

# Dry De-SOx De-NOx System

## 1 Overview

The Dry De-SOx/De-NOx System (DDDS) uses activated coke to remove environmental pollutants from the flue gases emitted from industrial equipment such as sintering machines, electricity generation boilers, waste incinerators, and cement kilns.

Sumitomo Heavy Industries (SHI) began research and development of the technology as an environmentally friendly form of flue gas treatment in the 1960s, and it has since become established in practical use. The first system for a sintering machine was supplied to Nagoya Steel Works of Nippon Steel & Sumitomo Metal in 1987, with a further 10 systems having since been supplied in Japan and three more overseas.

Nippon Steel & Sumikin Engineering agreed to acquire the DDDS business from SHI in November 2017, providing it with a range of products for sintering machines that it did not previously have. Nippon Steel & Sumikin Engineering is now collaborating with Beijing JC Energy & Environment Engineering (BE3) to further develop the business by primarily targeting the Chinese market where emission regulations for sintering machines are rapidly becoming more stringent.

## 2 Process Description

The main components of a DDDS are the adsorber, the regenerator, and the conveyor used to circulate and transport the activated coke. The system utilizes the adsorption capability and catalytic activity of the activated coke to remove sulfur and nitrogen oxides ( $\text{SO}_2$  and  $\text{NO}_x$ ) (see Figure 1).

The activated coke falls slowly from the top to the bottom of the adsorber where it comes into contact with the horizontally flowing flue gas, in the process adsorbing and removing environmental pollutants such as  $\text{SO}_2$ , dust, dioxins, and heavy metals. Furthermore, by injecting ammonia ( $\text{NH}_3$ ) into the flue gas, the catalytic

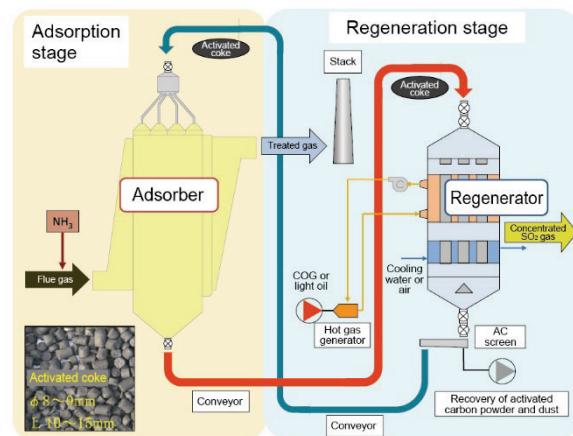


Figure 1 Overview of DDDS process

activity of the activated coke causes  $\text{NO}_x$  to break down into water ( $\text{H}_2\text{O}$ ) and nitrogen ( $\text{N}_2$ ).

Activated coke that has adsorbed environmental pollutants is discharged from the bottom of the adsorber and transported to the regenerator by a conveyor. It is heated to about  $430^\circ\text{C}$  in the regenerator in an inert atmosphere to drive off the  $\text{SO}_2$  and break the dioxins down into harmless substances. In downstream processes,  $\text{SO}_2$  is recovered as concentrated sulfuric acid or gypsum, which serve as valuable byproducts. After being stripped of its environmental pollutants in the regenerator and then sifted to separate powdered activated coke and dust, the activated coke is transported by a conveyor back to the adsorber where it is reused as an adsorbent.

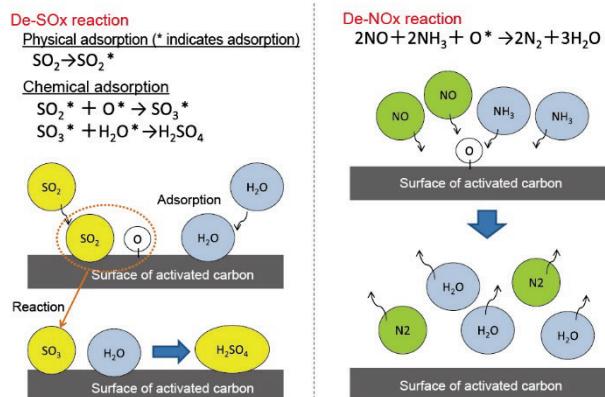


Figure 2 De-SOx and De-NOx reactions in the adsorber (examples)

### 3 Features

Common alternatives to DDDS for SOx and NOx removal include wet desulfurization combined with SCR removal of nitrogen oxides, and semi-dry desulfurization combined with SCR removal of nitrogen oxides. Wet and semi-dry desulfurization work by neutralizing and removing the SO<sub>2</sub> by bringing the flue gas into contact with an aqueous alkaline solution and slurry, producing gypsum as a byproduct. The removal of NOx by selective catalytic reduction (SCR) uses a catalyst to react NO with NH<sub>3</sub> and urea (reducing agents), breaking it down into N<sub>2</sub> and H<sub>2</sub>O.

As neither wet nor semi-dry desulfurization do anything to remove NOx, they need to be used in combination with an NOx system such as SCR. In comparison to these methods, DDDS has the following features.

- (1) Use of activated coke, which is effective as both an adsorbent and catalyst, means that the same system can remove environmental pollutants such as dust, dioxins, and heavy metals as well as SOx and NOx. The concentrations of these pollutants in the discharged gas are also sufficiently low for practical use.
- (2) Recovered SO<sub>2</sub> can be used to produce concentrated sulfuric acid (or gypsum) with high added value.
- (3) Because it does not use water for flue gas treatment, DDDS is suitable for locations where water is difficult to obtain and also keeps wastewater to a minimum.

### 4 Strengths of Nippon Steel & Sumikin Engineering Technology

The De-SOx and De-NOx performance of DDDS is determined by the inherent capacity of activated coke for sulfur and nitrogen oxide removal as well as by the design of the equipment that takes advantage of this capacity. Thanks to its accumulation of the following technologies and experience, Nippon Steel & Sumikin Engineering is able to design systems that provide both optimal and reliable operation.



Figure 3 Test system for evaluating performance of activated coke (example)

#### (1) Activated coke evaluation

As the capacity of activated coke for sulfur and nitrogen oxide removal varies widely depending on factors such as the form in which the coke is used, its composition, and the manufacturing process, Nippon Steel & Sumikin Engineering has its own test apparatus for activated coke that can evaluate its performance prior to use (see Figure 3). The capabilities of the test apparatus extend from measuring basic physical properties such as specific surface area, ignition point, and strength to assessing De-SOx and De-NOx performance using actual flue gas, replicating the gas and operating conditions used in practice. The apparatus was used to select a suitable activated coke for the DDDS in advance and to enable the system to be designed in the best possible way to suit various requirements based on data from testing with actual flue gas.

#### (2) Uniformity of activated coke movement in the adsorber

A lack of uniformity in the movement of the activated coke from the top to the bottom of the adsorber results not only in a drop in De-SOx and De-NOx performance due to regions of diminished flow where the activated coke is unable to work effectively, but also in thermal runaway (hot spots) caused by a buildup of heat from the SO<sub>2</sub> adsorption reaction, which can be severe enough to require the system to shut down. To deal with this, the adsorber made by Nippon Steel & Sumikin Engineering does not have any internal obstructions such as constrictions or steps, and the adsorber is divided into three zones (front room, middle room, and rear room) in the direction of gas flow to prevent a buildup of dust or

ammonium sulfate (a reaction product) during operation. Meanwhile, the roll feeder at the base of each zone transports the activated coke at a speed that is appropriate for their respective functions (see Figure 4). The front room, for example, traps dust and ammonium sulfate from the flue gas and therefore the activated coke is passed more quickly through this zone to prevent blockages.

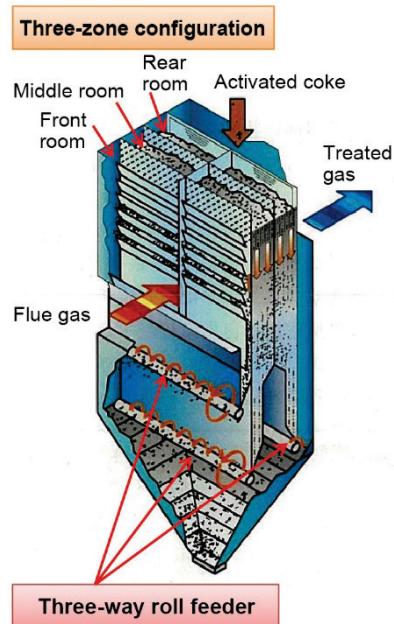


Figure 4 Internal structure of adsorber

### (3) Achievement of reliable operation based on many years of experience

The first DDDS was installed at Nagoya Steel Works of Nippon Steel & Sumitomo Metal in 1987 and has been in operation for more than 30 years (see Table 1). The system has been subject to periodic inspections during this time, building up knowledge about the extent of corrosion and other deterioration over time and implementing a series of equipment enhancements and improvements to operation and maintenance aimed at preventing problems like corrosion and hot spots. As a result, the system has achieved a long life, operating reliably over many years with no shutdowns due to corrosion or hot spots.

Table 1 Some past DDDS customers

Customer	Year of installation
Nagoya Steel Works, Nippon Steel & Sumitomo Metal	from 1987
Nagoya Steel Works, Nippon Steel & Sumitomo Metal	from 1999
BlueScope Steel (previously BHP Steel) Port Kembla	from 2003
Oita Steel Works, Nippon Steel & Sumitomo Metal	from 2003
POSCO Pohang steel works (two blast furnaces)	from 2004
Kimitsu Steel Works, Nippon Steel & Sumitomo Metal	from 2004
Kakogawa Works, Kobe Steel	from 2009
TISCO (two blast furnaces)	from 2010

## 5 Emission Regulations in China

The tightening of environmental regulations around the world is making the treatment of flue gas at steel works more important than ever. In particular, China's rules on the emission of SO<sub>2</sub>, NOx, and dust in sintering machine flue gas have undergone significant revisions since 2015, with a new set of rules intended to come into force in 2020 specifying levels that are more stringent than anywhere else in the world (see Table 2). Moreover, the regional government in China is taking a very strict approach to compliance with environmental regulations, including measures such as surprise factory inspections and online monitoring of the level of pollutants in emitted flue gas, and with steel works that are unable to comply with the environmental rules receiving significant fines or being issued with shutdown notices. This has led steel works to pick up the pace of investment in environmental equipment over recent years as measures for dealing with environmental issues become an urgent matter for companies, one that is crucial to their continued existence.

Fortunately, the evaluation of activated coke and operational experience of Nippon Steel & Sumikin Engineering indicate that its systems can comply with the new post-2020 rules.

Table 2 China's environmental rules for sintering machine flue gas

Year enacted	Geographic scope	SO <sub>2</sub> [mg/Nm <sup>3</sup> ]	NOx [mg/Nm <sup>3</sup> ]	Dust [mg/Nm <sup>3</sup> ]
up to 2014	—	600	500	80
from 2015	Generally applicable	200	300	50
	Designated zones only	180	300	40
from 2018	Designated zones only	50	100	20

## 6 Future Plans

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The DDDS supplied to the Chinese steel company TISCO in 2010 (see Figure 5) was the first of its type to enter operation in China and it serves as a model plant for other steel works and engineering vendors in China. While DDDSSs manufactured by Chinese engineering companies have become more common since 2015, Nippon Steel & Sumikin Engineering has taken advantage of its technical capabilities to get an early foothold in the market and establish a strong presence. Nippon Steel & Sumikin Engineering also intends to resolve environmental problems in Japan and elsewhere by utilizing its ability to provide reliable operation and a high level of performance at removing environmental pollutants in flue gas treatment.



Figure 5 DDDS at Chinese steel company TISCO (commenced operation in 2010)

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