MODERN BLAST FURNACE (BF) AND CONVERTER (BOF) GAS CLEANING – A REPORT OF STATE-OF-THE-ART TECHNOLOGY[1]

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Abstract

Since almost 15 years, Paul Wurth Umwelttechnik in Essen, Germany, is dedicated to blast furnace gas cleaning. The technology developed, applied and improved over the years is the so called Annular Gap Scrubbing technology. This wet gas cleaning technology, in combination with our patented Axial Cyclone development, represents a very efficient blast furnace gas cleaning. The axial cyclone is removing up to 85% of the dust in the BF gas. Compared to a standard dust catcher, which is still the main dry dust separation stage in the chain of BF gas cleaning, it is a significant increase in dust separation and leads to a minimized amount of dust separated in the wet stage. Less water consumption, higher energy output with TRT operation, and less valuable BF dust which has to be dumped are the logic consequences of this BF gas cleaning arrangement. This results in sustainable cost savings and reduces significantly the environmental impact. The dry dust can be recycled via sinter plant. The zinc fraction of the blast furnace gas which shall not be recycled to the blast furnace will be removed in the annular gap scrubber.

Key words: Environmental technology; BF and BOF gas cleaning; Annular gap scrubber; Axial cyclone.

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1 INTRODUCTION

The development of a modern gas cleaning technology started in the year 1970 with the first installation of an annular gap scrubber in Arbed steel plant, Esch-Belval, in south of Luxembourg (Figure 1).

Figure 1. BF A and BF B Arbed, Esch-Belval, Luxembourg, 1970.

Since that time, the technology was improved by Paul Wurth over the years based on customer needs and operational requirements. Design studies and process calculation in combination with the intensive exchange between operational and maintenance personnel lead to the present design. Today the state-of-the-art gas cleaning technology consists of an axial type cyclone, annular gap scrubber with external swirl type demister (Figure 2).

Figure 2. Gas Cleaning Plant AHMSA BF 6, 2010.

In the early 1970s most of the new and revamped blast furnaces were operated under higher pressure to increase the operational results. Due to this fact it was necessary to adapt the gas cleaning system in a way that besides the cooling and cleaning of the BF gas also the top gas pressure control function was enabled. The very common venturi scrubbers were not able to fulfill this function, and only in combination with an additional septum valve it was possible to ensure this pressure control. The combination of a venturi with internal movable cone, the so-called annular gap element, evolved into the ideal solution for the BF gas cooling, cleaning and top pressure control. High velocity inside the annular gap between the dust particles and injected droplets ensures the optimum separation of even finest particles. The shape of the inner cone and outer venturi (Figure 3) generates the possibility to make the top pressure control more precise compared to the old system with septum valve. Nowadays, most of the BF in the world are operating this system to achieve optimum BF top pressure control and cleaning to ensure the highest productivity of the blast furnace.

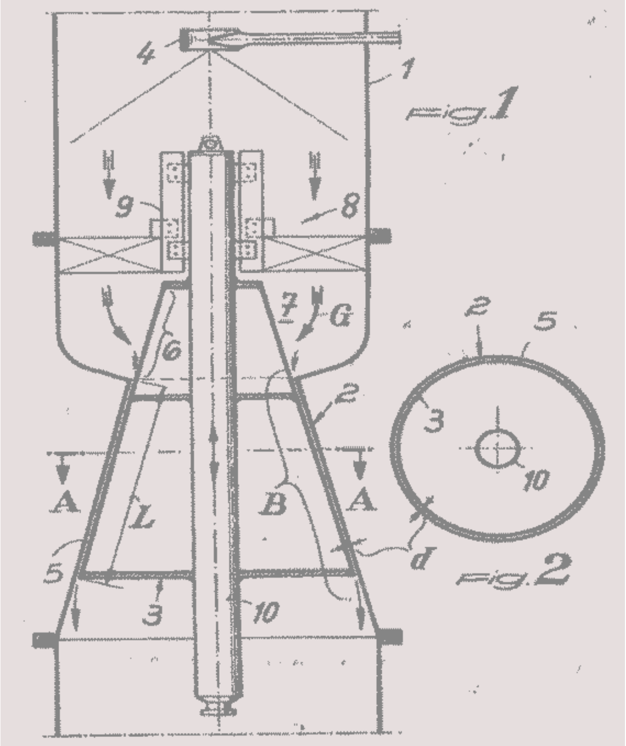


Figure 3. Annular gap element.

2 BF DRY AND WET GAS CLEANING STAGE

In 1999, Paul Wurth was able to take the next step for another improvement of the gas cleaning technology. The first installation of an axial type cyclone was made at ArcelorMittal Bremen at BF No. 2 (Figure 4). The axial cyclone substitutes the dust-catcher technology. It was possible to increase the separation of dust in the first gas cleaning step and to decrease the amount of sludge from the water treatment system of the next wet cleaning step.

Figure 4. Gas cleaning plant ArcelorMittal, Bremen BF 2, 1999.

The cyclone technology with tangential inlet was proven technology in several industrial fields and the main idea was to combine the advantage of the high dust separation of the cyclone with the structural advantages of a dust-catcher. With the axial inlet of the dust-catcher, it was possible to lead all the loads and forces coming from the down-comer pipe into the structure of the dust-catcher. With a tangential cyclone, it would be necessary to install an additional supporting structure so that these loads and forces can be compensated. The PW axial cyclone combined both, high separation efficiency and structural advantage. At the inlet of the axial cyclone, guide vanes are installed which produce the circumferential velocity of the gas to ensure the high separation efficiency of the dust. These guide vanes can be installed and maintained from the outside, where a platform ensures optimum accessibility.

Since 2008, another improvement was made by re-designing the inlet section of the axial cyclone (Figure 5). The two large inlet ducts required a certain height, and the shape of the bumped head was often difficult to fabricate if the necessary machines for bending were not available. The new conical inlet section (Figure 6) is much easier to fabricate and the height is reduced by 8 m. The separation efficiency of the cyclone will not be changed by this modification, but the weight and also the cost will be reduced by approx. 20 %. This new design is now in operation since spring 2012 for first time at BF 4 of SSAB Oxelösund, Sweden (Figure 7).

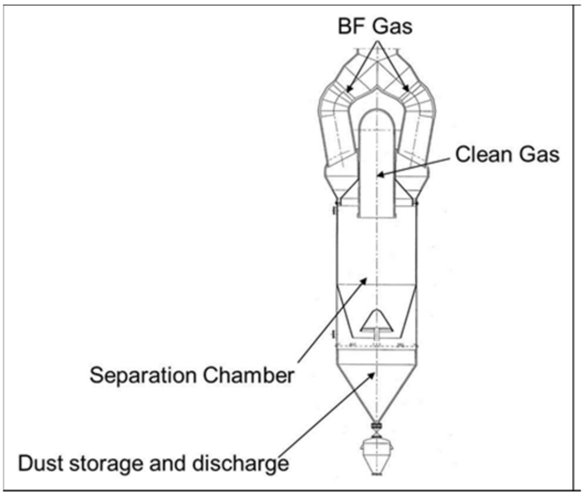


Figure 5. PW axial cyclone with inlet y-joint.

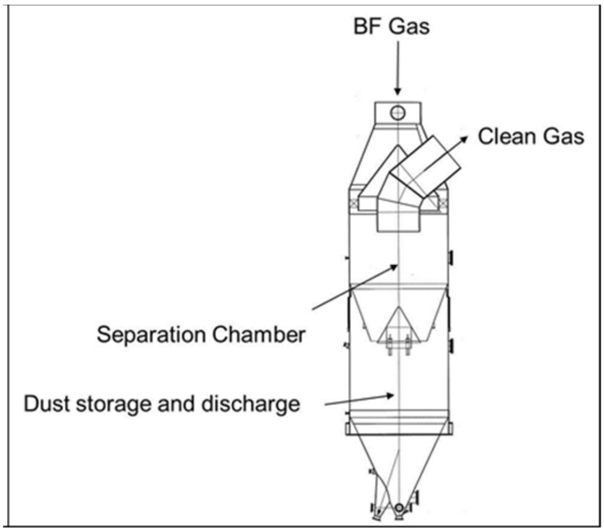


Figure 6. New conical inlet section.

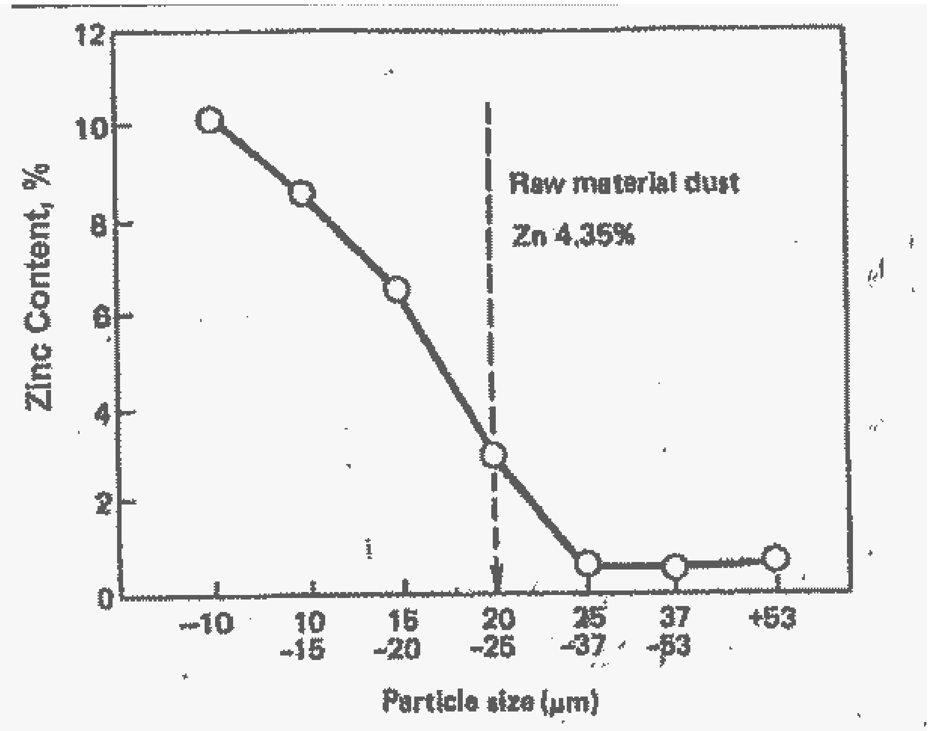
Figure 7. Gas cleaning plant SSAB, Oxelösund, BF 4, Sweden, 2012.

The higher separation of dust inside the cyclone is linked to the centrifugal forces and high circumferential velocities inside the cyclone compared to the dust-catcher technology. The higher velocities inside the vessel require a special protection of the surfaces inside the vessel. A dust-catcher is very often operated without any protection of the inner surfaces due to the low gas velocity, but the cyclone technology requires a protection of these surfaces in order to avoid wear.

The first installation in Bremen was entirely equipped with ceramic tiles which ensure, in general, long operational time, but made problems with high temperature fluctuation of the gas.

Wear resistant high alumina castable, in combination with ceramic tiles at appropriate locations, is the proven solution for this application. High temperature fluctuation can be compensated and the abrasion resistance is high enough to ensure long operation time. Installed by qualified personnel of the supplier, the material will last up to one BF campaign.

Since 1999, PW installed more than 30 cyclones which fulfill the customer needs to decrease the overall operational cost by improving productivity and lower material cost. Compared to the dust-catcher operation, it is possible to separate up to 85 % of the dust in the cyclone. The design of the cyclone is made in a way that only the particles which are not linked to Zinc and Lead are separated from the BF gas (Figure 8). These particles which are harmful for the blast furnace refractory lining are still transported to the wet cleaning step and will be separated there from the circulation.



Dependence of zinc content on particle size in the BF dry cleaning system dust at the Kokura Steel Works, Japan.[6]

Figure 8. Dependence of Zinc content on particle size.(1)

Compared to a dust-catcher, the shape of a cyclone is much thinner and smaller. This decreases the cost for the supporting structure and the foundation in case of a new installation or becomes possible to re-use the existing steel structure in case of a brown field installation. In both cases, the smaller diameter of the cyclone decreases also the storage capacity of dust to approx. 1 to 1,5 days. Due to the high flexibility of the cyclone technology it is possible to compensate this disadvantage by enlarging the lower dust storage section of the cyclone (Figure 9), so that it is possible to achieve the same storage time as for the bigger dust-catcher. Long storage times of more than 3 days can be performed in case of problems with the dust discharge or transportation.

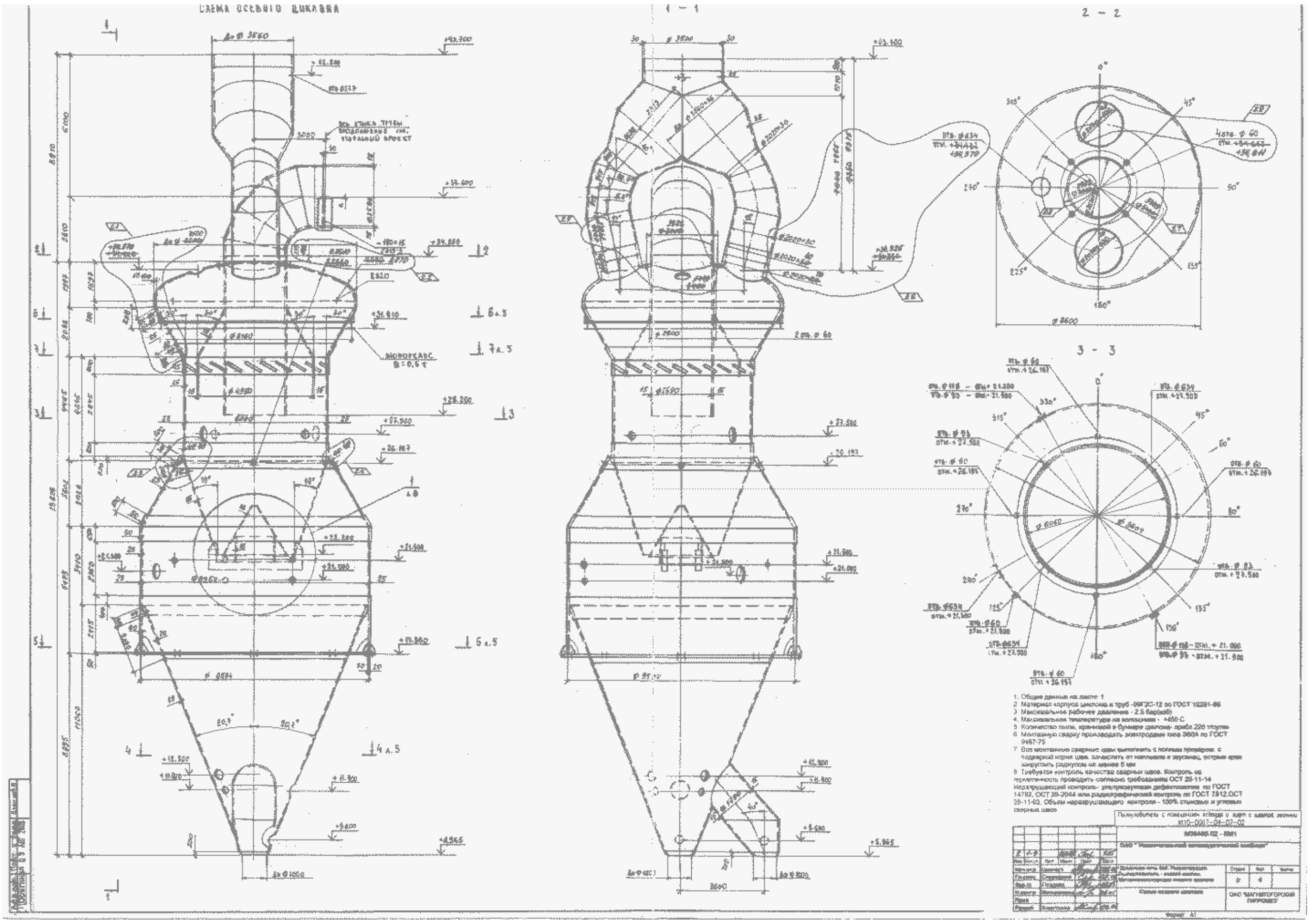


Figure 9. Axial cyclone with enlarged dust storage area.

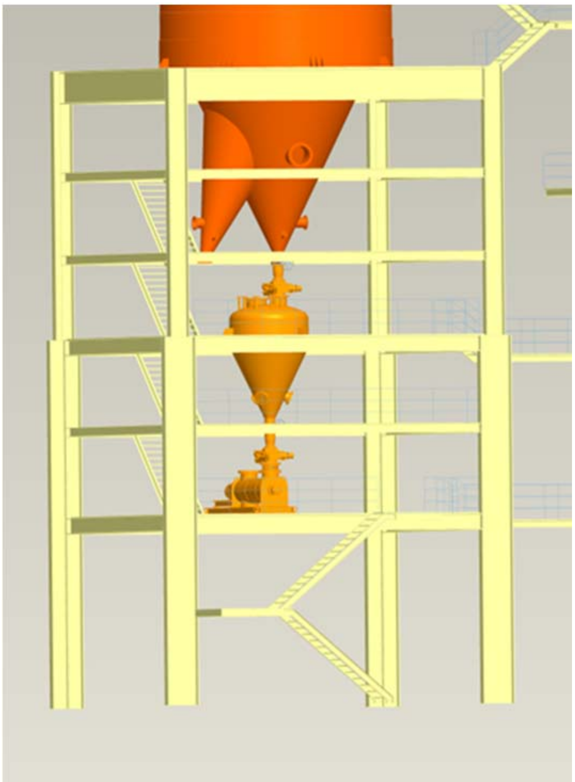


Figure 10. Dust discharge system.

Figure 11. PW GRITZKO Valve for dust discharge.

For the discharge of a high amount of dust separated inside the cyclone, it is necessary to have an automatic and very reliable dust discharge system (Figure 10). Below the cyclone the dust discharge will be made by means of an intermediate hopper and two automatic PW GRITZKO valves (Figure 11). The intermediate hopper works as a lock vessel where the dust will be purged and pressure reduction takes place before discharging to a pug mill with water spray. This ensures the emission free discharge of the dust into a rail truck or a lorry.

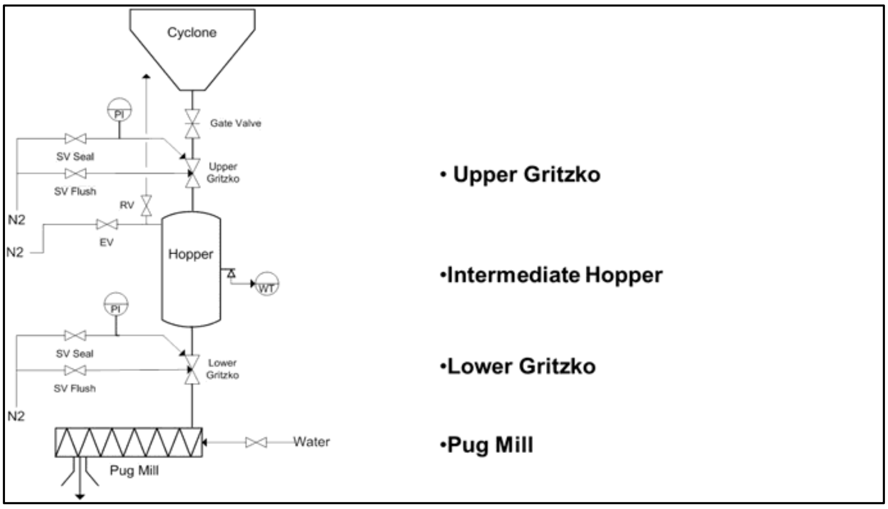


Figure 12. Schematic dust discharge system.

The higher separation of dust is not only an advantage for the dry cleaning step. If less dust enters the next wet gas cleaning step (Figure 13), less accretions and wear can be expected. Longer lifetime of all parts of the scrubber or water treatment plant can be expected which will reduce the cost for maintenance and spare parts.

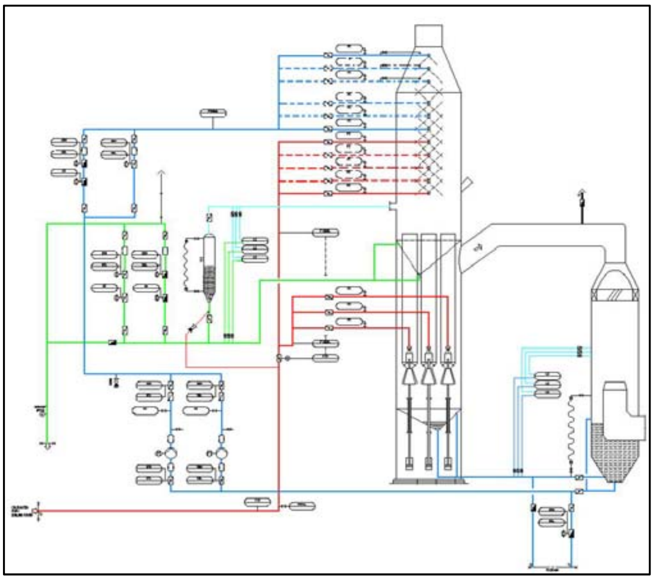


Figure 13. Water Circuit Wet Gas Cleaning Step.

In case of the operation with an axial cyclone it is possible to reduce the amount of injected water to the wet scrubber system. The water consumption required for the cleaning of the gas can be reduced by approx. 20 %. The lower amount of water enables the installation of a smaller thickener at the water treatment plant or to increase the retention time in case of an existing system. This will help to reduce the investment and operation costs.

The reduction of injected water will influence the cooling process of the gas and will increase the gas outlet temperature. In case where the gas passes a top gas recovery turbine (TRT), it is possible to generate approx. 2 % higher energy output.

To summarize the benefit of the installation of an axial cyclone for the complete gas cleaning system, the operational costs for a medium size blast furnace are listed hereafter (Table 1).

Table 1. Operational cost comparison dust-catcher vs. axial cyclone

BF data				
Top gas volume flow	m³./h (STP)	550.000		
Top pressure	bar, g	2,5		
Top gas temperature	°C	150		
Yearly operation	Days	340		
		GCP with Dust-catcher	GCP with Axial-Cyclone	Savings
				€/year
Dust Inlet content	g/m³ (STP)	15	15	
Efficiency	%	50	85	
Material to sinter plant	g/m³ (STP)	7,5	12,75	
Benefit	€/t	25	25	589.050
Amount of sludge	g/m³ (STP)	7,5	2,25	
Landfill	€/t	5	5	117.810
Required cleaning water	m³/h	1000	800	
Gas outlet temperature	°C	45	48	
Energy output TRT	MW	13,8	14,1	73.440
Energy cost	€/kWh	0,03	0,03	
			Total	780.300

3 BOF GAS CLEANING – THE LOGICAL NEXT STEP

The wet scrubbing technology on the basis of annular gap elements is not only state-of-the-art for blast furnace plants, but also applicable for basic oxygen furnace plants (BOF converter). In this case, the converter gas, which is generated by oxygen blowing process, is cleaned. The dust particles are removed from the gas flow significantly below dust concentrations of 50 mg/m³ (STP). The difference to blast furnace gas cleaning is that BOF gas is not continuously produced but with a higher temperature, only during the blowing period. The pressure drop necessary for the gas cleaning is generated by a fan which sucks the gas through the scrubber and demister. The converter gas is a high calorific gas and is normally stored in a gas holder for further processing or for heating purposes inside the steel mill. A typical 3D-scheme of a BOF converter primary gas cleaning is shown in Figure 14. The arrangement shows a plant which is installed at BOF shop 1 at ArcelorMittal Gent/Belgium. Three further installations (for three BOF converters) are nowadays under construction at the Arcelor-Mittal Temirtau works in Kazakhstan (Figures 15 and 16).

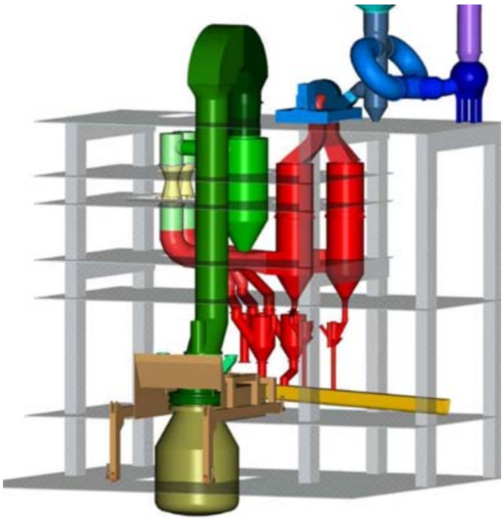


Figure 14. Typical 3D-scheme of a BOF Converter primary gas cleaning.

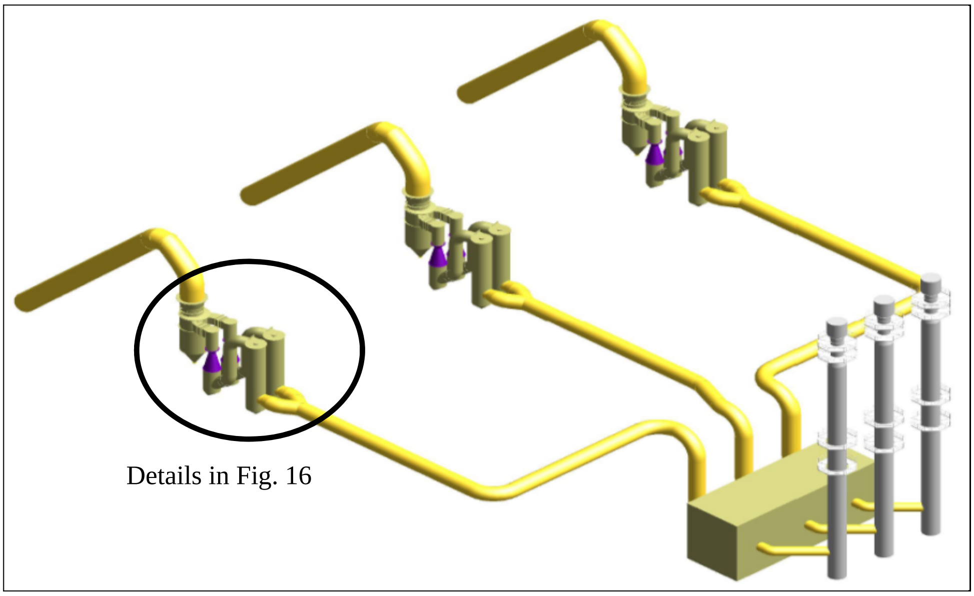


Figure 15. BOF gas cleaning of ArcelorMittal steel plant, Temirtau works, Kazakhstan.

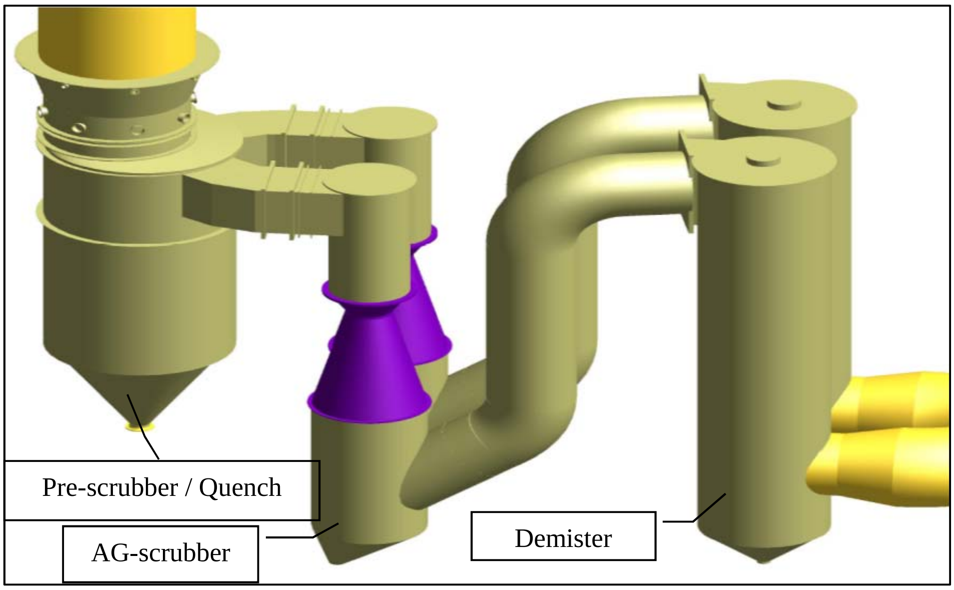


Figure 16. Plant items of the new AMT Kazakhstan Steel plant dedusting facility.

These three new BOF primary dedusting facilities will lead to a significant improvement of the environmental situation of the whole steel works. In a final step the BOF gas could be collected in a gas holder in order to improve the energy balance of the steel works (3 x 300 t converters with a gas cleaning capacity of 166.000 m³/h (STP) each.

4 CONCLUSION

Gas cleaning facilities based on the annular gap technology are widely spread over the world. In the recent 15 years, Paul Wurth Umwelttechnik installed almost 100 gas cleaning systems for BF and BOF operations which are fulfilling the given emission limits and contribute to a clean environment. The main advantages of this gas cleaning technology compared to other options are that there is a high flexibility and a wide range of possible inlet gas temperatures, corrosive gas components like chlorides and similar will be washed out with the water and are consequently no longer harmful to any kind of downstream installation or even to the ambiance. The annular gap technology is the ideal pressure control equipment for all sizes of blast furnaces. Both, gas cleaning and pressure control with the same plant equipment was a real breakthrough in the past.

A major gas cleaning step in particular for the blast furnace gas cleaning is the dry gas cleaning step based on the axial cyclone technology. The introduction of this kind of dust separation equipment has offered a real step forward in recycling of blast furnace dust back into the hot metal production chain and consequently has contributed to the reduction of water consumption and dumping of the residual dust. Furthermore, it has been shown that an axial cyclone can save significantly operation cost by the recycling of the dust (iron and coke/coal carrier), reduction of water consumption and an increased energy output if operating an expansion turbine (TRT).

REFERENCES

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