

The TripleCat DNX-LT SCR catalyst: Maximizing activity at low temperature

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1 Summary

SCR DeNO_x technology is considered state-of-the-art technology for reduction of nitrogen oxides (NO_x) from stationary combustion units, and is a globally well-proven technology for the past four decades.

Traditionally, in order to have an acceptable performance the SCR DeNO_x reaction's temperature window has been from 180 to 540°C. Recently, Umicore has developed a new SCR DeNO_x catalyst with significant improved performance from 150°C to 200°C – the TripleCat DNX-LT catalyst.

The TripleCat DNX-LT SCR catalyst is a game changer as it performs in an uncharted low temperature regime thereby allowing for completely new air emissions control solutions for thousands of WtE plants, biomass plants, cement plants and other boilers with tail-end SCR systems as well as optimizing the performance of existing installations.

The TripleCat DNX-LT SCR catalyst can omit the need of costly flue gas reheating, thereby making the SCR technology more cost-effective, and further helping to reduce the CO₂-footprint from many combustion units. Moreover, the reduced catalyst volume required would further lead to a reduced pressure drop across the catalyst bed.

In this paper, examples of multiple plants in which the TripleCat DNX-LT SCR catalyst has demonstrated its outstanding performance are presented.

2 Introduction

Practically all combustion processes lead to the emission of nitrogen oxides, NO and NO₂, commonly referred to as NO_x. The emission of NO_x is a global pollution problem as NO_x contributes to acid rain, form ground-level ozone and causes damage to human health.

Today, most industrialized countries have established guidelines and legislations regarding to what extent their local industries should reduce emissions of NO_x.

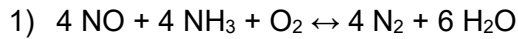
Various technologies exist to control NO_x emissions with Selective Catalytic Reduction (SCR) being the state-of-the-art NO_x reduction methods which when optimized can yield NO_x removal rates in excess of 95%.

In many combustion units for example on Waste-To-Energy (WtE), biomass and cement plants it is often favorable to have the SCR DeNO_x reactor located in a tail-end position, downstream a bag filter and upstream the stack in order to protect the catalyst from dust and contaminants. The challenge with this position is that the flue gas temperature may be too low for sufficient activity for a conventional catalyst and it may be required to reheat flue gas around 30 to 100°C which comes at a significant cost for the plant.

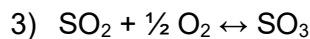
This paper reviews the experience gained so far with the new and innovative SCR DeNO_x catalyst developed specially for low temperature operation; The TripleCat DNX-LT catalyst.

3 The Selective Catalytic Reduction process

In the SCR process, NO_x reacts with a reducing agent to form harmless nitrogen and water vapor. The reducing agent is mainly ammonia (NH₃) but urea can also be used. The main reactions are:

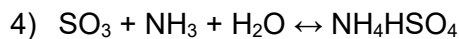


In addition to the NO_x reduction reactions, there is a side reaction:



SO₃ forms sulfuric acid upon reaction with water vapor, and this highly unwanted side reaction must always be taken into consideration in the design of a catalytic system.

SO₃ in the flue gas may also react with ammonia, forming ammonium bisulfate (ABS):



ABS is a sticky salt that causes reduced catalyst activity due to fouling of the catalyst surface. ABS may also lead to reduced efficiency of downstream heat exchangers, or plugging of ammonia injection nozzles.

Formation of ABS is only a problem at low temperature operation, below the ABS dew point. The catalyst's ABS dew point can be calculated based on the SO₃ and NH₃ concentrations in the flue gas. It should be noted that ABS condensation in the catalyst is a reversible reaction, therefore heating of the catalyst to 320-350°C will cause ABS to evaporate, and the catalyst activity will be regained.

The main components of the SCR system are a reactor including catalyst, and the ammonia storage, dosing and injection system. The SCR process requires precise control of the ammonia injection rate due to an insufficient injection results in low NO_x conversion and excessive injection results in an undesirable release of unconverted ammonia to the atmosphere, commonly called ammonia slip.

In WtE, biomass and cement plants, the SCR reactor is typically placed in a low dust position after a bag filter (BF), as shown on Figure 1. The low dust position generally has a positive effect on the catalyst deactivation and thus prolong catalyst lifetime because it is not exposed to dust and contaminants as in high dust positions. The relatively low SCR inlet temperatures of 170-200°C will on the other hand counteract this effect since the catalyst activity is lower at these temperatures.

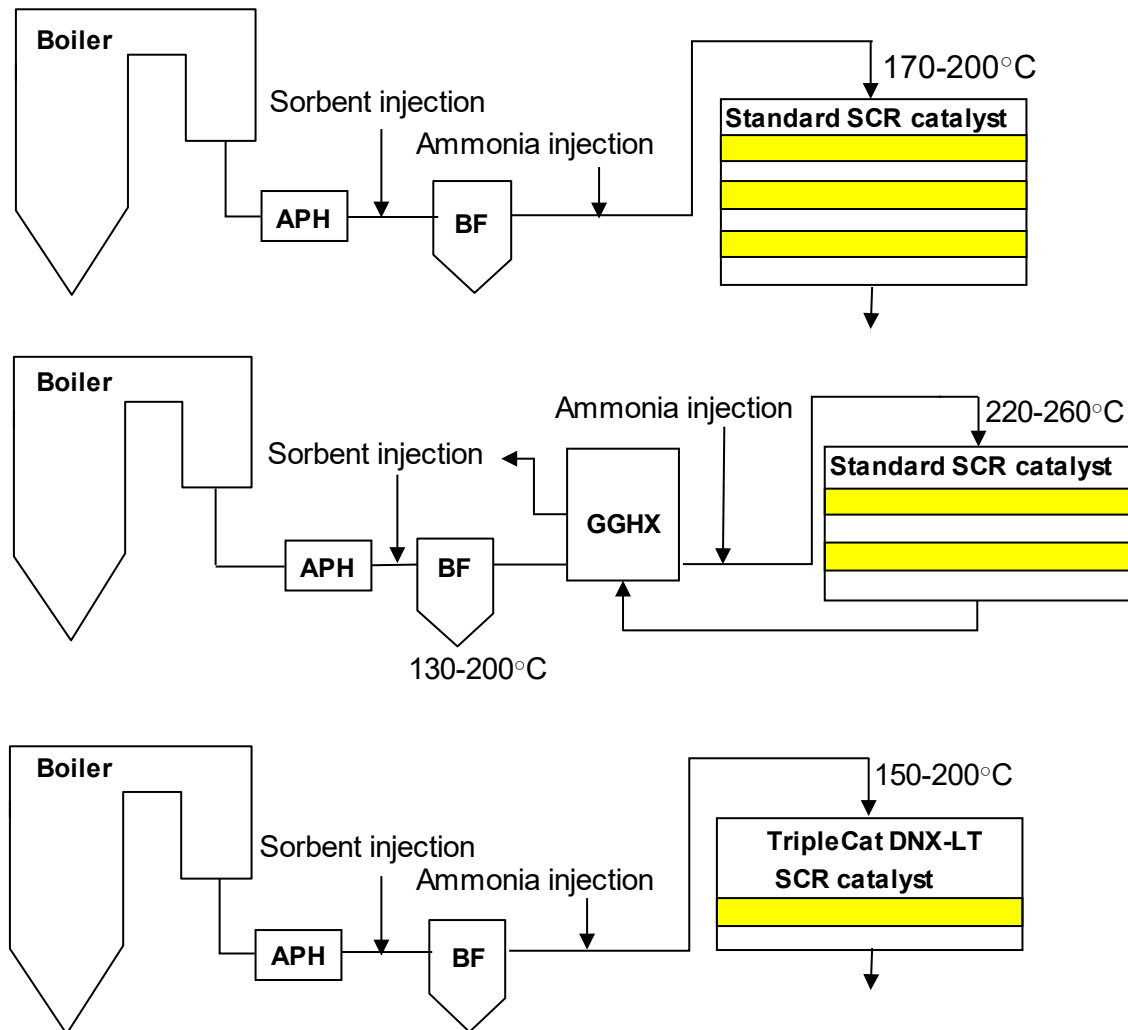


Figure 1: Three alternative configurations of the SCR DeNOx reactor.

The SCR positioning may also be a combination of the three scenarios shown, or the SCR may be placed after an electro static precipitator (ESP) or a scrubber.

The configuration with an SCR right after the bag filter often require three layers of standard SCR catalyst in order to compensate for low catalyst activity. This means a relatively large SCR reactor and high pressure drop over the SCR unit.

The configuration with the SCR placed after a bag filter + gas-gas heat exchanger (GGHX) provides the advantages of relatively high catalyst activity. This allows need of less catalyst volume, typically one or two layers, depending on how much the temperature is increased. The drawback is the higher investment and operational cost of a heat exchanger.

The third alternative with the SCR after a bag filter and Umicore's TripleCat DNX-LT SCR catalyst requires less investment cost and typically requires only one catalyst layer relative to

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three layers with a standard SCR catalyst. This allows the SCR to be quite small and compact, and also help to keep pressure drop over the SCR unit minimal.

Since exit temperature from a bag filter can be as low as 130°C there is often a demand from the industry for an SCR catalyst working down to this temperature. So far, with conventional SCR catalysts it has not been possible to go lower in temperature than 170°C at SCR inlet, therefore the need of expensive flue gas reheating has been required.

The introduction of Umicore's TripleCat DNX-LT catalyst significantly expands the temperature window where NO_x reduction can be conducted by SCR, thus making it possible to meet NO_x emission requirements after a bag filter without the expensive reheating of the gas.

4 The SCR catalyst

The DNX[®] SCR catalyst from Umicore is based on a porous titanium-dioxide (TiO₂) carrier material on which the catalytically active components in the form of vanadium pentoxide (V₂O₅) and tungsten trioxide (WO₃) are dispersed. The SCR catalyst is delivered either as single elements in a carbon steel cassette or as several elements grouped into modules on a metal frame for quick installation, see Figure 2.



Figure 2: SCR catalyst elements grouped as modules on a steel frame for easy installation in the SCR reactor.

The SCR catalyst is designed for each specific installation, where the optimal chemical composition, channel size (pitch), wall thickness and height is found during the design phase based on project specifications. This ensures the optimal catalyst volume is installed when taking process conditions, plant configuration and performance requirements into consideration.

4.1 Design of next generation SCR catalyst for low temperature operation

Reheating of flue gas in order to have sufficiently high operation temperature in the SCR system is a large expense for any plant. Following a detailed understanding of the need and challenges that the plants meet in their daily operation, Umicore's R&D team have worked intensely for pushing the borders for what is possible with the SCR technology.

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The TripleCat DNX-LT SCR catalyst is a further development of the well-known DNX® SCR catalyst series from Umicore. The TripleCat is specifically designed for high activity at low flue gas temperatures.

At 150°C the activity is approximately three times higher compared to a conventional SCR catalyst, see Figure 3, which basically means that only a third of the catalyst volume is needed at 150°C relative to other commercially available SCR catalysts.

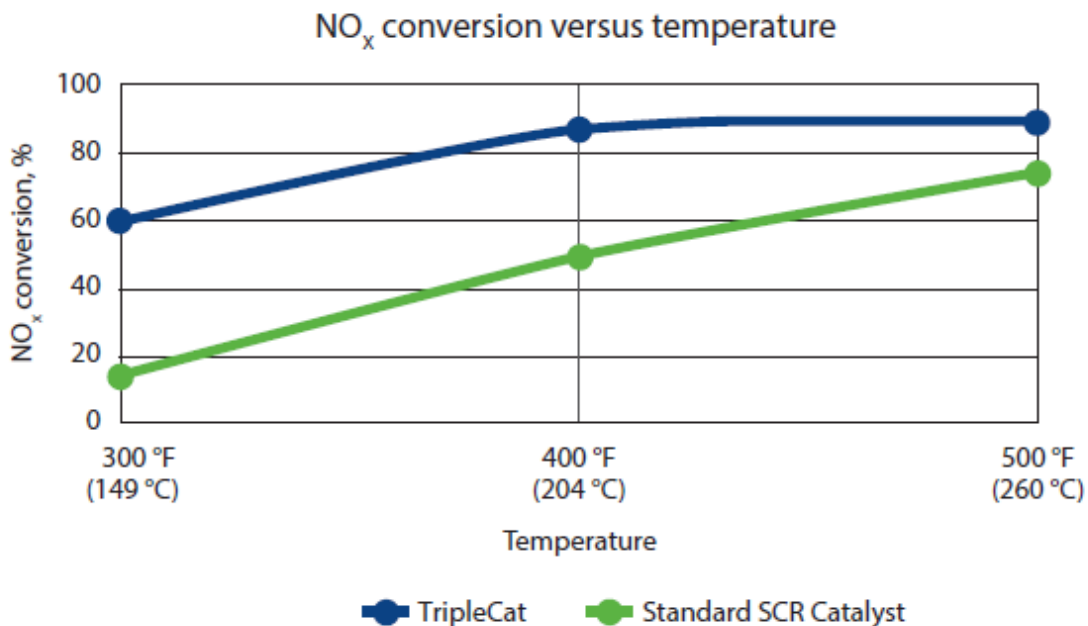


Figure 3: NO_x conversion versus temperature for TripleCat DNX-LT versus a standard SCR catalyst.

What makes the TripleCat DNX-LT catalyst unique is the ability to “carry” a high amount of catalytic active materials while not only maintaining a high efficiency of each active site, but also a good stability in the flue gas. This has been made possible by developing a unique production method in combination with the right choice of catalyst materials. Moreover, combining the catalyst with Umicore’s corrugated glass fiber-based substrate gives the opportunity to have a high catalyst mass which furthermore is beneficial for low temperature performance as well as a low pressure drop. The final catalyst is still vanadium based that is reinforced with glass-fibers which has been a well proven technology for flue gas after treatment for decades.

4.2 Save money on both CAPEX and OPEX

The greater SCR activity of the TripleCat DNX-LT catalyst will reduce the catalyst volume required to meet legislation, which in turn makes it possible to reduce space requirements for the SCR reactor and reduce the pressure drop over the SCR system.

The savings in energy consumption for flue gas reheating combined with less to no need of burners or heat exchangers will lead to significant savings on the plant operating costs. In

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addition, the reduced pressure drop will further contribute to lowering the operation costs. Examples of plants that have benefitted from having the TripleCat DNX-LT installed are presented in Section 5.

4.3 The great challenge by low temperature SCR operation

The injection of ammonia into an SCR system operating at low temperatures may lead to the formation of ammonium bisulfate (ABS). Formation of ABS is unavoidable if the temperature is below the catalyst's ABS dew point – which is often the case when operation temperature is less than 200°C. Hence it is prerequisite that SO_x in the flue gases are removed or kept well below 10 mg/Nm³ prior to the catalyst when operating an SCR catalyst at low temperatures. Based on long term operation of the catalyst in industrial installations, the catalyst has been proven to operate well and therefore Umicore can now offer a solution in this segment.

Even so, Umicore's R&D engineers continuously work on pushing the borders for what is achievable. Increasing the SO_x tolerance of TripleCat DNX-LT catalyst without compromising high activity is one of the ongoing studies, and several solutions are being investigated.

In the case where the TripleCat DNX-LT becomes deactivated by ABS fouling it is possible to regenerate the catalyst and completely regain the high activity. As seen in Figure 4 below, it was found that heating the catalyst to 350°C over a short period of time will lead to the loss of ABS and the catalyst regained the activity.

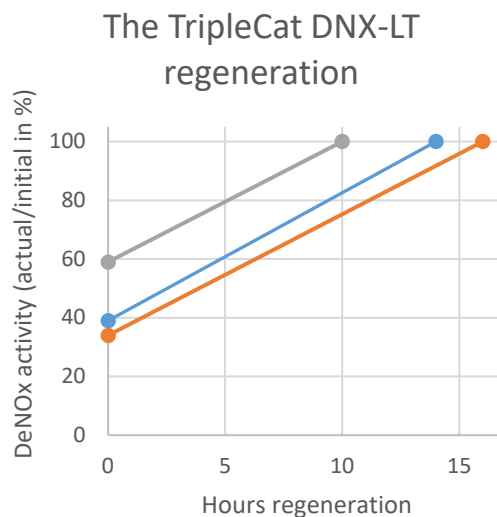


Figure 4: The regeneration of the TripleCat DNX-LT is regenerated to regain the complete activity. Test conditions: 175°C, 300 ppm NO_x, 360 ppm NH₃, 13% O₂, 8% H₂O, 2 Nm/s.

5 Examples of installations with TripleCat DNX-LT

5.1 16 MW Biomass plant, Spain

In the biomass plant the 16 MW boiler is firing mainly with olive derived biomass, “orujillo”, see Figure 5, and had been running for around four years with 30 catalyst modules (56 m³) of regenerated Haldor Topsoe catalyst. The SCR system is located after a bag filter and with a heat exchanger to increase flue gas temperature. The Haldor Topsoe SCR catalyst had been purchased used from another plant, then cleaned and impregnated with active components by the company STEAG. The design temperature was 170°C, but in reality, the plant was operating around 175-180°C most of the time.



Figure 5: 16 MW orujillo fired power plant, Spain.

As it was time for catalyst replacement, Umicore proposed the TripleCat DNX-LT SCR catalyst as an alternative. This solution turned out to be very attractive: With only 15 catalyst modules with a total volume of 21 m³, corresponding to a catalyst volume reduction of 60%, the TripleCat DNX-LT catalyst could do the same job – and at 150°C!

Thus, the new SCR catalyst would lead to significant savings in energy needed for flue gas reheating as well as 60% catalyst pressure drop reduction – from around 2.9 mbar down to

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around 1.1 mbar. A budget calculation made by the plant director showed that the annual savings in energy consumption at this biomass plant would be approximately EUR 100,000. In addition to this the time spent on catalyst loading/unloading and annual inspections will be halved since there is now only one catalyst layer instead of two. And finally, the plant will gain two production days per year due to less time required to reach 150°C after boiler cleanings. These two extra production days will add around EUR 11,000 to the annual revenue of the plant. Overall, the payback period of the installed TripleCat DNX-LT SCR catalyst is less than two years.

The installation of TripleCat DNX-LT SCR catalyst modules was carried out in September 2020, see Figure 6. Installation of the 15 catalyst modules was completed within one day, and in accordance with Umicore’s standard procedures.

Evaluation of process data over the next two months showed catalyst performance well within the guaranteed values. The plant operates at conditions slightly different than the design basis, with higher inlet NOx and an SCR inlet temperature around 160°C.



Figure 6: Pictures from the installation of TripleCat DNX-LT SCR catalyst at the biomass plant.

5.2 Package boiler, USA

In USA, a small natural gas fired boiler had struggled for several years to reach emission regulation. The challenge was a low flue gas temperature below 175°C at SCR location just upstream the stack, see Figure 6. The original SCR catalyst had been designed for higher operating temperatures than actual conditions, and even with overdosing of ammonia it was not possible to reduce NOx below the limit. The plant had been running with exceptions from their permit and was on their final and last exception.

The solution to this plant’s struggles seemed to be the expensive revamp of the system in order to increase flue gas temperature prior to SCR catalyst – and stack. So, when the plant owner was introduced to the new TripleCat DNX-LT catalyst there was no doubt that this was the optimal solution.

Today, Umicore has successfully brought this installation well under the emission limit.

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Figure 7: Package boiler with TripleCat DNX-LT installed upstream stack.

In Figure 7, right, the picture shows the compact TripleCat DNX-LT catalyst installation. The TripleCat DNX-LT has a much darker tone than a traditional DNX DeNOx catalyst which is an indication of the increased amount of active sites. In the center of the catalyst layer the test element containing nine smaller catalyst cartridges is seen. These cartridges allow the client to easily extract a sample and thereby to follow the performance of the catalyst over time. The TripleCat DNX-LT catalyst was installed in February 2020 and the plant is now able to meet requirements both for NO_x and NH₃ slip, demonstrating the strong performance of the new TripleCat DNX-LT catalyst.

5.3 WtE plant, China

In a 100,000 Nm³/hr. waste incineration line in China, an SCR unit has been in operation for several years. The SCR is located after sulfur removal and a bag filter. Flue gas exiting the bag filter was being reheated to 180°C with steam in a heat exchanger, in order to get sufficient catalyst activity.

The fuel is municipal solid waste, MSW, and due to the inhomogeneous nature of this fuel, there will be variations in the flue gas composition, including SO₂ concentration. SO₂-concentration at SCR inlet is in average below 5 mg/Nm³, but peaks up to 10 mg/Nm³ will occur for up to 30 hours per year.

The plant owner had a great incentive to lower the SCR inlet temperature in order to save steam. It was estimated that a decrease in SCR inlet temperature from 180°C to 150°C will result in 67% less steam consumption, corresponding to an annual saving of EUR 250,000.

Umicore made a design layout showing that with TripleCat DNX-LT the plant could realize operation at 150°C. With the forecasted savings in steam consumption, the catalyst payback period would be less than one year. The plant owner decided to install TripleCat DNX-LT SCR catalyst during a planned plant shutdown in the Spring of 2021.

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6 Conclusions

Umicore is proud to present a new SCR catalyst optimized for low temperature operation: The TripleCat DNX-LT catalyst designed to push the borders for efficient SCR operation from 150°C to 200°C.

ABS formation continues to pose a challenge for low temperature SCR operation. But in plants with low SO_x content in the flue gas Umicore now have good long-term operation experience.

The TripleCat DNX-LT SCR catalyst introduces new possibilities in tail-end SCR operation and can in many cases lead to significant savings in both CAPEX and OPEX as well as reduce a plant's overall CO₂-footprint.

The successful operation of TripleCat DNX-LT catalyst was demonstrated with three examples in this paper and a total of 5 installation is currently in operation around the world.

With Umicore's know-how and unique catalyst technology as well as close relationship with customers, it has been possible to develop the TripleCat DNX-LT catalyst that meet the demand for low temperature SCR operation.

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