reversible. There are many other advantages to the system including low pressure drop.

The precipitator is being developed in a city outside Seoul, Korea. There is a permanent test facility with Jet Fan, Precipitator, monitoring equipment and power supply in place and a demonstration of the system can be arrange by contacting RITCO.



High Speed High Efficiency Filter

High Speed High Efficiency Filter for tunnels

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