

Development of Advanced Electrostatic Fabric Filter

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Abstract

Recently, countermeasures to reduce ambient fine particulate matters, especially with the diameters less than 2.5 micron meters (PM2.5), have been highly required, because of their negative influence to human health. One of the main sources of PM2.5 is coal-fired power station, and dust collector equipped there is one of the most important devices to reduce ambient PM2.5. In the coal-fired power station, electrostatic precipitator (hereinafter ESP) or fabric filter are usually applied, and fabric filter has an advantage in achieving stable and high performance regardless of kinds of coal since it is not affected by the property of coal ash, such as resistivity, while it has also a disadvantage in its high pressure loss which causes a problem of high power consumption. In order to reduce the pressure loss of fabric filter, hybrid dust collector combined with ESP and fabric filter or pre-charging system for fabric filter have already been proposed, but nevertheless they have not yet been so commonly used.

Authors have also addressed to develop a compact pre-charger, which can be installed in the duct at upstream of fabric filter to charge dust particles electrically there, for the purpose to economically reduce pressure loss of fabric filter, and during the process of the development, we have found that the effect of reducing pressure loss is affected much by property of the dust, and the deterioration of performance of reducing pressure loss is caused by back corona, just like the performance deterioration of ESP. Authors have succeeded in the development of pre-charger which can correspond to high resistivity dust which may cause back corona easily, through rich experience of countermeasures to back corona in ESP, and around 30 to 40 % reduction of the pressure loss, together with splendid and stable reduction of outlet emission, of fabric filter have been confirmed.

1. Introduction

Fabric filter has an advantage in achieving stable and high dust collecting performance regardless of kinds of coal, however its pressure loss is high, and it causes much increase of power consumption which spoils the feasibility of the plant, especially when the plant capacity is large. In this regard, most of Japanese utility companies apply ESP as dust collector in coal-fired power stations, and this situation is the same in many countries at this moment, however, considering PM2.5 whose problems are focused recently, development of power-saving-type fabric filter with low pressure loss is highly required, in the view

point of implementation of more stringent emission standards. (Refer to **Figure 1**.)

In the United States and other several countries, hybrid dust collector combined with ESP and fabric filter, namely ESP followed with fabric filter installed at downstream of ESP, has been realized and commercially operated.⁽¹⁾⁽²⁾⁽³⁾⁽⁴⁾⁽⁵⁾ We have also already achieved the performance improvement in the existing two-field-type ESP in 250MW coal-fired power station in Japan, by replacing the internals of the second field to fabric filter to compose ESP (first field) + fabric filter (second field) in the same casing. (Refer to **Figure 2**.)

	ESP	Fabric Filter
Advantage	<ul style="list-style-type: none"> • Pressure drop is lower than Fabric Filter. (IDF operation cost is lower than Fabric Filter.) • Maintenance cost is lower than Fabric Filter. (Replacement of Filter Bags is unnecessary.) 	<ul style="list-style-type: none"> • Dust collection rate is not affected by coal composition. • Achievement of high dust collection performance is easier than ESP. <Dust concentration at outlet of Fabric Filter> <ul style="list-style-type: none"> • Guaranty : 10mg/m³N • Expected performance : A few mg/m³N
Disadvantage	<ul style="list-style-type: none"> • Dust collection rate is affected by coal composition. • For achievement of high dust collection, equipment size of ESP is larger than Fabric filter. 	<ul style="list-style-type: none"> • Pressure drop is higher than ESP. (IDF operation cost is higher than ESP.) • Maintenance cost is higher than ESP. (Replacement of Filter Bags is necessary.)



"Advanced Electrostatic Fabric Filter" is being developed combining advantage of ESP and Fabric Filter.

Figure 1. Concept of development of Advanced Electric Fabric Filter

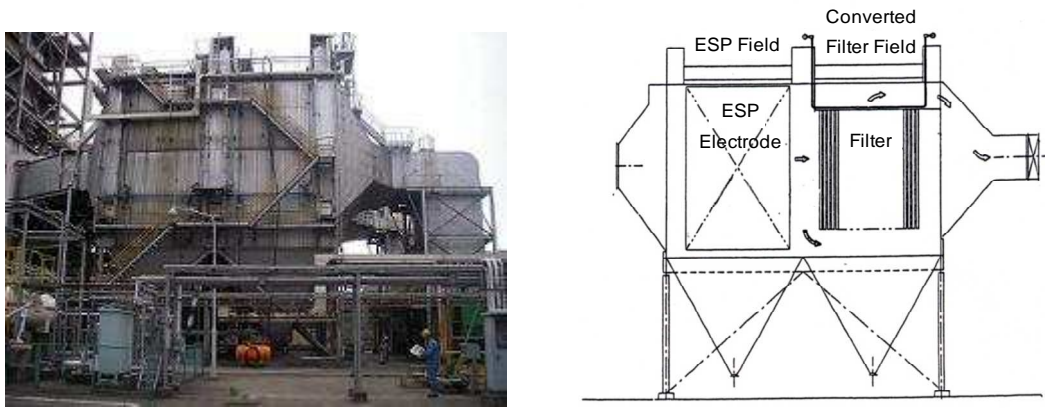


Figure 2. Actual achievement of ESP + Fabric Filter in 250MW coal fired power station

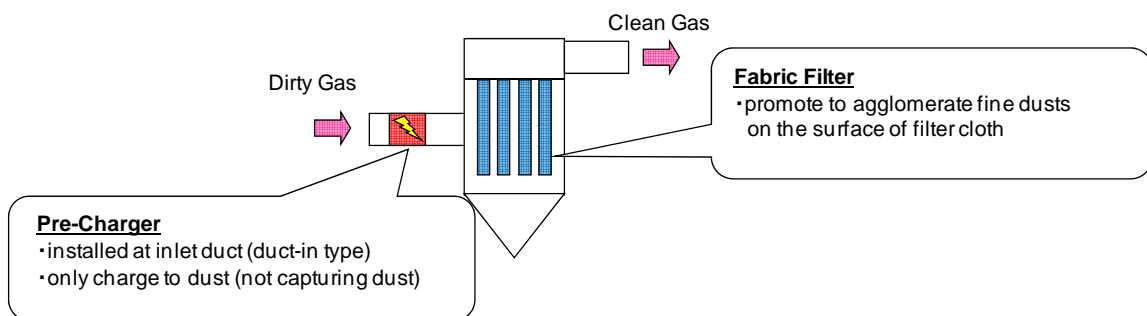


Figure 3. Flow of Advanced Electric Fabric Filter

In such hybrid dust collector combined with ESP and fabric filter, inlet dust concentration of fabric filter is reduced by ESP at upstream, and the charge effect to dust particles is also expected. Such effect may reduce pressure loss of fabric filter installed at downstream, compared with the stand-alone fabric filter. However, the reduction of

pressure loss of fabric filter is not so significant than the expectation, because it has also the disadvantage that coarse particles are mostly collected in ESP at upstream and fine particles are selectively introduced into the fabric filter at downstream. Hybrid dust collector is, therefore, effective for performance upgrading in the existing plant, but very difficult to enjoy

economical advantage in the green field project, compared with the stand-alone fabric filter.

The system which has been developed this time contains the pre-charger which is set in the fabric filter inlet duct whose gas velocity is high, and the pre-charger does never collect particles by itself and only charges the particles electrically, in order to get the economical domination due to the reduction of the pressure loss of fabric filter. (Refer to **Figure 3**.)

The conceptual image of dust collection upon filter media is shown in **Figure 4**. Dust particles are charged by pre-charger, and the fine particles are collected on the surface of the coarse particles, and coarse particles, together with fine particles, are removed from the surface of the filter media easily by reverse pulse jet, so that fine particles does not trespass into the inner layer of the filter media, and as the result, pressure loss increase due to the dust contamination is suppressed and the pressure loss can be reduced compared with fabric filter without pre-charger.

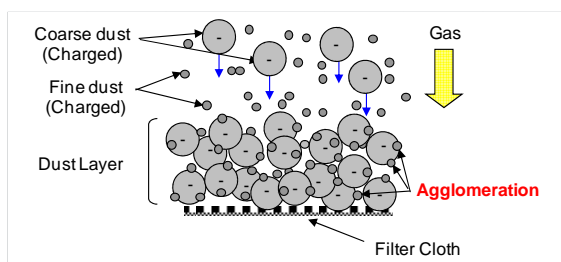


Figure 4. Concept of Advanced Electric Fabric Filter

2. Steps of the Development

It is well known that to apply electrostatic technologies is effective in the reduction of pressure loss of fabric filter, and some systems other than the hybrid dust collector have been investigated, such like the system which apply electrical field upon the filter media itself of the fabric filter⁽⁶⁾⁽⁷⁾, however it has not been so widely used because its filter media may be easily damaged by sparks, replacing filter bag may be difficult due to the existence of the extra parts such as electrodes, or cost reason may exist due to the additional parts.

Authors started the investigation of the system with compact pre-charger which charges the dust in the inlet duct of the fabric filter, considering the cost effectiveness, however even this system cannot avoid the increase of the capital cost of the additional

pre-charger. So, the development is going forward through the following steps shown in **Table 1**, confirming the cost effectiveness of the total system including the additional device such as the pre-charger.

Table 1. Steps of development of pre-charger

No.	Test contents	Test apparatus size
STEP I	Confirm the effect of pre-charging in laboratory test	Bench scale
STEP II	Evaluate the effect of pre-charging in laboratory test	Pilot scale
STEP III	System verification in field test	Actual equipment scale

In STEP I, bench scale test using apparatus shown in **Figure 5** was executed to confirm whether it is effective in reducing pressure loss or not due to dust pre-charging, repeating on and off of the electric power of the pre-charger, using only one filter bag. The effect of reducing pressure loss was confirmed in STEP I, then we proceeded to STEP II using the test apparatus mentioned in the next clause, in order to evaluate the effect more quantitatively.

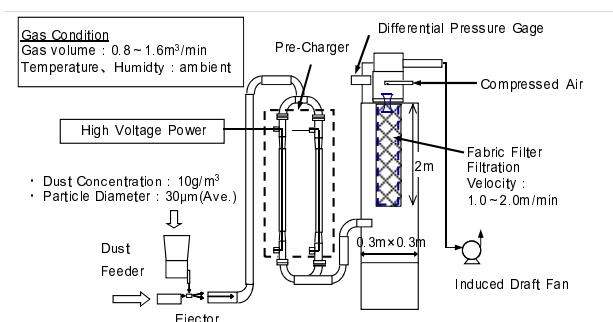


Figure 5. Flow of laboratory test apparatus (STEP I)

3. Test Apparatus in STEP II

In order to plan and realize commercial facility in sight, following points are paid attention to the test apparatus used in STEP II, in order to evaluate the effect of pre-charging quantitatively.

- (1) Two bags for fabric filter; to execute the comparison test for long term, two completely same design bags, one with pre-charger and another without pre-charger, are installed, and the test can be done simultaneously.

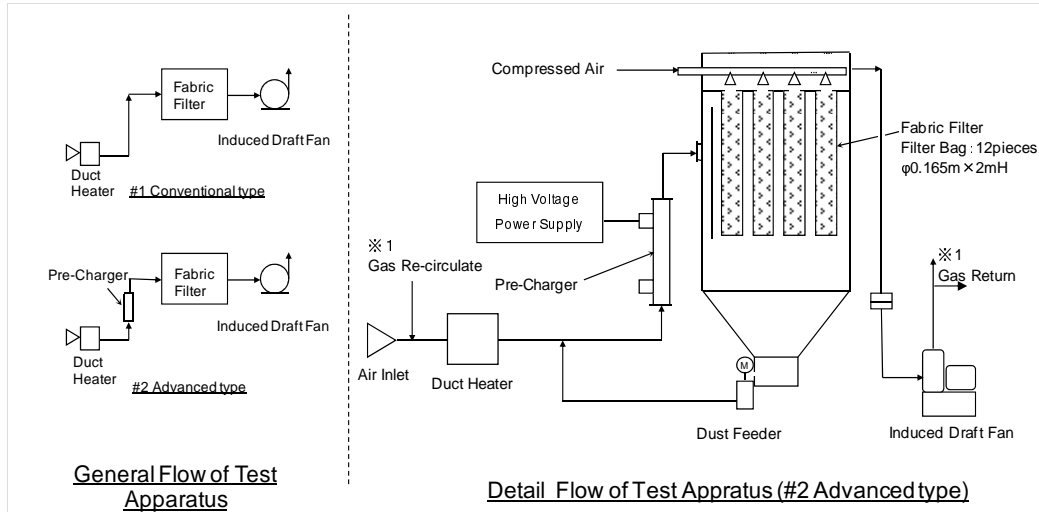


Figure 6. Flow of laboratory test apparatus (STE P II)

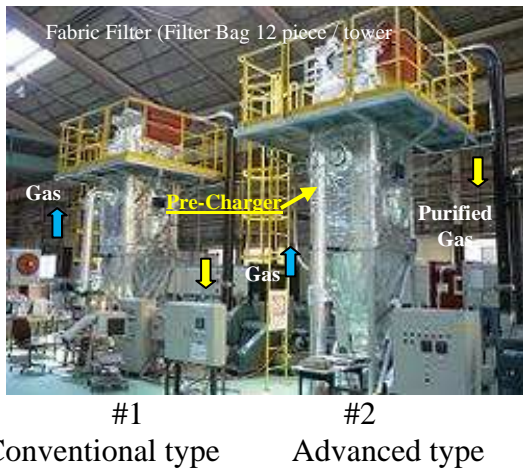


Figure 7. Laboratory test apparatus (STEP II)

- (2) Re-circulation of particles; to execute the test for long term, the collected dust is recovered from the hopper, and provided constantly to the inlet duct through the feeder. The outlet gas of fabric filter is also re-circulated to the inlet duct, so that fine dust particles in outlet gas are returned to the inlet of the fabric filter, to enable the stable operation.
- (3) Reverse pulse jet is applied to each 12 filter bag, with constant interval, to keep the repeatable characteristic of the increase of the pressure loss.

The flow diagram of the test apparatus is shown in **Figure 6**, and the outline of the test apparatus is shown in **Figure 7**.

4. Test Result

4.1 Back Corona Generation

In order to evaluate the reduction effect of pressure loss, long term evaluation of the system is required, and through the continuous long term test under the constant conditions, the new fact, which was not observed in the previous basic tests in STEP I, was newly found.

For the first time, the pre-charger was applied with the corona discharge system, and at that time the electric current of the pre-charger increased after a lapse of the test time, as shown in **Figure 8**, and the effect of the reduction of pressure loss decreased. In this case, the gas velocity passing the pre-charger was around 15 m/s, as the usual gas velocity at the inlet duct of the fabric filter, and we had considered that there should be no influence of the dust contamination since the gas velocity was high enough. We actually could not see any dust contamination on the surface of the inner parts of the pre-charger, by the visual inspection. However, reducing the energization

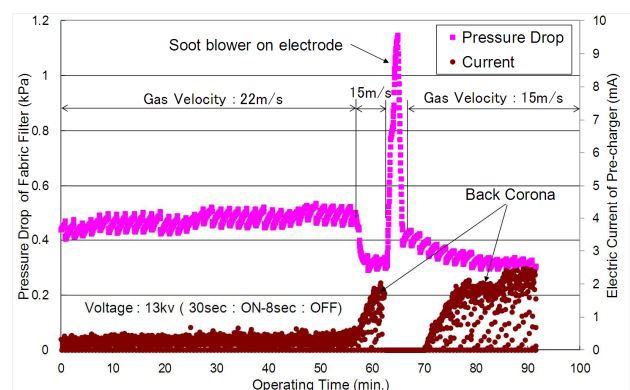


Figure 8. Test data of back corona

power of the pre-charger and increasing the gas velocity up to more than 30 m/s, to clean the electrode by such high velocity gas during the test, the electric current decreased, and the effect of the reduction of pressure loss was recovered to the initial condition.

Through such fact, it was confirmed that some slight dust contamination, which might be almost invisible, is inevitable on the electrodes of the pre-charger even at the gas velocity of 15 m/s, and back corona phenomenon just like usual ESP could occur. The occurrence of back corona phenomenon was also proven through the measurement of the electric charge amount at the different test, when electric charge amount was reduced while the electric current increased.

4.2 Countermeasure to Back Corona for Pre-Charger

When back corona phenomenon occurs even slightly in the pre-charger, ions with the reverse pole reduce the charge of dust very much, so that the countermeasure to back corona is absolutely required for the pre-charger.

In the case of ESP, the most common countermeasure to back corona may be intermittent energization, however in this case of the pre-charger, to adopt intermittent energization is difficult, because it targets the length of the device to be less than 1 meter long in order to be compactly set in the duct and the charging time to be within around 50 ms, so that most of the particles pass the pre-charger without being charged if intermittent energization is applied. Therefore, following countermeasures other than intermittent energization were proposed.

Plan 1: Configuration of the electrodes for corona discharge remains as parallel plate type, and the dust contamination is purged completely by the gas flow, under the periodic off-power condition.

Plan 2: Changing the energization system and adopting boxer charger.

Plan 3: Changing the configuration of electrodes and investigating new configuration

which is not influenced by the dust contamination.

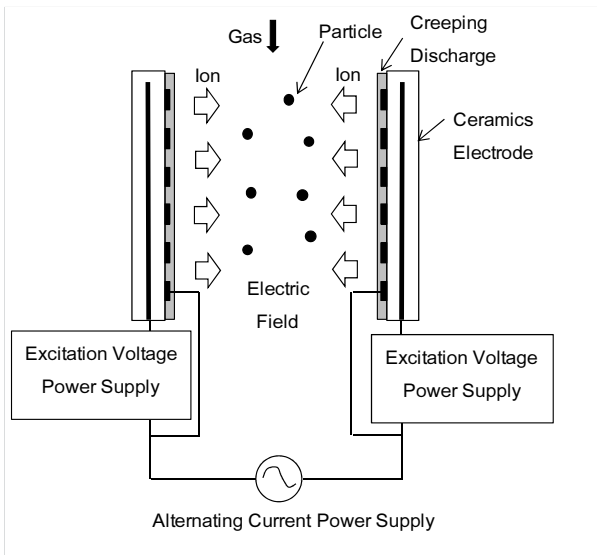
Among the three plans, Plan 1 is the countermeasure for the cleaning up by “power-off” + “increased gas velocity”, and one of the ideas for the commercial facility is to realize variable gas velocity using dampers. Previously mentioned **Figure 8** shows also the example of this idea, however, once back corona occurs, the effect of cleaning up dust would not be maintained for long time, and the gas velocity should be increased up to as high as around 30 m/s to remove dust, so that this idea has been judged to be impractical. So, Plan 2 and Plan 3 have been investigated, as described in the following clauses.

4.3 Changing Energization System as Countermeasure to Back Corona; Investigation of Boxer Charger

The new energization system investigated this time is called as boxer charger, and it is the energization system with which back corona does never occur theoretically. This system was invented by departed Professor Doctor Senichi Masuda more than thirty years ago, and it is still used in some power source for special purposes.

The principle and the electrical circuit of boxer charger are shown in **Figure 9**, and it is the energization system in which mono pole ions (positive or negative), whose source is the plasma generated by creeping discharge on the respective surface of two electrode groups, are discharged alternately (left and right) to the object, using alternate electrical field.

This system is different from the direct current corona discharge, and it discharges always only negative (or only positive) ions come and go alternately in the space, so that if dust layer is on an electrode, electric charge does not accumulated and back corona does not occur in principle. And electric charge is provided from both sides as if two boxers are opposed and competed, to enable the particles to be charged effectively.



Ceramics Electrode (Plate type)

Figure 9. Principle of boxer charger

In order to prove the effect of this system, energization unit shown in **Figure 9** has been set up in the test apparatus, and the test has been executed, to confirm the much reduction of the pressure loss as shown in **Figure 10**. **Figure 11** shows the discharging situation of the electrode after the test, and vague light is seen on the surface of electrode even if the dust exists, and stable energization has been confirmed.

The unit electrode made of ceramics like the construction shown in **Figure 9** is, however, difficult to be applied in the dirty condition like boiler flue gas and also difficult to be applied to the big size facility, so that another type of electrode which uses the commercially available mass-productive ceramics tube, to be applied in the commercial plant, has been designed and tested. As the result, the same effect of the reduction of pressure loss as the initially used unit electrode as shown in **Figure**

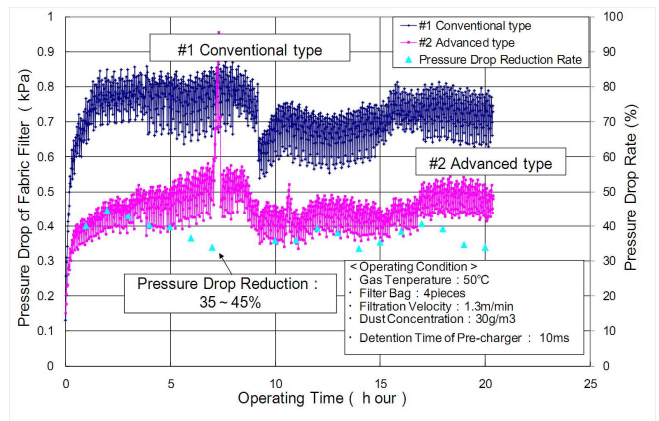


Figure 10. Test result of boxer charger (Plate type)



Figure 11. Creeping discharge of boxer charger (Plate type)

12, then the investigation of large-size apparatus for commercial plant has been started.

Figure 13 shows the electrode and energization system which can be set up in the duct whose gas volume is 100,000 m³N/h. The electrode is equipped with the protector at the upstream side to avoid erosion by particles. This device will be installed at the existing plant and the field test will be executed soon.

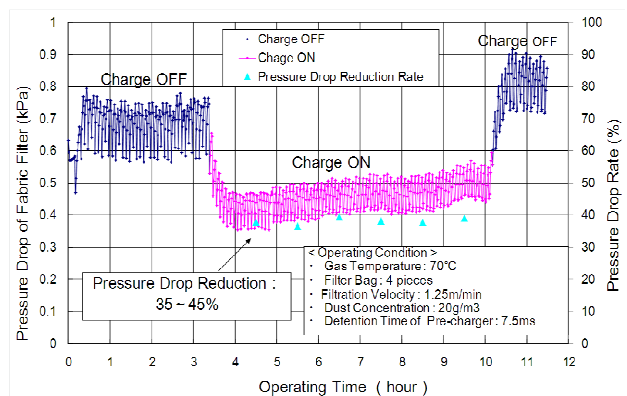


Figure 12. Test result of boxer charger (Tube type)



External view of boxer charger



Power supply unit

Figure 13. Boxer charger for field test of actual plant

4.4 Changing the Configuration of Electrodes as Countermeasure to Back Corona; Pre-Charger for Large-Size Facility

Boxer charger is the very special power source, and for the application of commercially operated large-size plant, large volume should be covered by one power source, not by many power sources installed in parallel, from the cost point of view, and more investigation of further scaling up is necessary at this moment.

Due to situation, we have also investigated the system which utilizes the ordinary corona discharge in maximum, and at this time, the countermeasure has been inspired by the situation of the protector for the erosion of the electrodes.

In the high velocity gas flow, upstream part of electrode metal is suffered with the severe condition of erosion by particles, and the countermeasure to avoid erosion is considered. In the case of boxer charger, the protector for electrode is provided, but this

protector is always maintained to be clean, without dust contamination.

Therefore, considering the situation of the protector without dust contamination, suppressing back corona may be possible if corona discharge can be applied only at this clean area. The grounded electrodes are composed of the group of cylindrical shape electrodes considering anti-erosion, and ordinary corona discharge is applied.

As the result, not so significant compared with the case of boxer charger but more than 30% reduction of pressure loss is confirmed in this system, as shown in **Figure 14**.

Figure 15 shows the conditions of the contamination of the electrodes of upstream side and downstream side, after the test, and at the upstream side metal surface of the electrode can be seen, because of the shot-blast effect of dust particles, and it is considered that such cleaning effect suppresses the back corona.

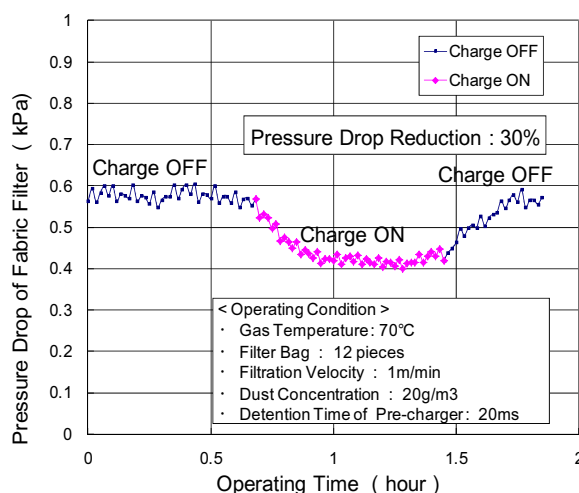


Figure 14. Test result of corona discharge type



Upstream side



Downstream side

Figure 15. Adhension of dust on the electrode of corona type

4.5 Summary of Tests

The results for the tests using two types of pre-chargers considering for the countermeasures to back corona are summarized in **Table 2**. and much reduction of pressure loss and significant reduction of outlet concentration of particles have been confirmed for both cases.

Table 2. Summary of reduction of pressure loss and outlet concentration of particles

Item	Corona type	Boxer Charger type
Reduction rate of outlet concentration of particles	56%	46%
Reduction rate of pressure loss	30%	40%

It is considered to have proven the concept that particles are charged by pre-charger, and the fine particles are collected on the surface of the coarse particles, and coarse particles, together with fine particles, are removed from the surface of the filter easily by reverse pulse jet, so that fine particles does not trespass into the inner layer of the filter.

Based on the test results, the economical comparison of usual fabric filter alone and fabric filter with pre-charger is summarized in **Table 3**. In this table, the reduction of pressure loss is simply converted to the power consumption of the fan, and it evaluates the years which can amortize the capital cost of the pre-charger, and the evaluation may change in accordance with the electrical power fee. However, at least, the fact that the outlet amount of particles is reduced to be half in the same conditions shows that the particles penetrating the filter media is significantly reduced, and the additional advantages such as expanding the life time of filter due to clogging is also expected.

5. Future Plan

For the next step, system verification in field test is being planned, for the future actualization of the commercial facility, which

will realize the dust collector with both stable and high dust collecting performance and the reduced power consumption.

Table 3. Economical comparison of Corona type and Boxer Charger type

Item	Corona type	Boxer Charger type
Initial cost	100	127
Pressure drop reduction rate (Base pressure drop : 1.5kPa)	30%	40%
Reduction of running cost per year (Reduction of IDF operation cost and filter replacement cost)	21	24
Payout time (year)	4.7	5.2

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