# SCR RETROFIT FOR $NO_X$ REDUCTION EXPERIENCES IN CHINA & POLAND TWO COUNTRIES WITH COAL AS DOMINATING FUEL *SOURCE*


## Abstract:

The key focus of this paper are the following topics:

- solutions to retrofit an SCR system into an existing boiler with limited space;
- key requirements to ensure high performance and safe operation;
- comparison of honeycomb and plate type catalysts in a long-term perspective;
- anhydrous ammonia, ammonia water and urea, which reagent to choose;
- catalyst testing and optimized management to reduce operation costs.

These topics are outlined in case studies of SCR systems in successful long-term operation. The market penetration of the SCR technology in these coal dominated countries reflects the fulfilment of the strict government requirements.

The case studies specifically pay attention on the challenges of retrofitting a high performance DeNOx technology into a coal fired boiler during operation, with minimized boiler shut down period. They also highlight important design factors and technical solutions to ensure reliable operation with low maintenance needs and cost.

Furthermore, a comparison of honeycomb and plate type catalyst is discussed to highlight the advantages and risks of each technology under long time operation. Special attention is paid on the impact on the overall plant behaviour and the reuse of old catalyst.

In addition, Yara as one of the world largest ammonia/urea producer, will propose advantages and disadvantages of anhydrous ammonia, ammonia water and urea as reagent – specifically for the SCR use. Special attention is paid to the operational aspects, such as handling and safety.

Catalyst testing is key to ensure an optimized management strategy and – as a result – reduced operation cost. The paper will also examine the most important catalyst deactivation mechanisms and demonstrate strategies on how to remove these impacts to recover original plant performance.



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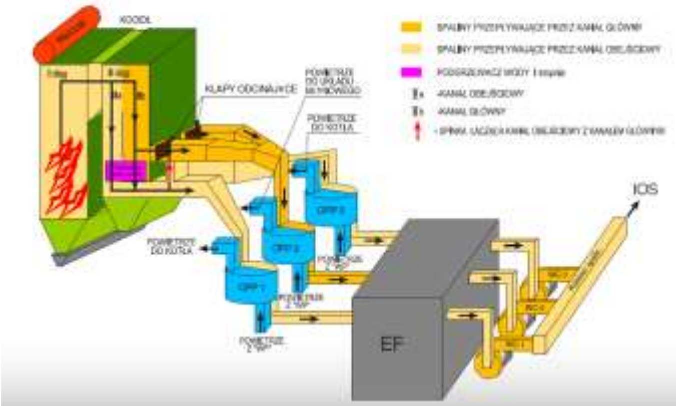
## 1. CASE STUDY LAZISKA (POLAND)
## INTEGRATING AN SCR IN THE 2ND BOILER PATH

2010 an DeNOx retrofit project was started to ensure all 4 boilers (original build in 1969) of TAURON Wytwarzanie S.A. in Laziska (*Picture 1*) fulfil the NOx regulations before 2016. The boilers are fired with hard coal and the SCR High Dust technology was chosen as best solution in addition to the existing low NOx burner and OFA.

As space is limited, the SCR was integrated in the 2nd path of the boiler. To ensure the optimum temperature window for the catalyst the existing ECO was split into two parts and the reactor have been installed in between. The reactor design consider 2 original catalyst layers and ½ spare layer for future installation on top of the second layer. Each layer is further equipped with sonic horns to keep the catalyst clean. No steam blowers have been installed as plate type catalyst have been selected and hard coal is used as fuel.

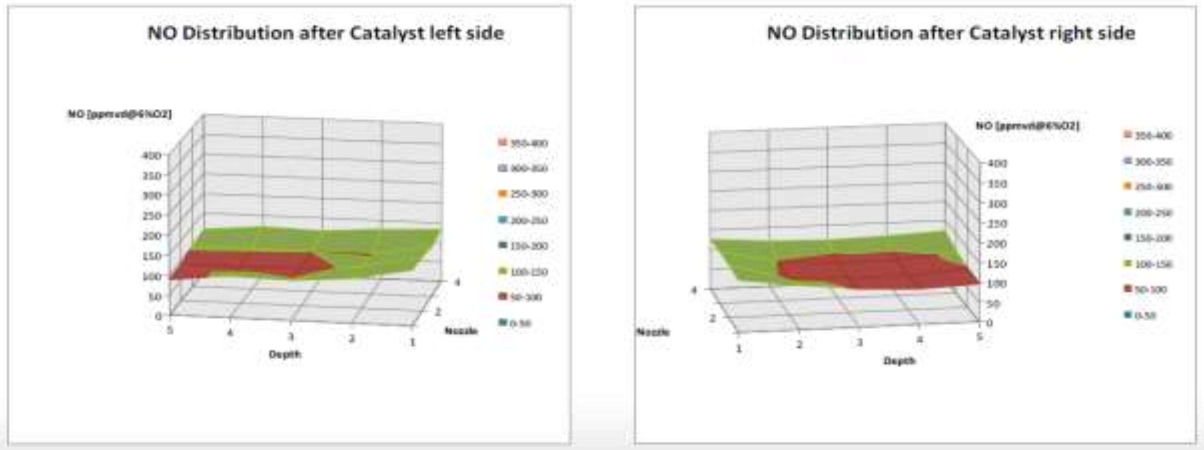
*Picture 1*

The integration of the SCR system was quite challenging as each boiler as split into 4 independent areas; front and back side as well as left and right side. As it can be seen in *Picture 2* the integration of the catalyst was even more complicate as the boiler have 3 APH. One for the left, one for the right side and one for the ECO bypass which is used to balance the overall temperature profile of the boiler.

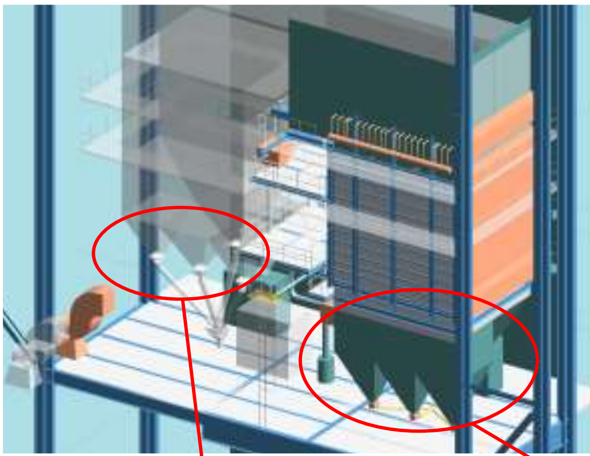



*Picture 2*

But in case of using the ECO bypass, a significant amount of flue gas is also not treated by the SCR system. Therefore the remaining flue gas stream need to be cleaned more efficient. As a result a complex control system have been applied to make sure the correct amount of ammonia is injected in each section of the boiler. The result is shown in below *Graph 1* where a homogenous NOx distribution at boiler outlet have been demonstrated.




*Graph 1*



Below *Picture 3* visualize the retrofit of the SCR in the 2nd boiler path. On the left side of the picture the original situation is shown. On the right side the layout after integrating the SCR reactor and ammonia injection system is indicated.

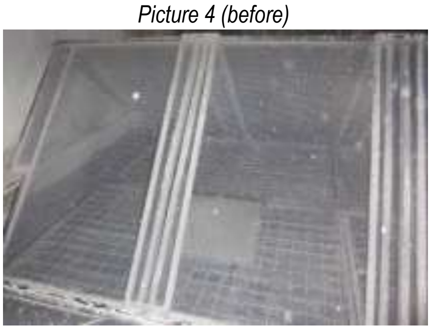
The site erection period took about 6 months as major Boiler modifications have been performed, such as

- Cutting 2nd boiler path and lowering bottom part
- Split existing ECO into 2 stages
- Reinforcement of steel structure
- Adding SCR reactor and catalyst

*Picture 3*

During the first year of operation an abnormal increase of pressure drop have been detected. The increase over operation time was in an much higher extend then in reference cases and occurred in several steps. After a deep dive into the problem it was identified that periodically large amount of fly ash was falling down from the heat exchanger surface of the boiler on the top of the catalyst (*Picture 4*). This happened specially during fast load changes and was worsen by the fact that the boiler have no soot blowing system installed. As a countermeasure YARA developed (and patented) an ash particle screen system which can be installed on the top of the catalyst (*Picture 5*). With this solution we ensured a safe and continuously operation of the boiler within the promised parameters. Below *Table 1* display the guarantee and actual performance.

*Picture 4 (before)*



*Picture 5 (after)*

| Parameter | Guarantee | Actual |
|---|---|---|
| **NOx at boiler outlet** mg/Nm³,dry@6%$O_2$ | < 450 | 350 - 450 (from boiler) |
| **NOx at SCR outlet** mg/Nm³,dry@6%$O_2$ | ≤ 190 | 160 – 180 (controlled) |
| **$NH_3$ slip at SCR outlet** mg/Nm³,dry@6%$O_2$ | ≤ 5 | < 1 |
| **$NH_3$ content in fly ash** mg/kg | ≤ 100 | < 30 |
| **$NH_3$ content gypsum** mg/kg | ≤ 10 | Not detectable |
| **$SO_2$ – $SO_3$ conversion** % | ≤ 1 | < 1 at lab test<br>at plant not measured, yet |

*Table 1*

This performance have now been fully demonstrated for years. Boiler 1 & 2 have already passed successfully the 3 years guarantee period. Boiler 3 is expected to follow within this year and Boiler 4 within 2018.

## 2. CASE STUDY FPG (CHINA) INSTALLING THE SCR ON TOP OF THE APH

The first approach and target is to use the existing steel structure. Modifications may be required such as crating openings in the structure for flue gas duct penetrations or re-enforcing the existing structure for additional weights. Below pictures show an example where the SCR system was retrofitted into the existing boiler / APH structure without building new columns.

After re-calculation and re-engineering some of the existing structure have been removed to give space for the flue gas ducts. In addition new structure for achieving the necessary strength and creating the necessary operation and maintenance platforms have been added (*Picture 6*).

Further the existing beams have been reinforced by adding stiffeners and changing the H-beams to box-beams as it can be seen in the *Pictures 7 and 8*.

*Picture 6*

*Pictures 7 and 8*

All modification of the steel structure, the installation of the SCR reactor and remaining system were executed during normal operation of the boiler. YARA applies a special design for coal fired SCR systems which reduce the required space, but also reduce the risk of catalyst plugging.

In this design the reactor, ammonia injection grid (AIG) and flue gas ducts are combined in one single equipment (*Picture 9*). This reduce the needed footprint. In addition less construction material is required which results in less new additional weight. The reactor with the related internals is further designed in modules which reduce the construction period.

*Picture 9*

After finishing the main installation, the tie-in work was performed during the boiler overhaul period. This was scheduled for 4 weeks but could be finished in less than 3 weeks. Even the time schedule was very tight, safety & health was one of the highest priorities for the execution and the project was executed without any accident.

The performance test demonstrated excellence performance as it can be seen in *Table 2*. The basis of this success is in a goo CFD modelling and the High Performance Ammonia injection System of YARA; as together with the catalyst these equipment are the heart of the SCR technology.

| | Unit | Guarantee | Actual |
|---|---|---|---|
| NOx Emission | mg/Nm3 | 70 | 42 |
| $NH_3$ Slip | ppm | 4 | 0.8 |
| Pressure Loss | Pa | 600 | 335 |

*Table 2*

The catalyst as main equipment to reduce the NOx emission and the AIG which ensures that the ammonia is well distributed and mixed with the NOx. Without an homogenous distribution, the catalyst could not perform his duty.

For this reason, YARA developed an high efficiency AIG. The technology of this new design is a multiple nozzle grid for adjusting the ammonia flow individual for each sector according to the actual needs, combined with a static mixer system for high efficiency mixing of the ammonia with the flue gas – but keeping pressure drop at a minimum.

The design is further considering the proper distribution of the ammonia into the flue gas with a minimum effect on the overall system pressure drop (typically below 10 Pa) as an important issue.

This SCR was equipped with a plate type catalyst (*Picture 10*), but YARA also have good operation experience with Honeycomb catalyst (*Picture 11*). Both catalyst types can achieve the same performance, but having slightly different advantages and disadvantages. Depending on each case, YARA will choose the best catalyst type.

*Picture 10*

*Picture 11*

One key characteristic for Indian applications is the erosion behaviour. Both catalyst types show sufficient erosion resistance as long as the flow design is proper done and the flow velocity is not too high.

An critical impact on this behaviour  is an high amount of erosive components in the fly ash (e.g. SiO2). This shall be taken into account during the overall SCR design.

In case of steam blower use, it is very important to ensure that the steam is superheated. Otherwise severe catalyst erosion will occur.

Below pictures show the Boiler Island before (*Picture 12*) and after (*Picture 13*) SCR retrofit.

*Picture 12 (before SCR retrofit)*

*Picture 13 (after SCR retrofit)*

### 3. SELECTION OF THE REAGENT

YARA – one of the world largest producer of nitrogen based products (such as ammonia and urea) – offers all kind of reagent storage, preparation and supply plants. This include solutions for the use of …

- Solid urea
- Urea solution
- Anhydrous ammonia
- Ammoniawater

Typically anhydrous ammonia is selected for larger consumptions due to logistic reasons, but having the disadvantage of being the most dangerous chemical out of the choices. The counterpart is the urea technology which is a total safe solution, but having the disadvantage of being typically the most expansive regent in terms of investment and operation cost.

This paper will therefore focus on the ammonia water which provides a good compromise out of the above options. Ammonia water is easy to handle, safe and can be installed and operated with low operation cost.

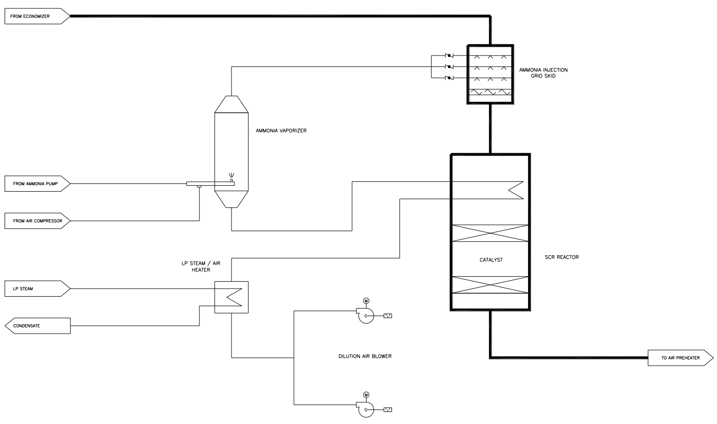
The storage of the aqueous ammonia is done by using a closed storage tank equipped with vacuum breaker and overpressure safety valve. In addition a gas seal tank is installed in case of an emergency situation. This system design avoids bad smelling and ensures the highest safety for the operator by applying a none pressure storage system (*Picture 14*).

*Picture 14*

For the supply of the aqueous ammonia to the vaporizer pulsation free pumps are used. This is a big advantage compared to dosing pumps. For the control of the aqueous ammonia flow a FCV is used which ensures the quickest and most accurate response.

The standard procedure is to heat up the dilution air by using an electrical heater and then evaporate the ammonia water by using a vaporizer. This needs a high amount of electrical energy which is very expensive in operation.

To vaporize the ammonia water, YARA have developed a special technology to reduce the operation cost and prove this technology already in many applications all over the world. In this case only a small LP steam heater (optional) is required for a pre-heating of the dilution air above dew point. The final heating is done by using a gas/gas heater in the SCR reactor (*Graph 2*).




*Graph 2*

With this solution the heat from the flue gas can be used and secondary energy consumption is avoided. As the temperature drop in the SCR system is typically less than 1°C the impact can be negligible. The same count for the pressure loss at is in the range of 1 Pa.

## 4. CATALYST MANAGEMENT

YARA have the technology and long-time experience for plate and honeycomb type catalyst. As a result of our after sales service during the operation of the SCR systems YARA also know about the behaviour of the catalyst during commercial use. Based on this knowledge, YARA developed a Catalyst Management program consisting of re-use of old catalyst (regeneration and repair) and delivery of new one to reduce the operation cost.

This regeneration technology is based on the following main benefits for the customer:

- reduces total operation costs dramatically
- avoids unnecessary raw material consumption
- avoids excessive generation of waste materials

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The technology is suitable for plate and honeycomb catalyst. The following example is a reference case for a 550 MW coal fired power plant (Taichung Power Station of TPC) which is equipped with a 6 mm pitch plate type catalyst.

Target of the performed regeneration was to restore the catalyst activity to ensure the NOx removal performance and not exceed the guaranteed SO2/SO3 conversion rate. Further the removal of dust plugging shall reduce the pressure drop to minimize the power consumption on the IDF and therefore to reduce the operation cost of the Power Plant.

In the first step the catalyst elements (boxes) have been removed from the modules and mechanically cleaned. This is very important as between the elements heavy dust deposit occurs and to ensure full performance with low pressure drop this plugging shall be removed.

In the next step the catalyst was regenerated in a 2 step washing process including re-coating of the catalyst. Due to a dust removal step in the washing water, the water management could be optimized. The waste water was treated by the existing plant in the Power Station and had a similar characteristic as the air-pre heater washing water.

After drying the catalyst it was re-installed and a performance test have been carried out. The below *Table 3* show the test results - analysed by an government authorized 3rd party – under design conditions.

| *Table 3* | Unit | Guarantee | Actual |
|---|---|---|---|
| NOx Removal | % | 80.0 | 80.6 |
| $NH_3$ Slip | ppm | 5 | 1 |
| Pressure Loss | mmH2O | 70 | 43 |
| SO2/SO3 conv. | % | 1.0 | 0.5 |

The regeneration can be typically performed during the boiler overhaul period (about 3 weeks). The catalyst will be dismantled from the reactor and moved to the on-site regeneration equipment where the catalyst modules will be prepared for cleaning procedure. The space requirement is about 200 m2. It is not mandatory to have all space at one location. Setting up a proper logistic allows splitting the required space into several areas.

Below table show an example for catalyst management of an 550 MW SCR in a coal fired boiler. The given cost are for one Layer catalyst replacement / regeneration.

| | Unit | New Catalyst | Catalyst Disposal | Regeneration | Total Cost |
|---|---|---|---|---|---|
| New Catalyst | EUR | 750,000 | 210,000 | - | 960,000 |
| Regeneration | EUR | 450,000 | - | - | 450,000 |

As it can be seen, the regeneration cost is about 50% of the cost compared to a new catalyst, considering the additional cost for dismantling and installation of catalyst are in both cases equivalent.