Reduction of Rapping Losses to Improve ESP Performance

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Abstract: The need to reduce emissions of particulate matter, NO_x, SO_x, VOC, and most recently CO_2 to address Global Warming, is becoming a worldwide concern. Electrostatic Precipitators (ESPs) have been predominantly used for many years to collect particulate matter from the gas stream of power plants and industrial processes. Unfortunately when the collecting electrodes are cleaned a portion of the precipitated material typically reenters the gas stream and exits the ESP. The amount of reentrainment losses from ESPs may not be suitable to meet lower emissions limits for particulate matter in the future.

Alstom Power Systems (APS) has developed a new technique to reduce the rapping losses from an ESP. This paper presents the key aspects of design and collected information from the current operating units in Guatemala and Finland. The new design is a cost effective approach to address this well-known problem for ESPs. With future development and refinement of the technology it may be possible to reduce the particulate emissions after an ESP to the Near Zero Emissions target being discussed by regulators from e.g. coal-fired power plants.

Keywords: ESP, rapping reentrainment, power plant, dust emissions, pressure drop, gas distribution, flow modeling

1 INTRODUCTION

The use of ESPs to collect particulate matter (PM) from exhaust gas streams of many different processes has been used for many years. There are thousands of ESPs in service today and many more are being purchased and installed on a regular basis. Alstom has supplied more than 4,000 ESPs since the early 1930’s on a wide range of applications. Most ESPs are used strictly to reduce the emissions of PM from entering the atmosphere, however there are a large number of units in use also for product recovery.

During the many years of supply and operation, ESP original equipment manufacturers (OEMs) have continually made design improvements to not only improve the collection efficiency of the units but also to improve reliability and the cost of operation. To address the harmful effects of air pollution, regulators are requiring much lower emissions from stationary sources then they ever have in the past. Very low levels of PM, NOx and SOx are being required in operating permits. In many locations today the required outlet emissions from the particulate collector is becoming so low that buyers are selecting fabric filters in lieu of ESPs. It is believed that the cost of a fabric filter system to achieve very low outlet emissions is lower than that of an ESP. This is however not true for all applications. Furthermore it may not at all be the case when considering a life cycle evaluation (taking into account the operating and maintenance cost of the entire system). An ESP can have a higher initial capital cost, but the life cycle cost for the same performance level may be lower. ESPs can and have achieved very low outlet emissions and this paper presents a new development that could help new and in many cases existing ESPs to achieve even lower outlet emissions.

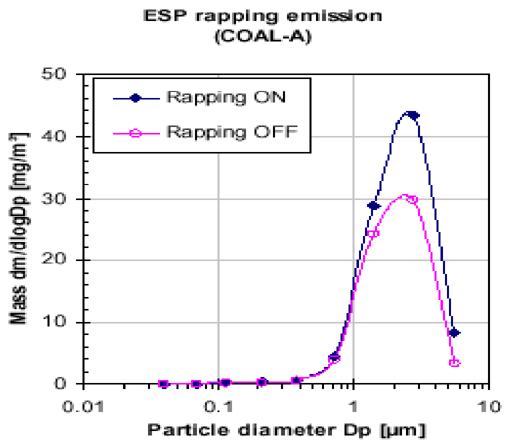
It is well known by people familiar with ESPs that it is imperative that the dust laden gas flow through the ESP must be prevented from “sneaking” around the charging and collecting zones in the unit. Gas baffles and distribution devices are used not only to direct the gas through the ESP, but also to ensure that the gas does not go above, below or around the treatment zones. Physical modeling and field measurements of the plant gas path to ensure that the arrangement minimizes sneakage have been extensively used. All ESPs include some form of gas distribution devices to address this issue and thus the overall collection efficiency of the ESP is improved. As little as 1% or less of the total flue gas flow through the ESP sneaking around the treatment zones could result in high enough emissions that the plant would not meet the required outlet emissions.

In addition to addressing gas flow and sneakage concerns in ESPs suppliers have also spent significant time and effort in improving the cleaning systems for the collecting plates and discharge electrodes. There are a number of different designs available to buyers today all with the purpose of keeping the ESP internals as clean as necessary for the given process conditions and performance requirements [1].

Unfortunately one of the negative aspects of efficient rapping systems in ESPs is the potential to reentrain some of the collected dust into the gas stream that exits the ESP. A number of tests and studies have been conducted to determine approximately how much of the emissions measured after the ESP are associated with rapping losses

[2]. Estimates show that as much as 20% of the measured emissions can be attributed to rapping losses. Fig. 1 below shows the results of a study that was completed several years ago. For even lower emission levels the relative contribution due to rapping is likely to go up further.

Fig. 1 ESP Emissions with and without rapping [3]



In order to minimize the impact of rapping losses OEMs have established design criteria for specific applications and required outlet emissions. Design criteria such as the number of electrical and collecting fields in the direction of gas flow, the maximum gas velocity through the unit and the aspect ratio (treatment length/treatment height) have been established based on performance results from operating units. Very little has been done in the form of mechanical equipment devices inside of a single ESP chamber to restrict the rapping losses from the ESP. APS has now developed and patented a new system to address this problem.

In Japan and some other locations there have been ESPs constructed and operated in a manner to address the problem of rapping losses. The method used is building the ESP with a number of independently isolatable chambers complete with inlet and outlet isolation gates. In this way one chamber can be removed from the gas path by closing the dampers while rapping all of the collecting fields in that chamber aggressively to remove any collected dust. Once the dust has settled into the hoppers the unit would be placed back into service. There are a number of units of this configuration in service today.

The largest negative aspect of the above described off flow rapping system arrangement is the added cost of the larger ESP size as well as the added cost and complexity of the added dampers. There is also a negative aspect of using isolation gates that need to be maintained and the disruption of the normal gas flow through the operating chambers when one chamber is closed for cleaning.

2 SYSTEM DESIGN

Many ESPs use perforated plate screens at the inlet face to distribute the gas into the collecting fields of the unit. There are a number of different arrangements provided by the equipment suppliers. The new Off-Flow Rapping System (OFRS) developed by Alstom uses perforated plates similar to the ones used in the inlet of the unit to help reduce or eliminate rapping losses from the ESP. A matched pair of screens, one fixed and one movable are located immediately after the last collecting field in the ESP. Fig. 2 shows the basic arrangement of the screens. In the normal resting position the holes in the movable screen matches those of the fixed screen. This is the open position. As the movable screen is lifted one hole-diameter upwards by the lifting mechanism the two screens will together block the corresponding duct. This is the closed position.
Unlike standard tumbling hammer position on the drive shaft, the hammers in the last system needs to be organized so that the collecting plates are rapped from one side to the other instead of "randomly" to enable OFRS.

The method of operation is as follows:

- screens are normally open;
- when rapping cycle is initiated, the first screen is moved to the closed position;
- the first collecting electrode (CE) is rapped;
- a delay time is established before the second screen is closed;
- the second screen is moved to the closed position;
- the second CE is rapped;
- a delay time is established before the first screen returns to the open position;
- the third screen is moved to the closed position;
- the screen closure and rapping of the CEs progress from one side of the ESP chamber to the opposite with suitable stop times between rapping and opening of the screens to allow the dust to settle or re-attach to the collecting plates.

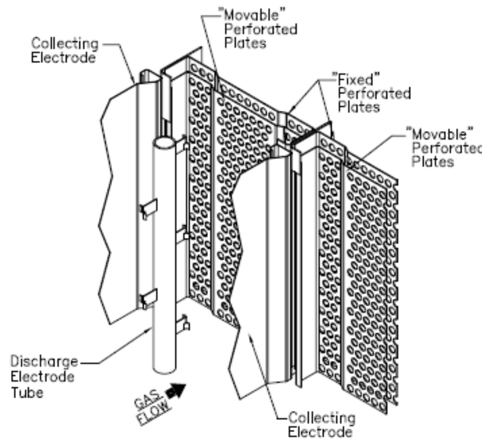


Fig. 2 APS OFRS General Arrangement

Fig. 3 shows the rapping of an interior CE of the ESP with the associated screens in the closed position.

Synchronization of the screen closure and the rapping action is achieved by electrical or mechanical interlocking of the camshaft that lifts the screens to the rapping hammer shaft. The staggering of the cams and the hammers must then also be mounted in a correct way. A variable speed drive with low revolution per minute output can be used to adjust the operation of the system in the field for optimum performance.

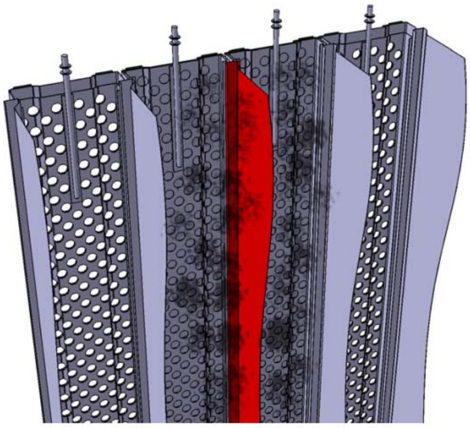


Fig. 3 OFRS in Operation

3 GAS DISTRIBUTION MODELING

With the OFRS located directly after the last collecting field in the ESP it is important to verify that the use of and operation of the system does not have a negative impact on the collection efficiency of the last field in the unit. To finalize the design of the system APS used physical modeling to evaluate the design. From the study efforts it was determined that the baffles used directly above and below the screens must be positively sealed to the roof girders and the hopper end walls respectively. Fig. 4 below shows the arrangement of the physical model that was used to evaluate the system.

Fig. 4 Physical Modeling of OFRS

The model ESP size and arrangement were as follows (but 1/10 scale):

Number of fields:	5
Number of gas passages	38
Gas passage spacing	400 mm
Plate height	14.7 m

Results of the model study efforts provided the following information:

- With two screens blocked the RMS deviation changed from 8.3% to 17.0%.
- It was determined that the use of the OFRS should be used in ESPs that are of moderate size so that the % of the through area of the ESP blocked during operation is 10% or less. Higher percentage of blocked area within the ESP results in poor gas distribution in the last field of the ESP potentially having a negative impact on collection efficiency.
- Different porosity screens were tested and tests were conducted with and without gas distribution screen in the outlet funnel.
- To ensure that the gas distribution in the last field of the ESP remains optimized, the screens in the outlet funnel are to remain in the ESP.
- Pressure loss measurements were also conducted with and without the screens in the ESP. Since the gas velocity in the ESP is very low where the screens are located, the pressure losses across the system are negligible.

4 LABORATORY TESTING

To confirm proper operation of the lifting mechanism for the movable screens and to ensure that the design did not have any problems associated with binding or wear, three sections 400 mm wide by 14 m tall were testing in the laboratory in Vaxjo, Sweden (See Figs. 5 and 6). During the testing different arrangements for drive systems were tested and evaluated. The successful lab tested arrangement was then used for the system installed in a full size ESP in Finland.

Fig. 5 Laboratory Testing of OFRS

The lifting mechanism for the OFRS consists of a shaft supported by a number of brackets mounted to the roof girder in the ESP and specially designed cams that lift and drop each section of movable screen. See Fig. 6. The shaft is rotated by an externally mounted variable speed drive.

The alignment and spacing of the cams on the shaft are such that as the shaft rotates the screens are opened and closed in sequence from one side of the ESP to the opposite side. As the screens close the associated rapper for the collecting plate impacts the plate to dislodge the precipitated dust. After time for the dust to either fall into the hopper or being charged and re-collected onto the collecting plate, the screen is opened allowing normal gas flow out of the unit.

As the screens are moved from the closed position to the open position they are dropped a short distance to accelerate the section to dislodge any dust that might have collected on the screen.

Fig. 6 APS OFRS Lifting Mechanism

5 FIELD DEMONSTRATIONS

There are now two ESP installations equipped with the APS patented OFRS. The first installation is in a small ESP after an oil/Orimulsion fired diesel engine in Guatemala. This unit is a two field ESP with the collecting plates spaced on 300 mm centers. The collecting plate height is 5 m. See Fig. 7.

Fig. 7 ESP Installation in Guatemala

The nature of this process is that there is a large amount of unburnt carbon in the form of fine particulate exiting the engine. This dust has a low resistivity and poor adhesion to the collecting plates. Therefore it is difficult to achieve high removal efficiencies and rapping losses are an important factor in the emissions from the unit.

After a period of operation wherein adjustments and tuning of the ESP were completed, the emissions from the unit remained higher than desired. It was decided to incorporate the OFRS into the unit. The following are the performance results after the system was installed:

- Removal efficiency increased from 62% to 70.5%;
- Outlet emissions reduced from 22 to 14.75 mg/Nm^3;
- Outlet emissions reduction of about 33%;
- ESP migration velocity increase of about 11%.

As a result of the success of the OFRS in the ESP in Guatemala, APS began promoting the use of the system in additional ESP projects. The second opportunity to employ the design is in a new ESP that has been added after an existing multi-fuel fired fluidized bed combustor system in Finland (See Fig. 8).

Fig. 8 ESP after FBC in Heinola, FI

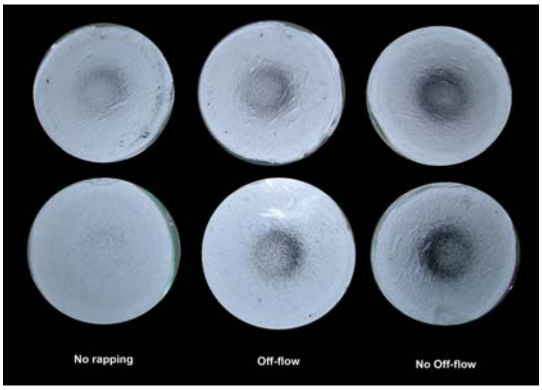


Fig. 9 Test Filters from an ESP with OFRS

The boiler output capacity is 120 MW and it is fired with coal, peat, biomass and oil. There is a WFGD system after the ESP to reduce the SO_2 emissions from the system.

This ESP has three collecting fields in the direction of gas flow. Each field contains 19 gas passages with 400 mm spacing between the collecting panels. The collecting plate height is 15 m.

The primary fuels fired in the boiler are biomass and peat. The ESP performs very well when these fuels are fired resulting in very low emissions exiting the ESP. It was difficult to validate exactly how much lower the emissions from the ESP were when comparing operation with and without the use of the OFRS. Fig. 9 shows the filters from the testing that was performed when the boiler was firing biomass and not at 100% of operating capacity. The measured mass emissions from the unit were less than 5 mg/Nm^3. It is possible to see the impact of the use of the OFRS by comparing the difference in the amount of dust collected on the filters.

The filters in the left column are from testing with no rapping of the last field in the ESP during the test. The center column of filters shows the results with rapping of the last field and OFRS in operation. The filters in the right column are with rapping and the OFRS not in operation.

A second test campaign for the ESP system was conducted when the boilers was firing a mix of coal and biomass and at close to 100% capacity.

The results of this testing campaign in some cases showed positive improvement in the ESP performance when using OFRS. However the results were not consistent. During the first test series the outlet emissions were lowered from 33 mg/m^3 to 18 mg/m^3. The ESP removal efficiency improved from 99.31% removal to 99.62%.

The results of the second series of tests did not demonstrate the same degree of improvement. The emissions reduced from 18 mg/m^3 to 14 mg/m^3. The efficiency improved from 99.58% to 99.68%. It is difficult to conclude exactly why the results of the two test series of tests where not consistent, however the results were still positive when the OFRS was used. Based on analysis of the test data it is believed that there were some changes in the way the boiler was operating between the test periods that impacted the result.

Some additional testing of the system was conducted during the same test campaign wherein the emissions were measured without the use of rapping of the collecting plates in the last field of the ESP but the measured emissions were higher then measured values collected earlier in the program. It was again believed that changes in boiler operations were impacting the results.

6 SYSTEM INSPECTION AND EVALUATION

After several months of operation the ESP installation in Finland was stopped for normal boiler service and maintenance. During the boiler outage an extensive inspection and evaluation of the installed OFRS was conducted. The following items were identified during the inspection:

- The OFRS was working properly;
- The screens were clean and no evidence of material accumulations on the system were detected;
- The synchronization of the screen closure and the rapping of the CEs was working correctly;
- The gas baffles associated with the OFRS need to be improved to minimize sneakage when the screens are closed;
- The distance between the fixed and movable screens needs to be reduced.

The conclusion for the results of this project is very positive. Some minor design improvements to the system are being implemented in the next installation.

7 SUMMARY AND CONCLUSIONS

The allowable PM emissions from power plants and industrial processes are continuing to be lowered. ESPs are a cost effective way of meeting PM emission requirements. It is well known that rapping losses from cleaning the collecting electrodes of the ESP contribute to the mass emissions measured at the outlet of the ESP. Inclusion of new technologies in ESPs such as the new Off-Flow Rapping System developed by Alstom Power will enable ESPs to cost effectively meet the required low PM emissions. The emissions and collection efficiency of the first two ESPs using the OFRS has been improved. With some minor improvements in the system design, future ESPs using the system will be able to achieve lower outlet emissions due to the improved reduction in rapping losses.

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