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NOx REDUCTION IN OPOLE POWER PLANT

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Abstract

In 2016, Polish NO_X *emission regulations require nitrogen oxides emission reduction below 200* mg/Nm^3 *(at 6%C>2) under the large combustion plant directive (LCPD). Reaching this level of* NO_X *emissionswith application of traditional primary measures and selective non-catalytic reduction (SNCR) systems while keeping the same efficiency of electric power production is practically impossible. Alternative, traditional secondary method i.e. SCR technology (selective catalytic reduction) is prohibitively expensive. Due to a large number of boilers in Poland that must be below 200* mg/Nm^3*, some plants have taken action to find a solution which is technically proven, as well as attractive in terms of capital and operational costs.*

In 2008 PGE Elektrownia Opole ordered a "turn-key" retrofit execution of the combustion system to reduce NO_X emission at BP-1150 boiler. The project included modifications of burners as a first stage, and then ROFA system installation for combustion optimization and primary reduction of NO_X, and Rotamix system installation for the further, secondary NO_X reduction. The condition to install ROFA and Rotamix systems was keeping the same parameters of the power unit operation, in particularCO emission level, fly ash LOI and bottom ash LOI, ammonia slip, ambient noise, boiler availability and efficiency, material wastage rate, steam flow rate and temperature, as well as consumption of urea, water, electricity and compressed air. The work for this project was performed by a consortium that included Nalco Mobotec, Remak-Rozruch (a Consortium Leader) and SEFAKO.

Furnace and Boiler Description

This BP-1150 RAFAKO tower boiler normally operates between 180 and 380 MWe. The boiler operates at subcritical steam parameters: steam temperature 545°C and pressure 18.7 MPa rated at 1170 t/h of steam. The furnace system includes five pulverizers that feed ten burner levels. As a result ofpre-modernization operational tests, two operational limits were found:(1) an electric output limit for the steam turbine - generator, and (2) flue gas fans (ID fans) capacity limit if the furnace O2 value went above 4.5% at full boiler load. There are three air pre-heaters; two are used for secondary and over-fired air, and one is used for primary air supplied to the mills to dry and transport coal. The boiler had overfire air (OFA) and separated overfire air (SOFA) nozzles installed prior to ROFA project. The existing OFA system was retained during the installation of ROFA system, but OFA nozzles were replaced with new redesigned ones. The existing SOFA system was completely removed and replaced with ROFA system.

The basic fuel is coal which comes from as many as 18 different mines. In addition the biomass is cofired by mixing biomass and fuel with the coal in the fuel yard. Max. up to 8% of the fuel (by weight) can be biomass.

ROFA system

The ROFA system was installed to create the volumetric combustion which enables deep air staging and at the same time a significant reduction of NOx formation. The ROFA system has been designed to increase mixing in the upper furnace for CO an LOI burnout. The ROFA system includes a boosted-pressure ROFA fan (photo 1), interconnecting air ducting and air injection nozzles. The ROFA air is taken from the air preheater discharge. The air pressure at ROFA nozzles is selected to obtain optimum mixing in the furnace. All air flow to ROFA nozzles is controlled based on a relationship to boiler steam flow, to maintain tuned pressure in windboxes as load changes.

The ROFA system consists of a variable frequency drive (VFD) controlled centrifugal fan. The ROFA fan sucks the air from two air preheaters with two individual ducts (photo 1). Each duct has a venturi flow meter to allow the boiler control system to account for air flow through the ROFA system. Extensive on-site investigation swere carried out

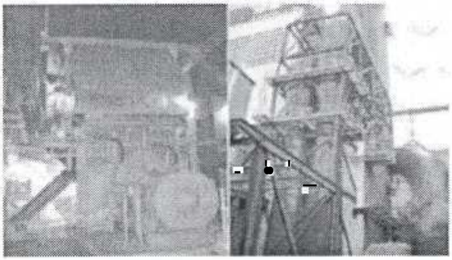

Photo 1. ROFA fan (left) and its suction and discharge ducwork

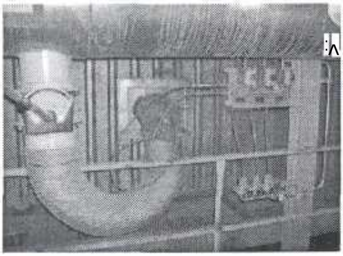

Photo 2. Rotamix nozzle with the injection of air, diluted urea and humidification water

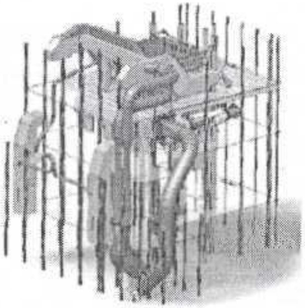

Fig. 1.3D representation of ROFA ducts

to determine the most efficient and cost effective way to direct the secondary air to the upper furnace ROFA ports. The ROFA air suction and discharge duct routing was meticulously planned particularly in furnace walls adjacent areas (fig. 1).

Rotamix system

The Rotamix system consists of air delivery system and liquid (urea and water) delivery system. The air delivery system contains a small air fan and ductwork similar to ROFA, but much smaller in diameter. As Rotamix system utilizes ambient temperature air it eliminates the need for ductwork thermal insulation. There are a few Rotamix ports levels, including the nozzles placed in the gaps in the wall superheater bands, and nozzles in the upper furnace between the platen superheater bands. Granulated urea is delivered to site and loaded into a storage hopper through pneumatic conveying. The diluted urea mixture is created by batch-mixing pre-calculated doses of urea and water in a day tank. The diluted urea is then distributed to multiple furnace injection ports via variable-speed pumps. The variable speed feed rates are controlled individually as a function of boiler load. Any number of injection sites can be individually activated using solenoid valves. An air purge of urea delivery line and spray nozzle is performed whenever an injection device is taken out of service. In addition to the diluted urea, humidification water is delivered to each injection device that is in service - in practice water is not used at all. A humidification water storage tank supplies water to the humidification water pumping system. The tank is supplied with water from the existing plant domestic water supply system.

The humidification water system adds additional control and tuning capability to the Rotamix system, as urea injection concentrations can be manipulated to compensate for furnace flow anomalies.

System performance

Nitrogen oxides (NO_X) emission

Before modernization the boiler with SOFA system emitted between 350 and 500 mg/Nm^3 of NO_X (fig. 2, green open symbols). The data on these emissions come from the period between December 13 to 19, 2009 and are considered as baseline data indicative of for the boiler normal operation before the retrofit. In order to keep LOI (in fly ash) and CO manageable, the amount of air through the SOFA system was low (only ca. 13% of TAF) and this did not create a sufficient sub-stoichiometric burner zone for de-NO_x, leading to higher than expected NO_X emissions with SOFA system application.

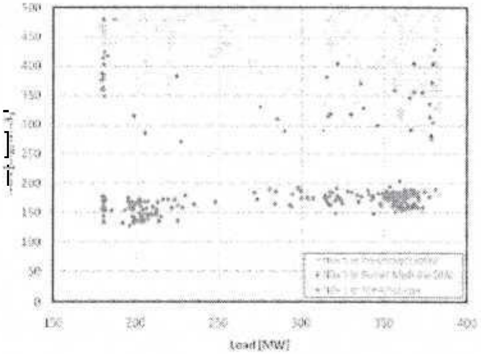

Fig. 2. One-hour NO* data (average) plotted versus load for boiler operation before modernization with SOFA system (green), burners modifications (blue) and

Fly ash LOI

Fig. 3 plots fly ash LOI data for Unit 3 (with ROFA/Rotamix), as well as the other three units in Opole not fitted with ROFA/Rotamix system. The goal is to keep LOI below 5% to maintain ash sales. For most days this is the case, with several samples slightly higher than 5%. The average LOI value for fly ash over the ten-day

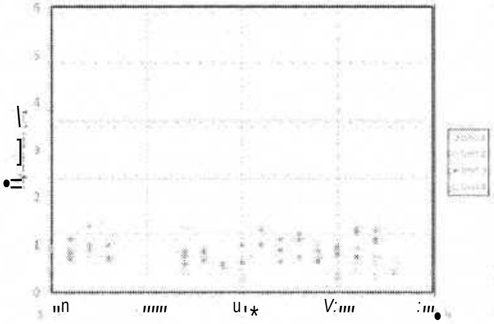

Fig. 3. Fly ash LOI from boiler 3 (ROFA/Rotamix) and three other boilers ROFA/Rotamix systems in service (red)

test period was 3.5%, meeting the project LOI requirement. Good mixing in the upper furnace allowed to achieve low LOI values in fly ash.

O2content

In Fig. 4 the measured oxygen in the furnace is plotted versus load. Excess oxygen at low load is required to maintain SH and RH temperature. Excess oxygen at high load is only required to maintain the combustion efficiency. Lower excess oxygen typically leads to high LOI and CO with application of the traditional primary methods. Due to the mixing provided by ROFA system the excess oxygen is reduced in the furnace. This is beneficial for two reasons. First, NO_X concentration is much lower,with lower furnace O2. Secondly, the boiler efficiency is improved. It is clear that O2 level in the furnace has been reduced by'almost 1% (from 3.7 to 2.6%). This results in 5% less TAF and improves the boiler efficiency (through reduced stack loss), as well as reduced FD fan amps, ID fan amps and air preheater leakage.

The trends are similar for both cases. Peaking at full load where there is shorter residence time and less excess oxygen to promote CO burnout. There were spikes of higher CO with the ROFA case, but this will be tuned during ongoing optimization.

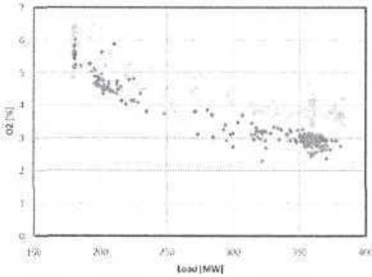

Fig. 4. Average 5-minute 02 data plotted versus load before retrofit (green) and for the boiler with ROFA/Rotamix system (red).

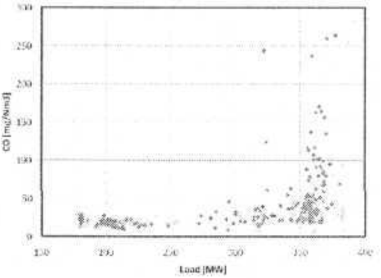

Fig. 5. Average 5-minute CO data plotted versus load before retrofit (green) and for the boiler with ROFA/Rotamix system (red).

Rotamix SNCR Analysis

Because Rotamix was never out of service during the ten-day test, it is not possible to verify the actual SNCR NO_X reduction. In fig. 7 the urea flow rate and ammonia (NH3) slip are plotted versus load. The average NH_3 slip for the entire 10-day test period was 3.1 ppm. The urea flow rate is the highest at low load. Fewer injection ports are used at low load and these ports spray urea directly into the open furnace. Proportionally more urea can be used at low load resulting in better NO_X reduction without the concern for NH3 slip. During tuning it was observed at low load that Rotamix system reduced NO_X by more than 50%. At low load the ammonia slip is below 1 ppm. The normalized stoichiometric ratio (NSR) for urea from design data is estimated to be ca. 2.0 for loads between 180 and 230 MW. For loads between 330 MW and 380 MW, the primary Rotamix injection points are located in the SH platens region and are subject to rapid cooling. In this region, less NO_X reduction is possible (i.e., 20% to 30%) and slip is the primary limiting factor. When the one-hour average load was over 330 MW, the average ammonia slip was 4.8 ppm. The urea usage rate is much lower at high load and the NSR is estimated to be between 0.8 and 1.0 for the load over 330 MW. This can result in a significant chemical savings compared to other SNCR systems.

Ammonia content in ash and gypsum

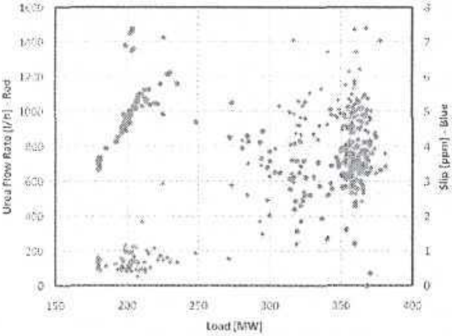

Fig. 6. Urea consumption and ammonia slip versus load

After urea injection into the boiler, urea reduces NO forming N2. Excess of unreacted urea is carried by flue gas. This effect colloquially called ammonia "slip" must be controlled as ammonia can be absorbed by ash particles or may pollute gypsum which is produced in the wet flue gas desulphurization plant. Therefore the ammonia content measurements in exhaust flue gas are performed Ammonia content shall be limited to values which assure that both combustion by-products i.e. ash and gypsum will retain their sale values. In table 1 the average values of ammonia content are presented and test run measurements performed every day.

Table 1. Ammonia in ash and gypsum - average values

		Min.	Average	Max.	Deviatin
Slag NH_3	fmg/kgl	1.7	2.3	3.2	65%
Ash NH_3	[mg/kgl	29	35	44	43%
NH3 in gypsum (produced)	[mg/kg]	9.2	9.8	10.7	15%
NH3 in gypsum (shipped)	fmg/kg]	8.1	8.6	9.5	16%

The ammonia content in slag is very low (2.3 mg/kg), because Rotamix-SNCR system is located in the vicinity of the furnace outlet. Ammonia content in fly ash was higher, 3.5 mg/kg on average. The limit value mandatory in Poland, which is 50 mg/kg, was never exceeded during the 10-day test run. Gypsum produced in WFGD plant is then flushed to remove chlorides. This operation also removes ammonia. During the test run the ammonia content in gypsum was 8.6 mg/kg on average, that is below the permissible limit of 10 mg/kg.

* * *

To sum up, ROFA and Rotamix system applied at BP-1150 boiler in PGE Elektrownia Opole guarantees:

1. NO_X emission much below 200 mg/Nm^3 (average 168 mg/Nm^3) in the entire range of boiler load while keeping the output and steam parameters.
2. Low NO_X emission while firing various coals with low fly ash LOI value (3.5% on average) and low CO level (41 mg/Nm^3 on average),
3. Very effective utilization and at the same time low consumption of ammonia used for secondary reduction with low ammonia content in outlet flue gas (3.1 ppm on average),
4. No ammonia contamination of ash; keeping the average fly ash ammonia content at 35 mg/kg, i.e. below the permissible limit of 50 mg/kg.
5. No ammonia contamination of gypsum keeping the average gypsum ammonia content at 8.6 mg/kg, (i.e. below the permissible limit of 10 mg/kg).

"Achieved NO_X reduction was between 52% to 66% compared to the level before retrofit"

Summary

Nalco Mobotec Rotating Opposed Fire Air (ROFA®) and Rotamix-SNCR system was installed at BP1150 boiler at the power unit no. 3 in PGE Opole

Power Plant to reduce NO_X emission to the level below 200 mg/Nm^3. PGE Opole has selected the technology of Nalco Mobotec after the prior thorough analysis of traditional methods, both primary and secondary, previously applied in the power industry. ROFA system was selected to demonstrate the capability of deep NO_X reduction by means of the primary measures without the necessity to apply costly SCR technologies (selective catalytic reduction). It was also allowed for the slight support of the primary method with cheap secondary one, i.e. selective non-catalytic NO_X reduction. The BP-1150 boiler retrofit included three stages: (1) the analysis of the existing combustion system in operation, mechanical and capacity terms leading to modification and retrofit of windboxes and burners; (2) the existing SOFA system was replaced with Nalco Mobotec ROFA system; and (3) Rotamix SNCR system was installed which introduced urea into the upper furnace.