Low-Cost Solutions for the Removal of Dioxin from EAF Offgas

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The iron and steel industry is under considerable pressure to continuously reduce the levels of generated dioxins and other harmful emissions from process offgas. In the early 1990s VAI commenced with the investigation of new offgas cleaning systems for sinter plants and electric arc furnaces (EAF) which resulted in a considerably improved offgas-cleaning efficiency. This paper outlines the technological solutions of the newly developed gas-treatment systems and application results in the steel industry.

INTRODUCTION

Of the various pollutants generated in metallurgical processes, dioxin is by far the most toxic. The problem of dioxin emissions is particularly critical in electric steelmaking plants where large quantities of externally purchased scrap—with the omnipresent organic and chloride compounds—are melted to reusable steel.

Dioxin is a generic term for a total of about 75 PCDD (polychlorinated dibenzo-p-dioxins) and 135 PCDF (polychlorinated dibenzo furans) compounds (Figure 1).

Important for judging the dioxin behavior in several technical processes is the knowledge of the vapor pressure as well as its formation and destruction attributes (Figure 2).

At high temperatures dioxin compounds are largely destroyed. However, during the gas-cooling phase dioxin reforms as a result of the reaction of organic components and chloride in the offgas at temperatures in the range of 200–600 °C. At a temperature range of 250–400 °C the de novo synthesis of dioxin is at a maximum. The temperature-dependent formation and destruction of dioxin is shown in Figure 3. As the reformation of dioxin is both temperature- and time-dependent, the actual quantity of generated dioxin is thus a function of the temperature-dependent gas kinetic parameters and the retention time that the gas lies within the de novo synthesis temperature zone (Figure 4). Therefore, in order to minimize the dioxin reformation, rapid cooling of the process offgas to below approximately 200 °C is the most efficient option.
The strategy for minimizing dioxin concentrations in offgas emissions is three-fold:
1. Maximum thermal destruction of dioxins and furans in the offgas by the prolonged retention of these components at temperatures exceeding 850 °C
2. Prevention of the regeneration of these components (de novo synthesis) during cooling by accelerated cooling of the offgas in the temperature zone 600–200 °C
3. Separation of the remaining dioxin/furan components from the offgas stream through the injection of activated adsorbents followed by filtering

As a leading supplier of electric steel-making plants, particularly in connection with the preheating of scrap in shaft furnaces, VAI developed various solution approaches to counter the problem of dioxin emissions to the environment. Following exhaustive testing these were industrially applied with considerable success. The outcome of these investigations and examples of operational results are outlined in this paper.

TECHNICAL SOLUTIONS
In order to limit the emission of dioxin to the environment a modularly designed EAF offgas system was developed by VAI which meets the specific process requirements of different EAF operation modes and furnace systems (conventional vs. shaft furnaces) (Figure 5). Each of the equipment units (boxes in this figure) of the individual treatment steps were optimized under operational conditions.

Combustion Zone
In conventional EAF offgas treatment systems a drop-out box is installed after the furnace elbow to trap the coarser dust particles and liquid slag droplets. The hot offgas stream (typically up to 1,000 °C) contains significant portions of CO gas which combusts upon contact with inducted ambient air. Simultaneously, the inherent VOC compounds and dioxin—arising from the organic substances contained in the charged scrap and, for example, from recycled materials—are partially destroyed depending on the prevailing gas temperature (see Figure 4).

With shaft-type EAF offgas treatment systems a combustion chamber is installed after the shaft exit into which air and fuel are injected and combusted to ensure that sufficiently high temperatures (e.g., > 850 °C) are achieved necessary for the destruction of the organic components and dioxin in the process offgas (Figure 6). A drop out box is not required because the coarser dust particles and liquid slag droplets from the EAF process itself are effectively filtered from the offgas stream by the scrap column in the shaft.

Gas-Cooling System
After the combustion zone a water-cooled, hot-gas line cools the offgas to a temperature of approximately 600 °C after which the gas is further cooled in either a water-spray cooler or in a forced draught gas-gas cooler to below 200 °C. The advantages of water spray cooling are high cooling rates, low pressure drops and the possibility for easy post-installation within an existing offgas system. The advantage of the forced draught cooling system is that no water is required which also simplifies cooler operations.

Spark Arresting Unit
In order to prevent damage to the bag filters spark arrestors are usually installed, depending on the respective EAF unit, the charge materials and the arrangement of the offgas system. Different designs are available (axial cyclones, deflection and gravity separators) in accordance with the required spark separation efficiency.

Dioxin Adsorption Zone
The still remaining dioxin present in the offgas stream can only be removed by means of condensation and/or through adsorption techniques followed by filtering. Decisive for a high degree of separation efficiency is the homogeneous dispersion of suitable particles (high specific surface area) into the offgas stream to maximize condensation and adsorption of dioxin (Figure 7). Normally, activated coal, (open hearth furnace coke) or activated coal blended with lime are used. The quality and quantity of the se-
Selected adsorbent is an important factor for overall plant-safety, i.e., reduced danger of ignition and explosion in the bag house. The adsorbent-injection system consists of an adsorbent silo, a dosing system, a spider distribution unit and the adsorbent-injection unit.

Filter Unit
The dioxin-enriched particles are filtered from the offgas stream in a suitably dimensioned bag house (pulse-jet or reverse-air filter system). The dust is collected in a dust silo after which it is normally agglomerated followed by subsequent recycling or disposal.

INDUSTRIAL APPLICATIONS
The above-described solution approaches for the removal of dioxin from EAF offgas were carried out at three well known EAF steel works in Western Europe.

Shaft Furnace
(Project Completion 2000)
A dioxin removal system was first installed in a shaft-type EAF plant. This project, including all optimization activities, was completed in the year 2000. The system features a postcombustion chamber with a natural gas burner system. After the combustion chamber the offgas passes through a water spray cooler equipped with a two-phase nozzle system. An adsorbent injection device is installed after the primary and secondary offgas mixing chamber. The dioxin-bearing gas is then cleaned in a pulse-jet type filter.

Conventional EAFs
Two other dioxin removal systems were installed in conventional EAF plants and the projects were completed in the years 2001 and 2002 respectively. Postcombustion takes place in a drop-out box after which coarse particles are removed from the offgas stream either in a water spray cooler equipped with a two-phase nozzle system (Project 2001) or in a forced draught air cooler (Project 2002). The cooled primary offgas is then mixed with secondary offgas after which it passes through a fabric filter where the fine particles are removed.

Measurement Results
A number of measurement campaigns were performed following the start-up of the offgas systems of the shaft furnace and the conventional electric arc furnaces. In order to accurately determine the system parameters for an efficient dioxin removal not only was the dioxin concentration in the clean offgas measured, but also at certain points within the offgas system itself.

The results of the dioxin concentration measurements for the shaft furnace are shown in the Sankey diagram in Figure 8 and compared with those of the conventional EAF offgas balance in Figure 9. It can be clearly seen that the dioxin concentrations in the primary offgas are very similar in both systems, but that the dioxin concentration in the secondary offgas is 4 to 5 times higher in the shaft furnace offgas system. This results in a slightly higher dioxin concentration at the filter entry site. As a result of the injection of adsorbents into the offgas stream, the dioxin concentration emitted to the atmosphere could be reduced to only 0.04–0.06 ng I-TEQ/Nm3_, which is well below the strictest environmental regulations of Western Europe. It must be emphasized that these extremely low dioxin emission values can only be achieved through the application of a suitable adsorbent injection system.

The measurement results taken from numerous conventional EAFs shows that the value of 0.1 ng I-TEQ/Nm3_ could be reached only in a few plants.

CONCLUSION
Dioxin Removal Efficiencies
1) With respect to the dioxin removal efficiency from the EAF offgas, considerable improvements can be achieved...
A high cleaning efficiency of the EAF off-gas system requires an optimized plant design and superior operational skills. Dioxin concentrations can be reduced to levels well below the specified environmental regulations through the combination of thermal treatment of the primary offgas (postcombustion), rapid cooling in an offgas cooler, entrained flow technology and efficient gas filtering. The outlined solutions to reduce the dioxin content in EAF offgas to values well below the strictest regulations represent the latest state-of-the-art in environmental technology.

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