The Gas Suspension Absorber at Norcem's Brevik Plant

Steven W. Miller
Product Manager
Pyroprocessing Technology
FLSmidth Inc.
USA
steven.miller@flsmidth.com

Flemming Jensen
General Manager
Airtech, Air Pollution Control
FLSmidth A/S
Denmark
flj@flsmidth.com

1 Summary / Abstract:

In the cement industry many plants are looking for ways to reduce their gaseous emissions to comply with new environmental laws. Such is the case with the Norcem plant in Brevik, Norway, which committed to reduce emissions of sulfur dioxide (SO_2) by 400 tons per year. This is part of the Gothenburg Protocol, an objective to reduce overall industrial sulfur emissions in Norway by 5,000 tons by the end of the year 2010. To accomplish this, a semi-dry scrubber system called a Gas Suspension Absorber (GSA) was purchased in 2009 and installed in early 2010 as an alternative to a more costly wet scrubber. The GSA system has been commissioned and optimized during 2010 and initial test results indicate that the Brevik plant will achieve their new emissions targets for SO_2, as well as reducing emissions of hydrochloric acid (HCl) and hydrofluoric acid (HF). The plant is also well positioned to reduce mercury emissions in the future with the addition of shuttling or wasting dust from the dust collector after the GSA. This paper will review the details of this project and the results that were attained.

2 Introduction

Norcem AS, part of HeidelbergCement since 1999, owns the only two cement plants in Norway, one located at Kjøpsvik and the other at Brevik. The Kjøpsvik plant is located near the Arctic Circle and has the distinction of being the northernmost cement plant in the world. The Brevik plant (Fig. 2-1) is located approximately 40 kilometers southwest of the city of Oslo and has been in operation since 1916. The Brevik plant's annual cement production of 1.3 million t/yr is produced by a single kiln line with a rated capacity of 3500 tpd. The plant produces three types of clinker and seven types of cement that it sells on the market.

The present kiln system at Brevik was initially installed in 1966. It was upgraded to a twin preheater with an in-line calciner in 1998 and the calciner was further modified in 2004 to its present state. The twin preheater tower has two separate downcomers each with a gas conditioning tower to control the gas temperature as required and an ID fan. The gas from one preheater tower is taken to the raw mill system while the gas from the other preheater tower is partially taken to the coal mill with the remainder vented separately. The dust collection for the gas from each tower is handled in a separate electrostatic precipitator followed by a bagfilter. The bagfilters were a later addition to the plant to achieve a lower particulate emission.

As part of the Gothenburg Protocol, an objective in Norway to reduce overall industrial sulfur emissions by 5,000 tons by the end of 2010, the Brevik plant needed to look at methods to reduce their SO_2 emissions. The plant uses two different raw mixes in order to make their three different clinker types. One of the raw mixes produces a negligible SO_2 emission, while the other raw mix can produce an SO_2 emission up to 400 mg/Nm^3 dry. Therefore, the plant required a technology that would only need to be used part of the time when they operated with the high SO_2 raw mix.

After reviewing potential technologies, the plant decided to install FLSmidth's Gas Suspension Absorber (GSA) technology. Norcem AS was already familiar with this technology as they had purchased a GSA in 1991 for installation at the Kjøpsvik plant in the kiln bypass system for SO_2 emission control. At the time it was the only operating GSA in the global cement industry.

Fig. 2-1: The Norcem Brevik Plant

3 Semi-Dry Scrubber Technology

Similar to a wet scrubber, a semi-dry scrubber uses a combination of water and sorbent injection to achieve a reduction of certain gaseous pollutants. However, unlike a wet scrubber, which operates at a temperature near the water dew point and has a wet bottom, a semi-dry scrubber operates at a temperature above the dew point such that all water injected evaporates and exits the system with the gas stream. There are a number of suppliers of semi-dry scrubber technology with the differences between the suppliers being mainly the details of the system layout and the type of sorbent used.

Fig. 3-1 shows a typical semi-dry scrubber system. Process gas enters at the bottom of the scrubber and flows upward through the reactor. At the bottom of the reactor the gas passes through a venturi-like section to increase the gas velocity before entering the reactor. In this section lime slurry is injected as an absorbent through an air atomized nozzle. In the reactor, the gas velocity is reduced such that the absorbent flow behaves like a fluid bed reactor.

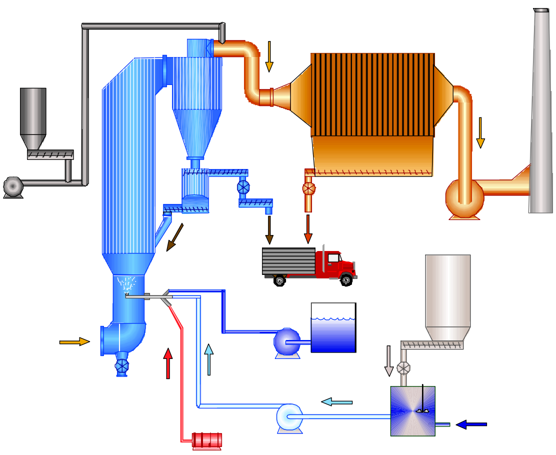

Fig. 3-1: Semi-dry scrubber system

Fig. 3-2 shows how the gas and lime interact within the reactor. In the reactor the lime comes in contact with gaseous pollutants such as SO_2, HCl, HF, and mercury and captures them. At the exit of the reactor is one or two cyclones (depending on the gas flow volume), which removes most of the entrained dust and absorbent from the gas stream. The cyclone catch is conveyed to a bin which circulates the material back into the reactor. The recirculation rate to the reactor is controlled by a screw conveyor at the bottom of the bin, while a screw conveyor at the top of the bin removes overflow material, which is either wasted or returned to the system depending on the pollutant being removed and the overall material balance. In this manner, the absorbent can be recycled through the reactor up to 100 times to maximize its absorption potential. After the cyclone, the gas flows to a dust filter, which collects the remaining entrained dust for disposal or return to the system. A fan located after the dust collector controls flow through the semi-dry scrubbing system at a constant rate.

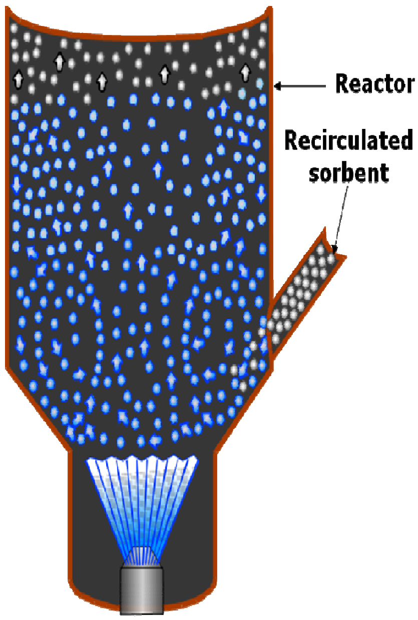

Fig. 3-2: Flow in reactor

The absorbent can be burnt lime or hydrated lime and is typically stored in a bin when received at the plant. The bin feeds a water tank which slakes the lime and produces lime slurry for feed to the reactor. Compressed air and any needed make up water is also added to the lime slurry before it enters the reactor through a single air atomized nozzle as shown in Fig 3-2. As an alternate to feeding lime slurry in the semi-dry system, the water spray and lime addition can also be done independently. This is useful in cement applications where the preheater gas is used in the raw mill and the semi-dry system is located downstream. In this other case the temperature entering the semi-dry system is already quite low (typically 80-95^{0}C) when the raw mill is running and there is limited ability to spray water while still injecting lime for scrubbing.

In a cement plant there is some flexibility with locating the semi-dry scrubbing system. It can be used as a tail pipe solution after the main filter, it can be located in line between the raw mill and the main filter, or it can be located in the raw mill bypass. The best place for a given plant will depend on layout (i.e. where there is room to place the system) and how much the gas needs to be conditioned. For example, does the semi-dry scrubber system need to run 100% of the time or only when the raw mill is down? The semi-dry scrubber system is compact and does not require much room to fit it into an existing plant. A typical system layout can be seen in Fig 3-3.

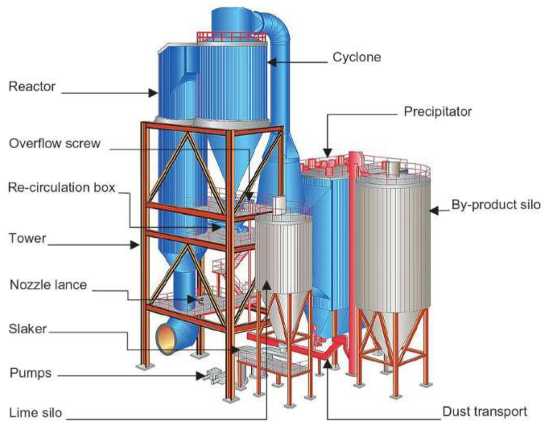

Fig. 3-3: Semi-dry scrubber layout

Depending on the initial concentration, the semi-dry scrubber system is capable of reducing SO_2, HCl, and HF emissions by 95+% and mercury emissions by 80+%. If additional mercury reduction is needed, activated carbon can be injected in the duct after the cyclone as shown on the left side in Fig 3-1 to achieve an even higher mercury reduction of 90+%.

4 Project Highlights

As there are two separate gas streams from the kiln system, it had to be decided if two separate semi-dry systems were needed to be installed. Because one gas stream goes through the raw mill system, which is a natural SO_2 scrubber, it was decided to only install a semi-dry scrubber system in the gas stream that did not go through the raw mill. In Fig. 3-4 it can be seen how the new semi-dry scrubber system is located in between the existing electrostatic precipitator and bagfilter.

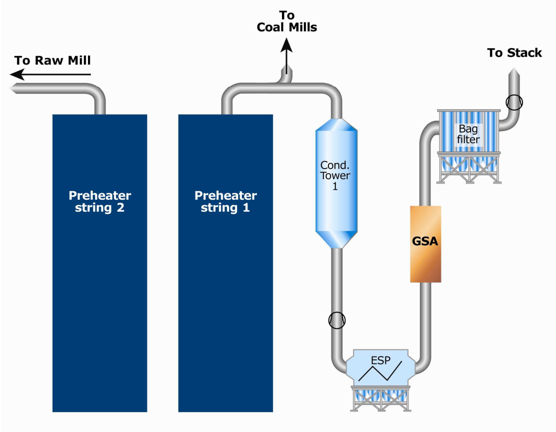

Fig. 3-4: Preheater gas layout

Table 4-1 shows the process design criteria for the semi-dry scrubber system.

	Unit	Normal	Interval
Inlet Flow	Nm^3/h, wet	200,600	150,000-205,000
Inlet Temp	^0C	160	130-175
Water	Vol%, wet	16	14-18
O_2	Vol%, dry	9	8-10
SO_2	mg/Nm^3 dry	400	≤500
HCl	mg/Nm^3 dry	20	≤60
HF	mg/Nm^3 dry	3	≤80

Table 4-1: Semi-dry Scrubber Design Criteria

The scope of the project includes the complete semi-dry scrubber system (reactor, two cyclones, recirculation bin, lime/water mixing tank, and lime slurry spray system) and a new booster fan to handle the extra pressure drop across the system. For the burnt lime storage an existing 60 ton silo was used. Based on the process design criteria the reactor dimensions are 3.65m diameter x by 14.2m tall and the two cyclones are 4.0m in diameter. The new equipment sizes for the lime slurry injection system include a 2.0 m^3 slurry tank and a slurry injection system rated for 800 liter/hr.

The contract for the semi-dry scrubber system became effective in April 2009 and included a schedule of approximately one year from contract to start up. As equipment was shipped and received at site, much of the erection could be done while the existing plant remained in operation. Only a 17 day system shutdown was required to connect the new equipment to the existing plant and in April 2010 the semi-dry scrubber system was commissioned.

5 Results and Discussion

The commissioning and optimization of the semi-dry scrubber system went smoothly. The only significant issue encountered was difficulty in generating the desired density of the circulating load in the reactor. The fineness of the raw meal dust and absorbent were such that the efficiency of the collection cyclone after the reactor was lower than expected based on previous experience. The lower material circulation would potentially result in reduced cooling capacity and lower scrubbing efficiency. The solution to this issue is to recirculate a portion of the dust captured in the bagfilter back to the semi-dry scrubber system. To accomplish this, a conveyor that collected dust from the gas conditioning tower, electrostatic precipitator, and bagfilter was tapped into and a portion of this dust was transported back to the dust recirculation bin. This modification allowed the reactor to operate with the proper material circulation and improved its performance.

In November 2010 a series of measurements were made to determine the performance of the semi-dry scrubbing system. The average results obtained from these measurements can be seen in table 5-1 below.

	Unit	Value
Inlet Gas Flow	Nm^3/h wet	153,775
Inlet Gas Temp.	^0C	163
Outlet Gas Temp.	^0C	88
Outlet O_2	%Vol. dry	9
Inlet SO_2	mg/Nm^3 dry	405
Outlet SO_2	mg/Nm^3 dry	10.8
Outlet SO_2	ppmv dry @ 7% O_2	4.4
Inlet HCl	mg/Nm^3 dry	34
Outlet HCl	mg/Nm^3 dry	1.6
Outlet HCl	ppmv dry @ 7% O_2	1.2
Lime Usage	kg/h	74

Table 5-1: Test results

From the test results it can be seen that the semi-dry scrubbing system reduces the SO_2 emissions by 97.3% and the HCl emissions by 95.2%. In comparison, the performance guarantee for emissions reduction for SO_2 given by the equipment supplier was 93.8% (from 400 to 25 mg/Nm^3 dry). Note that HF was also measured during the testing; however, the level was below detection limits at both the inlet and outlet.

The average lime usage shown above from the testing is based on $Ca(OH)_2$ with 100% purity on a dry basis. This translates to a normalized stoichiometric ratio of lime to scrubbed SO_2 and HCl of 1.2. During the testing the actual lime used had a purity of 95% and the lime slurry injected into the reactor was an average 24% $Ca(OH)_2$ by weight.

Mercury emissions are not measured at the plant during normal operation; however, a mercury emissions test was performed in February, 2011 to evaluate the potential of the semi-dry scrubber to reduce mercury emissions. Mercury sorbent pots were used to measure the mercury emissions before the semi-dry scrubber as well as in the main stack. The results of three separate trials made during the testing are shown in table 5-2. It can be seen from the results that the mercury emission was reduced by an average of 93% by the semi-dry scrubber. In order to maintain or even improve on this reduction level continuously, the plant would need to start shuttling some of the main filter dust to the finish mill system. These results show that the plant is in a good position to control emissions of mercury in the future if their environment regulations become more stringent.

	Unit	Trial 1	Trial 2	Trial 3
Inlet Gas Flow	Nm^3/h wet	162,500		
Inlet Gas Temp.	^0C	161		
Stack Gas Temp.	^0C	85		
Inlet Hg	µg/Nm^3 dry	2.01	22.8	6.38
Stack Hg	µg/Nm^3 dry	0.14	0.66	0.71
% Hg reduction	%	93.0	97.1	88.9

Table 5-2: Mercury test results

6 Conclusion

To date the semi-dry scrubber system installed at this plant has exceeded its designed performance, achieving 97.3% reduction of SO_2 emissions and 95.2% reduction of HCl emissions. It has proven that it can achieve reductions in SO_2 and HCl emissions that are similar to what can be achieved in a more expensive wet scrubber system.

In addition, the semi-dry scrubbing system also gives the plant the capability to reduce mercury emissions as environmental regulations become more stringent in the future.