The two-fluid nozzle with its flat spray pattern distributes the reducing agent evenly across the exhaust gas duct.

Pictures: Düsen-Schlick

Brilliant droplets

Nozzles and injection lances for NOx removal from flue gas

Air pollution regulations increasingly limit the amount of nitrogen oxides (NO_X) in flue gases produced by industrial combustion processes. Two of the technologies commonly used to control NO_X, selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR), both involve injecting ammonia or urea into the flue gas. Correct design of the injection lances is critical to good performance of the system as a whole.

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Both SCR and SNCR use ammonia (NH_3) or urea to reduce nitrogen oxides (NO_X) to nitrogen (N_2) and water (H_2O). SNCR is cheaper than SCR and easier to retrofit, in part because the reducing agent is injected directly into the boiler.

SNCR works best when the ammonia or urea is injected into the flue gas at a temperature close to 950 °C. Below 850 °C the reduction reaction is too slow, and unreacted ammonia is discharged from the stack. Above 1,100 °C ammonia decomposes to nitric oxide (NO), which is equally undesirable.

In a typical combustion plant there are few points where the flue gas temperature is within the temperature range 850–1,100 °C, and the residence time at these temperatures is also very short. For good results, SNCR therefore requires uniform dosing of the reducing agent over a wide duct cross-section.

SCR can remove a larger percentage of NO_X than is possible with SNCR, and with less slippage of ammonia. SCR differs from SNCR in that the reducing agent is injected at a temperature of 200–500 °C, after which the flue gas passes through a catalyst bed. To ensure even distribution of the reducing agent, static mixers may be positioned between the injection point and the catalyst bed.

This multiple nozzle head is fitted with two-fluid nozzles with external mixing and is suitable for large duct diameters.

Both processes normally use aqueous solutions of either ammonia (25 percent) or urea (40 percent). Urea is easier to transport and store, being odorless and non-toxic, but it tends to crystallize inside the injection nozzle.

Lance and nozzle design

The reducing agent is sprayed into the flue gas duct in a crossflow pattern for SNCR, and parallel to the gas flow in the case of SCR. Injection lances and nozzles are made from stainless steel, which for SNCR must be capable of operating at temperatures up to 1,150 °C.

Narrow droplet size distribution and accurate spray distribution are essential to good performance. Up to 1,500 l/h of liquid may need to be distributed evenly across a duct measuring 5 m x 2 m, with high gas velocities, rapidly changing flowrates and high turbulence. For best performance, the droplet size should be in the range 40–60 µm; poor control of droplet size or distribution increases reagent consumption and NO_X levels in the treated flue gas.

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Schlick injection lances are designed on the tube-in-tube principle, with a central tube for the reducing solution and an outer tube that carries low-pressure air. By preventing the solution from boiling within the lance, this arrangement extends nozzle life and helps to ensure accurate dosing. The compressed air also operates the atomizing nozzles (see below).

Schlick uses two-fluid atomizing nozzles to produce a flat cone of uniformly-sized droplets. In a two-fluid nozzle, compressed air or another carrier gas breaks up the fluid stream into droplets and accelerates them to sonic velocities.

The angle of the spray cone is adjustable in the range 10–40°, and the axis of the spray can be adjusted through 360° for best coverage. The nozzle tips can be replaced easily when they start to wear or to change the spray pattern.

External or internal mixing?

The air in a two-fluid nozzle can be introduced either inside or outside the nozzle. For SNCR and SCR, nozzles with external mixing are often preferred, because these are significantly less susceptible to blocking than two-fluid nozzles with internal mixing, or single-fluid nozzles. These simple and reliable devices are suitable for flowrates of up to 200 l/h per nozzle.

External mixing has its disadvantages, however. The high air velocity needed to form droplets with the correct size and size distribution creates a high-velocity spray cone with a relatively narrow angle. This works best in duct diameters up to 600 mm, and also requires a long downstream section to allow enough time for the liquid to evaporate.

The patented Schlick internal mixing nozzle reduces the droplet speed to around 45 percent of its value for a two-fluid nozzle with external mixing, more than doubling the effective contact between the flue gas and the urea or ammonia solution. These nozzles are suitable for individual flowrates up to 800 l/h and duct diameters up to 1,000 mm.

In this design, the liquid is forced into a mixing chamber and onto the tip of a central cone, forming a film that is then torn into droplets by the compressed air. The droplets leave the mixing chamber through holes around the base of the cone, aligned with the sides of the cone so as to create a wider spray pattern. The result is a nozzle that is highly resistant to blocking and which uses less air to create the same size droplets, thereby reducing the velocity of the spray and increasing the residence time.

For large ducts (DN 1000 and upwards), the reducing agent is sprayed into the center of the duct using a single lance carrying multiple nozzles. Two-fluid nozzles with interior mixing produce droplets that are too slow to reach the duct wall in the available residence time, so nozzles with external mixing are used instead. These nozzles produce cones with an angle of 30° and a high enough speed to ensure good mixing even in very large ducts. Current flowrates are in the range 200–1,000 l/h, though higher values are technically feasible. ■