2ND GENERATION OF DRY-TYPE ESP AND HYDRO HYBRID FILTER TECHNOLOGY[1]

Jan Adams[2]
Thilo Wübbels[2]
Helmuth Ester[3]
Klaus Schmale[2]

Abstract
The compliance with environmental regulations and energy recovery in steelmaking plants have become a major issue within the last few years. Thus, clean, green and sustainable technologies for the steel industry have become a major focus. In BOF plants utilizing converter gas recovery, nowadays gas cleaning is only possible by wet scrubber or round dry-type electrostatic precipitators (ESP). As environmental regulations will become more restrictive and wet scrubbers may no longer fulfill these requirements, dry-type ESP are a suitable alternative. However, the current generation of ESP for BOF primary off-gas dedusting processes do not comply with the latest available state-of-the-art ESP technology. Due to this fact, the two companies SMS Siemag and ELEX have founded a joint venture, the new company SMS ELEX AG, with the intention to develop a new generation of gas cleaning equipment for converter off-gas from BOF meltshops. Consequently, SMS ELEX has designed a 2nd generation of round dry-type ESP, incorporating the latest electric filter know-how. Moreover, a brand-new process has been developed and patented to upgrade existing gas cleaning systems using wet scrubbers with a round wet-type ESP. The combination of these two technologies is called Hydro Hybrid Filter and enables existing BOF scrubber units to comply with most restrictive environmental regulations, at very low investment cost. The presentation illustrates the main points of improvement of the 2nd generation dry-type ESP. Secondly, the principle of the Hydro Hybrid Filter will be explained, followed by highlighting investment cost and the effects on operating costs.
Keywords: Oxygen steelmaking; Gas cleaning; Environmental technology; ESP filter.

SEGUNDA GERAÇÃO DE PRECIPITADORES ELETROSTÁTICOS (ESP) A SECO E TECNOLOGIA DE FILTRAGEM HIDRO HÍBRIDA

Resumo
O cumprimento com regulamentações ambientais e recuperação de energia em aciarias tem se tornado um tema de maior relevância nos últimos anos. Por isso tecnologias ecologicamente sustentáveis para a indústria do aço se tornaram de grande foco nas empresas. Em aciarias integradas BOF com recuperação de gases de convertedores, a limpeza tradicional é possível através de sistema úmido com lavador (tipo “scrubber”) ou sistema seco com precipitadores eletrostáticos (ESP). Como as novas regulamentações ambientais estão se tornando mais exigentes, e o sistema de lavagem por “scrubbers” não poderá atender mais tais parâmetros, o sistema a seco ESP se torna a alternativa viável. De qualquer modo, a atual geração de ESP para processos de exaustão primário de gases de convertedores em trabalho, não correspondem à mais moderna tecnologia ESP disponível. Por este motivo, as empresas SMS Siemag e ELEX estabeleceram uma “joint-venture”, a nova companhia SMS ELEX AG, com o objetivo de desenvolver a nova geração de equipamentos para limpeza de gases provenientes de aciarias integradas com BOF. Em consequência, a SMS ELEX projetou a segunda geração de sistema de limpeza a seco ESP, incorporando a mais recente tecnologia de filtro eletrostático. Além disso, um novo sistema foi desenvolvido e patenteado para melhorar a eficiência de sistemas existentes de limpeza de gases por lavadores, acoplando os mesmos a sistemas de filtragem a seco ESP. A combinação destas duas tecnologias é chamada de Filtragem Hidro Híbrida, e possibilita que instalações existentes de lavagem de gases atinjam às exigências das regulamentações ambientais atuais, a um baixo investimento. A apresentação ilustra os pontos principais de melhoria desta segunda geração de sistema de limpeza a seco ESP. Ademais, os princípios do sistema de Filtragem Hidro Híbrida serão apresentados, com respectivos dados gerais sobre investimento e custos operacionais.
Palavras-chave: Aciaria a oxigênio; Limpeza de gases; Tecnologia ambiental; Filtro ESP.

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[2] *SMS ELEX AG, Eschenstrasse 6, 8603 Schwerzenbach, Switzerland. jan.adams@sms-elex.com / thilo.wuebbels@sms-elex.com*

[3] *SMS Siemag AG, Eduard-Schloemann-Straße 4, 40237 Düsseldorf, Germany. helmuth.ester@sms-siemag.com / klaus.schmale@sms-siemag.com*

Introduction

In BOF plants utilizing converter gas recovery, gas cleaning is nowadays possible by wet scrubbers and the round-type ESP. As environmental regulations will become more restrictive and wet scrubbers may no longer fulfill these requirements, the round dry and wet-type ESP are the only alternative.
The dry-type round ESP has the following main advantages compared with the wet scrubber system:

- Lower clean gas dust content
- Lower operation costs
- Less maintenance work
- No water treatment system required
- Less water consumption

However, the current generation of ESP for BOF primary off-gas cleaning processes does not comply with the latest available state-of-the-art ESP technology. In view of this situation, the two companies SMS Siemag and ELEX have founded a joint venture, the new company SMS ELEX AG, with the intention of developing a new generation of gas cleaning equipment for converter off-gas from BOF meltshops.
Consequently, SMS ELEX has designed a 2nd generation of round dry-type ESP incorporating the latest electric filter know-how. Moreover, a brand new process has been developed and patented to upgrade existing gas cleaning systems using wet scrubbers with a round wet-type ESP. The combination of these two technologies is called Hydro Hybrid Filter and makes it possible for existing BOF scrubber units to comply with most stringent environmental regulations at very low investment costs. Another advantage is that only short downtimes are required for the modernization of the existing scrubbers connected to the system.

1 Second-generation dry-type ESP system in the BOF process

The off-gas from the converter is cooled down in the cooling stack. This water-cooled ductwork brings about a reduction in the gas temperature from 1,600℃ to approximately 900℃. In order to establish optimum conditions for the ESP, the gas has to be cooled further in a second step after the cooling stack. Therefore, the gas flows through a gas conditioning tower (GCT) before entering the ESP. The gas temperature at the GCT outlet is 200℃, and the gas is partly saturated. Thanks to these optimum gas conditions, the ESP is capable of separating the dust with a high efficiency of 99.98%. An internal bottom scraper pushes the dust into the chain conveyor below the ESP and from there it is transported by a nitrogen-flushed chain conveyor into the fine dust silo. Alternatively, dust can be transported by a pneumatic system.

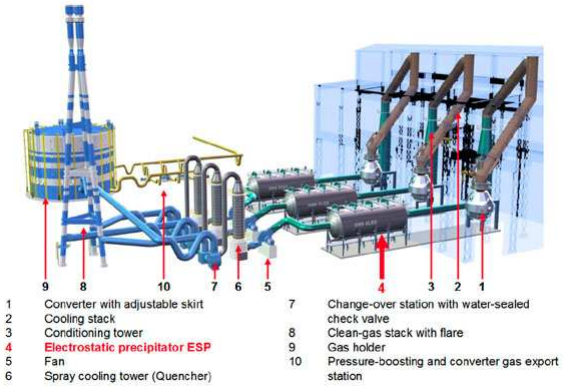

Figure 1. Converter gas cleaning and recovery plant with ESP.

The gas flow through the GCT and the ESP is generated by an induced draft fan (ID fan), located downstream of the ESP. Depending on its CO content, the clean gas is either directed to the flare stack or into the downstream gas recovery process. The energy contained in the gas with more than 45% CO can be used, and the gas is consequently stored in the gasholder. This process requires further conditioning of the gas so that it can be stored at atmospheric conditions. Therefore, a quenching tower (QT) is installed between the ID fan and the switch-over station. Gas with less than 45% CO is routed through the flare in order to safely burn the remaining CO. The dust content of the off-gas at the clean gas stack is lower than 10 mg/m^3 (all flow rates to standard conditions for temperature and pressure, STP).

1.1 Gas conditioning tower (GCT)

The GCT has two basic functions. First of all, the gas temperature needs to be decreased to a lower level for further processing. Secondly, the gas has to be conditioned in order to allow the ESP to work at its best possible efficiency.

The off-gas at the end of the cooling stack has a maximum temperature between 900 and 1,000℃. By means of special gas distribution i nternals the gas entering the GCT of SMS ELEX is first distributed in order to obtain an optimized gas flow over the entire GCT cross-section. The figure illustrates in principle the difference between the gas velocity distribution inside the GCT without, and with gas distribution internals. However, in particular cases the gas distribution is being customized based on simulations taking into account individual layout and process data.

Thanks to this gas optimized gas distribution at the GCT inlet, a back-streaming gas flow and dust built-ups on the side walls, most likely near the points of injection, can be avoided. These deposits that accumulate in many of the first-generation GCTs may cause major damage to the dust conveying device by getting too big and falling off. By utilizing gas distribution at the GCT inlet, the entire system is more reliable with less maintenance work during the converter relining period. Moreover, this attribute ensures a better efficiency of the ESP downstream of the GCT.

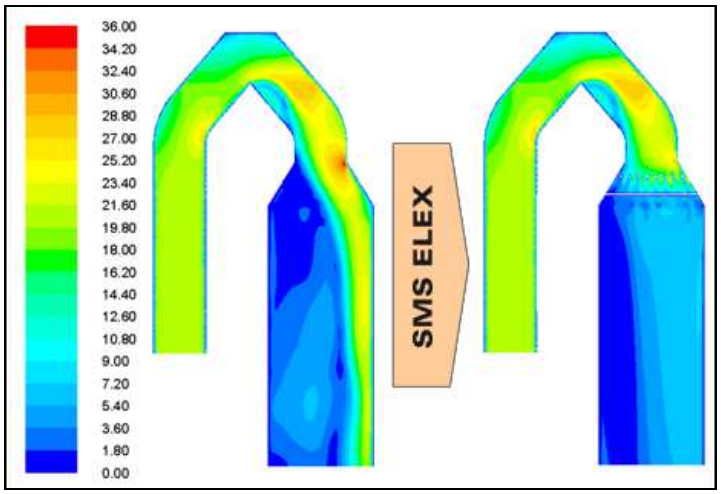

Figure 2. Velocity over the cross-section in GCT (in m/s).

In order to decrease the temperature to 200℃, wate r is injected by means of spillback nozzles into the hot gas flow below the gas distributing components. Spillback nozzles creates water droplets with a maximum diameter of 400µm. Water pressure at the nozzles of minimum 30 bar is required to maintain the droplet size. As soon as the water droplets are injected into the hot gas flow, the heat transfer from gas to water starts and the water finally evaporates. Thus, the gas temperature decreases continuously to 200℃ at the GCT outlet. Due to the evaporated water, the gas is well conditioned for ESP operation with a water vapor content of 30%. A major advantage of using spillback nozzles is that this system only requires a single water supply system and no additional media supply such as steam or nitrogen which would be required for two-media injection nozzles. This keeps the operation cost at a low level. Even with gas distribution internals, the entire GCT creates a maximum pressure drop of less then 4.5 mbar. The coarse dust, which is separated in the GCT due to gravity, is discharged by a chain conveyor system.

1.2 Second-generation dry-type ESP

The function of the dry-type ESP is based on electrostatic separation. Electrons are emitted from discharge electrodes which are charged with a high negative voltage. Due to the differential potential, the electrons migrate to the earthed collecting plates. During this period, the electrons accumulate on the dust particles in the gas flow. As a result, the dust particles become negatively charged and the electrical field forces them in the direction of the collecting plates where the dust is deposited.
In the SMS ELEX round-type ESP, the collecting electrodes consist of profiled plates. These form a system of passages through which the exhaust off-gas flows. The discharge electrodes are arranged along the axis of the 400 mm wide passages. Mechanical rapping units clean the collecting plates by means of periodic rapping. Discharge electrodes and collecting plates will be explained in greater detail in the following chapter.
The ESP is separated into so-called “fields”. Usually, an ESP for BOF primary gas cleaning has four fields, which are separated electrically and mechanically. The mechanical separation means that each field has its own rapping unit and its own dust scraper. The electrical separation is effected by applying one high voltage unit per field. With this design, dysfunction in one field does not influence other fields.

1.3 Discharge electrodes

The discharge electrodes in electrostatic precipitators are the key components. If they do not function correctly, proper ionization of the dust is not possible and consequently, the efficiency of the ESP decreases heavily. Furthermore, it is extremely important for the function of an ESP that the discharge electrodes do not break and cause short circuits of the electrical field. Many customers have reported such problems, especially in existing ESPs for BOF primary off-gas cleaning. A reason for this has been found in the separated dust, which is not oxidized during the blowing process due to the reducing atmosphere caused by the carbon monoxide. During the non-blowing period, ambient air is routed through the ESP, and the dust sticking on the internal parts starts to glow on the surface. This causes heavy stress for the internal parts due to thermal expansion and critical material temperatures. In particular, the discharge electrodes in the first field are affected. As a result, electrodes get distorted, break and cause shut-down of the field according to customer reports.
Based on these reports and the 75 years of experience of ELEX, the patented discharge electrodes have a special tubular design, high resistance to stress and a high rigidity. In addition, the discharge electrode suspension system patented by SMS ELEX allows thermal expansion of the electrodes.

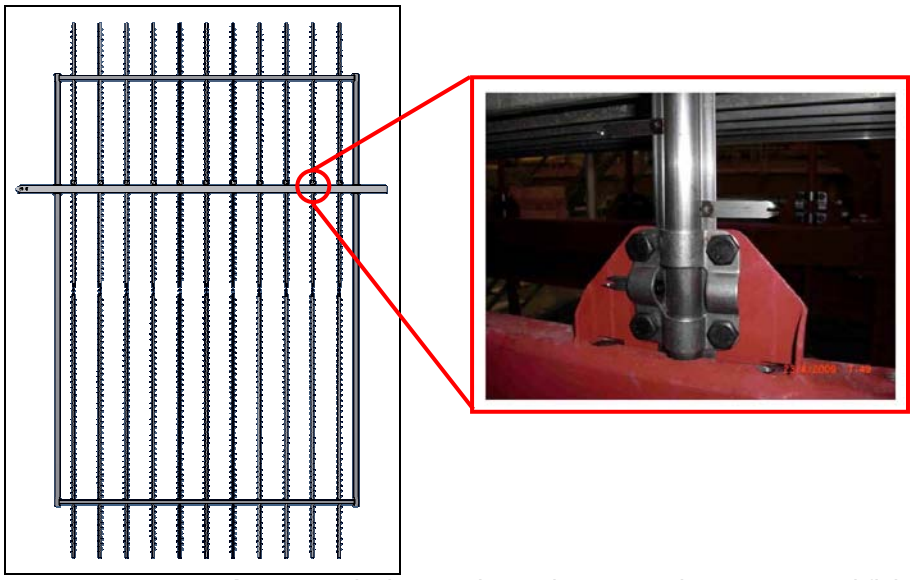

Figure 3. Discharge electrode suspension system and fixing point.

1.4 Collecting plates

SMS ELEX collecting plates are designed as profiled plates. In order to allow thermal dilatation of each plate and easy rapping and to avoid any mechanical stress, SMS ELEX has designed a new patented collecting plate system. Furthermore, the system ensures easy assembly.
The plates are split in the center of the ESP, and a distinction is made between “hanging” and “standing” plates. As mentioned above, two plate walls form one passage. One plate wall consists of 11 hanging plates and 11 standing plates in gas flow direction.
All the hanging plates in one wall are connected to one plate-supporting profile,

located under the ESP roof. The standing plates are also supported in a plate-supporting profile which is located at the bottom of ESP . Furthermore, all plates of one wall are guided in the rapping bar in the center of the ESP. Each pair of plates (one hanging and one standing plate) touches one arrestor in the rapping bar, by which the rapping impulse is transferred. The rapping bar itself is held either by two bolts in two upper plates or by a pendulum construction outside of the field.
Each individual plate in one field can move independently of the other ones as they are not attached to each other. As a result, the new patented suspension design allows thermal elongation of each plate. The plates are therefore not affected by mechanical stress, and rapping no longer damages the collecting plates.

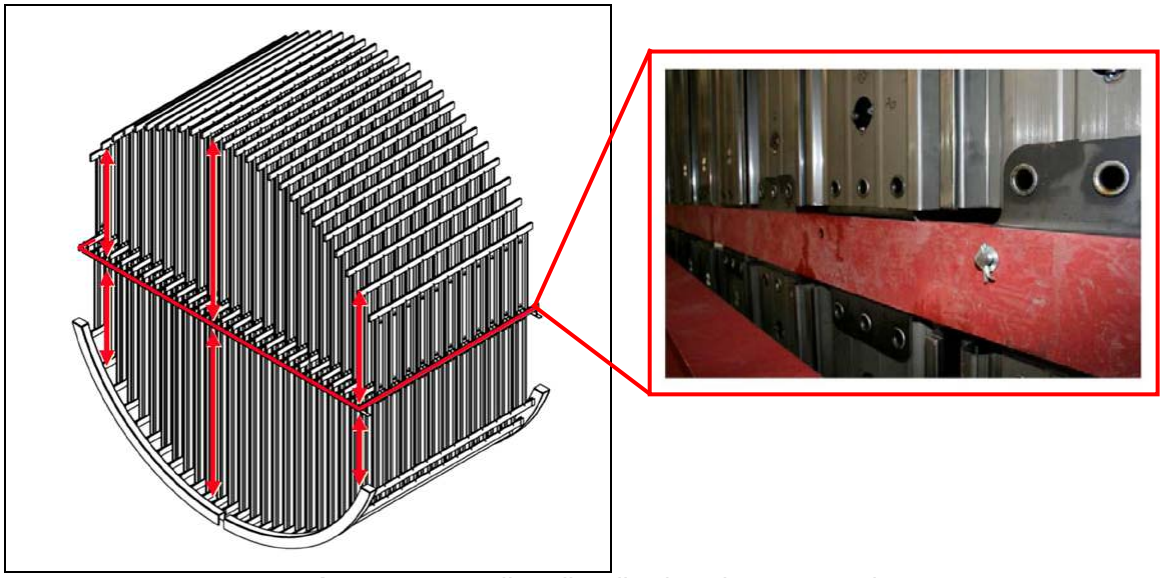

Figure 4. Centrally split collecting plate suspension.

1.5 Rapping system

In the SMS ELEX dry-type ESP, discharge electrodes and collecting plates are rapped mechanically. The two rapping units are not connected to each other and have separate drives. Each ESP field has one electrode and one plate rapping unit. Forged one-piece hammers are used in both rapping units. The company has been building these applied systems for 75 years and no hammer has fallen off or broken so far. This reliability makes the rapping systems unique and keeps operating and maintenance costs at a low level.
In addition to reliability, the plate rapping unit has yet another advantage: As the plates are not fixed to each other and the rapping bar design has been adapted, rapping effects have been optimized. One physical rapping with the rapping hammer ensures acceleration values in the entire plate wall which are in line with the experience of over 75 years. Systems with interlocked plates need two rapping system, one from each side of the field.
The SMS ELEX rapping system ensures optimized rapping effects to prevent dust from sticking onto the plates. Furthermore, the long-term experience with the system ensures reliability and correspondingly low operating and maintenance costs.

2 Hydro Hybrid Filter System

The new and patented Hydro Hybrid Filter System has been developed by SMS ELEX. The system is designed for upgrading existing BOF steel plants with an installed wet scrubber system so that they comply with the most stringent environmental regulations, while keeping the investment costs low.
The upgrade makes it possible to connect a wet-type round ESP between the existing wet scrubber and the switch-over station. The exhaust gas of the scrubber has a temperature of 70℃ and is fully saturated. T hese are optimum conditions for the wet-type ESP. The principle of dust precipitation is the same as in the dry-type ESP. The gas at the ESP outlet is directed into the further process of gas recovery system or in the flare stack as mentioned in the description of the dry-type ESP.

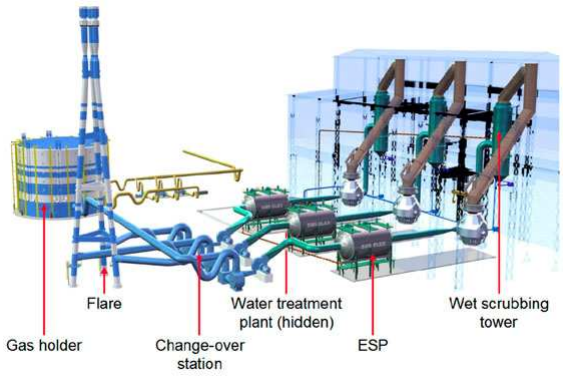

Figure 5. Hydro Hybrid Filter System.

Two main differences in construction compared with the dry-type system have to be mentioned. First, the collecting plates in the wet-type ESP are not split. The collecting plate walls are supported only in the upper supporting profile. The second difference is the cleaning of the internal parts. Instead of being rapped mechanically, the wet-type ESP is simply cleaned with water that is injected through nozzles located outside of the passages. In addition to this cleaning system, so-called “fog water” is injected at the beginning of each field in order to keep the collecting plates permanently wet.

2.1 Energy management with the Hydro Hybrid System

The Hydro Hybrid Filter System helps our customers to comply with the most restrictive environmental regulations and at the same time reduces the energy consumption of the entire system.

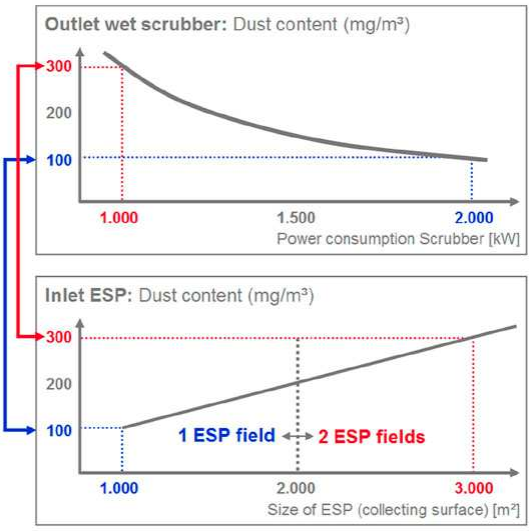

Figure 6. Energy management for existing BOF plants.

Case 1 (blue line)
The scrubber has a clean gas dust content of 100 mg/m³. Therefore, the pressure drop across the scrubber creates an energy consumption of 2,000 kW for the induced-draft fan (ID fan).
By connecting a 1-field wet-type ESP to the scrubber, a clean gas dust content of 10 mg/m³ can be obtained. The power consumption of the ESP has a minor impact on the total consumption, as only additional 75 kW are required.
Case 2 (red line)
Compared with case 1, the scrubber clean gas dust content is increased to 300 mg/m³ and accordingly the ID fans' power consumption is reduced remarkably by 50%. The following two-field wet-type ESP decreases the dust content in the clean gas to 10 mg/m³. The ESP power consumption of 120 kW is insignificant compared to the savings.
An optimized combination of scrubber and wet-type ESP can decrease the power consumption considerably while still complying with most stringent environmental regulations at very low investment costs.
This new Hydro Hybrid Filter System has following main advantages:

- Clean gas dust content of less then 10 mg/m^3
- Possible reduction in power consumption of 50% compared to stand-alone scrubber systems
- Can be combined with almost all existing wet scrubbers
- Existing water treatment of the scrubber can be used for the wet-type ESP without augmentation
- Low investment cost
- Short down-time of existing system during installation
- Wet-type ESP for final gas cleaning downstream of the gasholder is no longer required

3 Summary

The dry-type ESP and wet-type ESP of SMS ELEX comply with the official regulations regarding dust emissions. Operation and maintenance costs are reduced

thanks to the latest improvements in design. 75 years of ESP know-how guarantee a highly professional service for engineering, installation and after-sales.
Our second-generation dry-type ESP is preferably installed in new BOF plants or it is used for the modernization of existing BOF plants. The Hydro Hybrid Filter system is most likely to be installed for the modernization or upgrade of almost any kind of existing BOF scrubber system, at the same time ensuring very low investment costs.