HOT FLUE GAS CLEANING

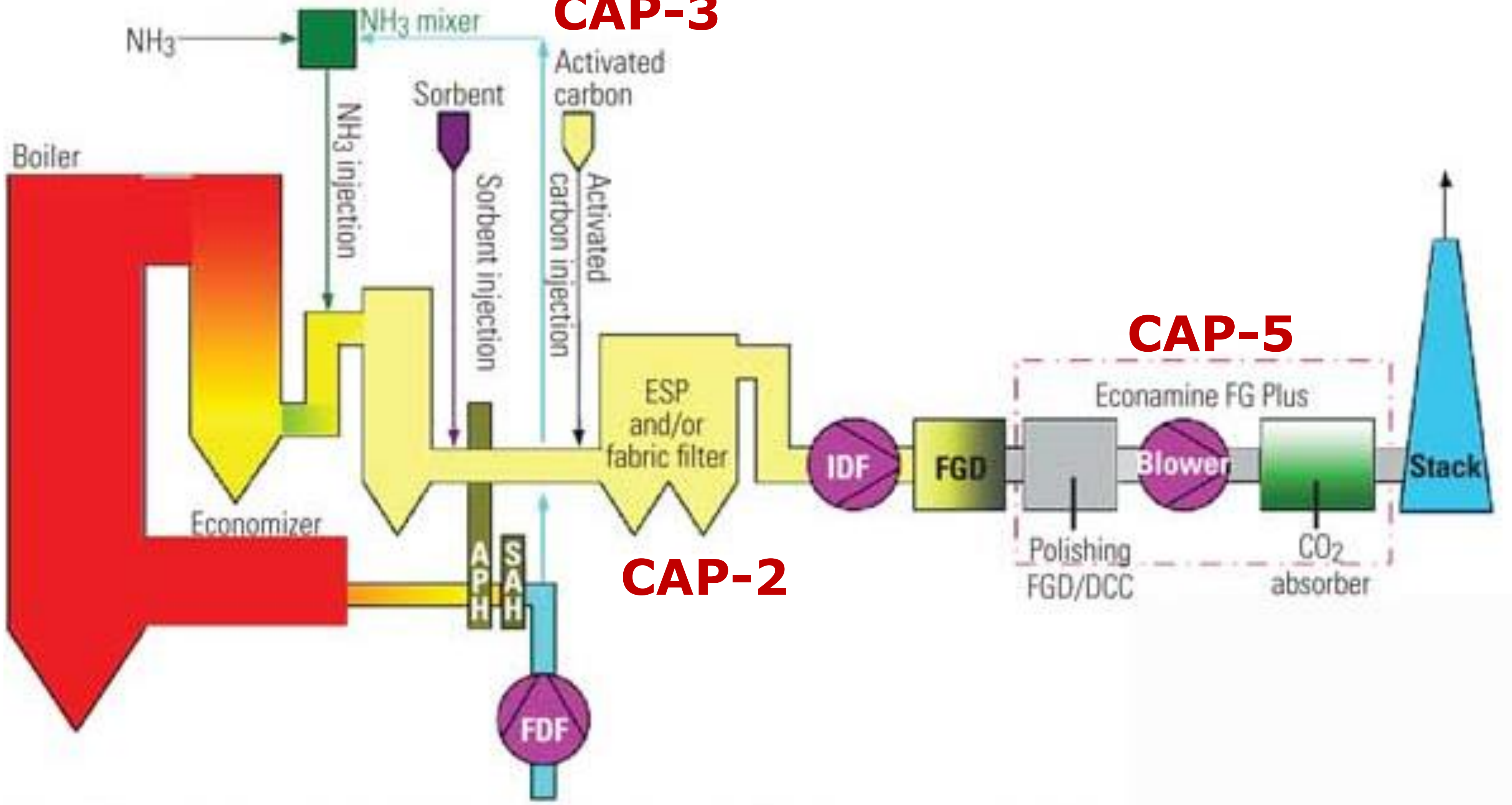
Guidelines for New Plants

Clean Development Mechanism (CDM)

Good engineering practice (GEP)

NOx REMOVAL

IN COAL FIRED POWER PLANTS



Notes: SCR = selective catalytic reduction, APH = air preheater, DCC = direct contact cooler, ESP = electrostatic precipitator, FDF = forced draft fan, FGD = flue gas desulfurization, IDF = induced draft fan, SAH = steam air heater

Industrialization of Kazakhstan

БИРЖА НОВЫХ ТЕХНОЛОГИЙ
АО «Национальный научно-технологический холдинг «Парасат»

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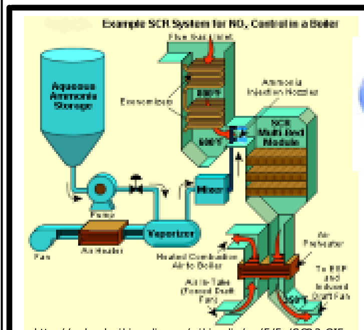

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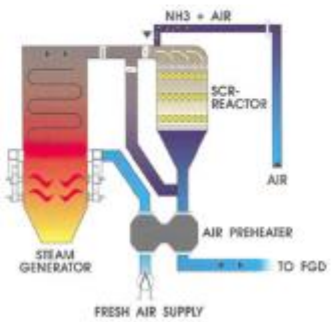

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Selective Catalytic Reduction

deNOx, Inc., has over 20 years of design, construction and start-up experience in Selective Catalytic Reduction (SCR) systems, NOx emissions control, Nitrogen Oxide removal, ammonia injection systems and SCR catalyst management. We provide SCR system components including ammonia storage and handling equipment, ammonia flow control unit (AFCU) skids, ammonia injection grids (AIG), ammonia distribution manifolds and SCR process control panels. We also conduct SCR operator training...........
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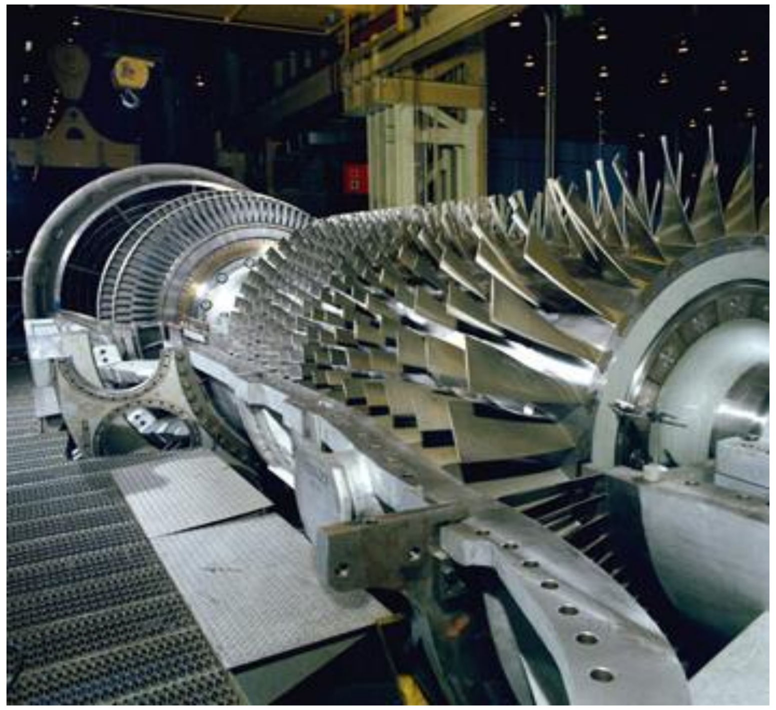
AMMONIA FLOW CONTROL



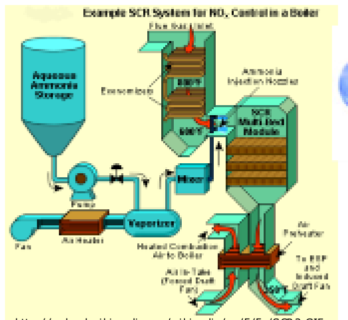
Selective Catalytic Reduction

Ammonia gas (NH_3) is injected into the HRSG. Inside, it mixes with the NOx that is present in the gas turbine exhaust. The catalyst accelerates the reaction between the two reagents as the mixture flows across it.

Selective catalytic reduction (SCR) *is a means of converting nitrogen oxides, also referred to as NOx with the aid of a catalyst into diatomic nitrogen, N_2, and water, H_2O. A gaseous reductant, typically anhydrous ammonia, aqueous ammonia or urea, is added to a stream of flue or exhaust gas and is adsorbed onto a catalyst. Carbon dioxide, CO_2 is a reaction product when urea is used as the reductant.*

Selective catalytic reduction of NOx *using ammonia as the reducing agent was patented in the United States by the Engelhard Corporation in 1957. Development of SCR technology continued in Japan and the US in the early 1960s with research focusing on less expensive and more durable catalyst agents. The first large-scale SCR was installed by the IHI Corporation in 1978.*

Commercial selective catalytic reduction systems are typically found on large utility boilers, industrial boilers, and municipal solid waste boilers and have been shown to reduce NOx by 70-95%. More recent applications include diesel engines, such as those found on large ships, diesel locomotives, gas turbines, and even automobiles.



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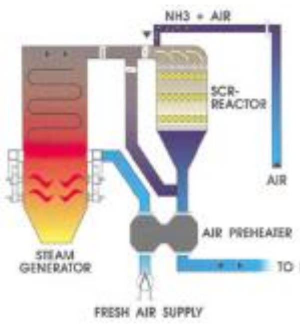

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http://en.wikipedia.org/wiki/Selective_catalytic_reduction

Chemistry

The NOx reduction reaction takes place as the gases pass through the catalyst chamber. Before entering the catalyst chamber the ammonia, or other reductant (such as urea), is injected and mixed with the gases. The chemical equation for a stoichiometric reaction using either anhydrous or aqueous ammonia for a selective catalytic reduction process is:

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

$$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$$

$$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$$

With several secondary reactions:

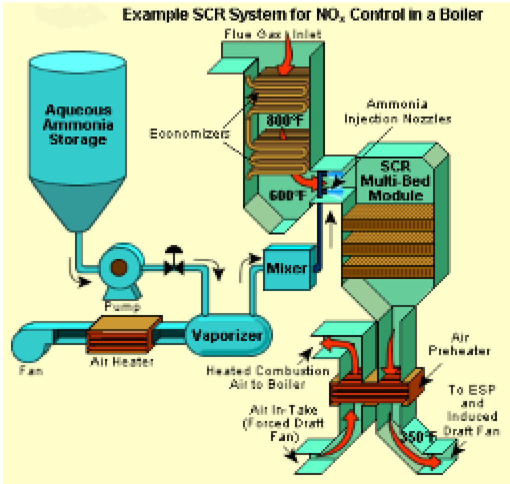
$$2SO_2 + O_2 \rightarrow 2SO_3$$

$$2NH_3 + SO_3 + H_2O \rightarrow (NH_4)_2SO_4$$

$$NH_3 + SO_3 + H_2O \rightarrow NH_4HSO_4$$

The reaction for urea instead of either anhydrous or aqueous ammonia is:

$$4NO + 2(NH_2)_2CO + O_2 \rightarrow 4N_2 + 4H_2O + 2CO_2$$



The ideal reaction has an optimal temperature range between 630 and 720 K, but can operate from 500 to 720 K with longer residence times. The minimum effective temperature depends on the various fuels, gas constituents, and catalyst geometry. Other possible reductants include cyanuric acid and ammonium sulfate.

Catalysts

SCR catalysts are made from various ceramic materials used as a carrier, such as titanium oxide, and active catalytic components are usually either oxides of base metals (such as vanadium, molybdenum and tungsten), zeolites, or various precious metals. Each catalyst component has advantages and disadvantages.

Base metal catalysts, such as the vanadium and tungsten, lack high thermal durability, but are less expensive and operate very well at the temperature ranges most commonly seen in industrial and utility boiler applications. Thermal durability is particularly important for automotive SCR applications that incorporate the use of a diesel particulate filter with forced regeneration. They also have a high catalysing potential to oxidize SO2 into SO3, which can be extremely damaging due to its acidic properties. Zeolite catalysts have the potential to operate at substantially higher temperature than base metal catalysts; they can withstand prolonged operation at temperatures of 900 K and transient conditions of up to 1120 K. Zeolites also have a lower potential for potentially damaging SO2 oxidation. Iron- and copper-exchanged zeolite urea SCRs have been developed with approximately equal performance to that of vanadium-urea SCRs if the fraction of the NO2 is 20% to 50% of the total NOx. The two most common designs of SCR catalyst geometry used today are honeycomb and plate.

The honeycomb form usually is an extruded ceramic applied homogeneously throughout the ceramic carrier or coated on the substrate. Like the various types of catalysts, their configuration also has advantages and disadvantages. Plate-type catalysts have lower pressure drops and are less susceptible to plugging and fouling than the honeycomb types, but plate configurations are much larger and more expensive. Honeycomb configurations are smaller than plate types, but have higher pressure drops and plug much more easily. A third type is corrugated, comprising only about 10% of the market in power plant applications.

Reductants

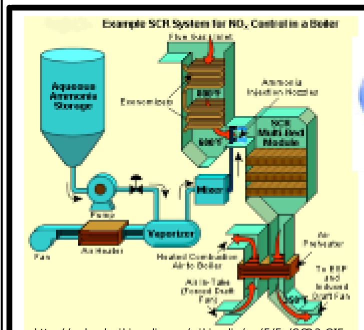
Several reductants are currently used in SCR applications including anhydrous ammonia, aqueous ammonia or urea. All those three reductants are widely available in large quantities.

Pure anhydrous ammonia is extremely toxic and difficult to safely store, but needs no further conversion to operate within an SCR. It is typically favoured by large industrial SCR operators. Aqueous ammonia must be hydrolysed in order to be used, but it is substantially safer to store and transport than anhydrous ammonia. Urea is the safest to store, but requires conversion to ammonia through thermal decomposition in order to be used as an effective reductant.

Limitations

SCR systems are sensitive to contamination and plugging resulting from normal operation or abnormal events. Many SCRs are given a finite life due to known amounts of contaminants in the untreated gas. The large majority of catalyst on the market is of porous construction. A clay planting pot is a good example of what SCR catalyst feels like. This porosity is what gives the catalyst the high surface area essential for reduction of NOx. However, the pores are easily plugged by a variety of compounds present in combustion/flue gas. Some examples of plugging contaminates are: fine particulate, ammonia sulfur compounds, ammonium bisulfate (ABS) and silicon compounds. Many of these contaminants can be removed while the unit is on line, for example by sootblowers. The unit can also be cleaned during a turnaround or by raising the exhaust temperature. Of more concern to SCR performance is poisons, which will destroy the chemistry of the catalyst and render the SCR ineffective at NOx reduction or cause unwanted oxidation of ammonia (forming more NOx). Some of these poisons include: halogens, alkaline metals, arsenic, phosphorus, antimony, chrome, copper.

Most SCRs require tuning to properly perform. Part of tuning involves ensuring a proper distribution of ammonia in the gas stream and uniform gas velocity through the catalyst. Without tuning, SCRs can exhibit inefficient NOx reduction along with excessive ammonia slip due to not utilizing the catalyst surface area effectively. Another facet of tuning involves determining the proper ammonia flow for all process conditions. ia is over-injected into gas stream, temperatures are too low for ammonia to react, or catalyst has degraded (see above).



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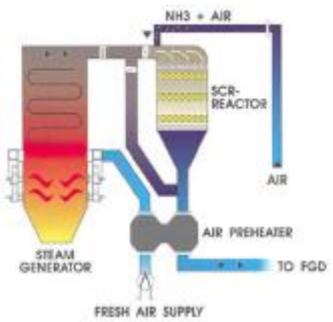

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Power plants

In power stations, the same basic technology is employed for removal of NOx from the flue gas of boilers used in power generation and industry. In general, the SCR unit is located between the furnace economizer and the air heater, and the ammonia is injected into the catalyst chamber through an ammonia injection grid. As in other SCR applications, the temperature of operation is critical. Ammonia slip is also an issue with SCR technology used in power plants.

Other issues that must be considered in using SCR for NOx control in power plants are the formation of ammonium sulfate and ammonium bisulfate due to the sulfur content of the fuel as well as the undesirable catalyst-caused formation of SO3 from the SO2 and O2 in the flue gas.

A further operational difficulty in coal-fired boilers is the binding of the catalyst by fly ash from the fuel combustion. This requires the usage of sootblowers, sonic horns, and careful design of the ductwork and catalyst materials to avoid plugging by the fly ash. SCR catalysts have a typical operational lifetime of about 16,000-40,000 hours in coal-fired power plants, depending on the flue gas composition, and up to 80,000 hours in cleaner gas-fired power plants.

Alstom's world leading SCR system is further improved with the addition of a highly efficient Ammonia Injection Grid (AIG) and mixing technology which can remove up to 95% of NO_x from flue gas.

Unique design adds performance benefits to Alstom's SCR design

***With over 80 systems installed in power plants around the world**, Alstom's Selective Catalytic Reduction (SCR) system is a leading industry-recognised solution for removing NOx from the boiler flue gas. Alstom developed the high efficiency ammonia injection grid (AIG) and IsoSwirl™ mixing system to meet the increasingly stringent NOx emission targets being imposed by regulatory authorities worldwide. Ammonia is injected into the flue gas duct using the optimised AIG design and is efficiently mixed with the boiler flue gas using proprietary IsoSwirl™static mixers. The intense turbulent mixing patterns created and the even flow distribution of the flue gas into the catalyst layer(s) allow up to 95% NOx removal. The high efficiency AIG and the IsoSwirl™ mixers support the SCR catalyst in reliably meeting NOx removal guarantees for long term operation, delivering the most competitive initial capital investment and lowering operational and maintenance costs.*

Advantages of IsoSwirl™

over conventional designs The high efficiency ammonia injection grid uses diluted ammonia-air mixtures with external flow control and its design configuration features fewer pipes and nozzles compared to earlier SCR designs. This robust configuration is not only easier to access and maintain but also easier to operate and control, eliminating the complex operation of fine tuning the injection grid.
To obtain the proper NH3/NOx interface, the high efficiency system also features IsoSwirl™ mixers. These in-duct static mixers,located downstream of the ammonia injection grid, take the ammonia flow and mix it intensely with the flue gas stream. This produces an extremely well-mixed gas with enhanced distributions. The effectiveness of the IsoSwirl™ mixers makes this ammonia injection system design ideal for high performance applications. The quality of the mixing enables the system to meet applications with challenging NOx emission requirements or varying operating environments.
Alstom approaches each customer on a caseby-case basis. After thorough investigation of site constraints and required removal efficiencies, we will design the equipment accordingly and recommend the ideal shape, quantity and in-duct location of mixing blades that will fulfill the plant's requirements in an optimised and cost-efficient way.

http://www.alstom.com/Global/Power/Resources/Documents/Brochures/aqcs-scr-isoswirl-mixer-ammonia-injection.pdf

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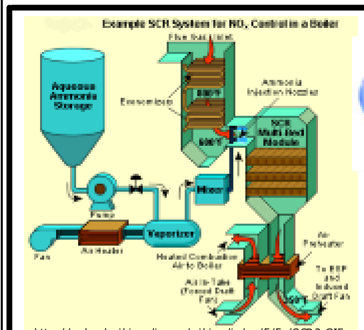

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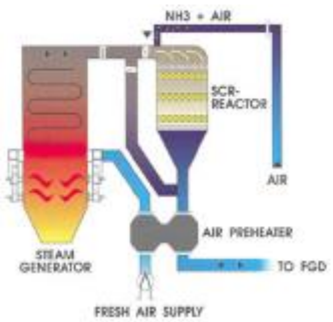

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