Innovative Methods of Low-pollutant and Economically Efficient (Waste) Combustion

A number of new methods to optimize (waste) combustion processes have been developed and patented by Karlsruhe Institute of Technology (KIT).

Fixed-bed Burnout Control
INSPECT pro control® (1)
- Heterogeneous fuels, such as domestic waste, vary considerably in their burnout behavior.
- Use of special infrared and/or video camera systems, combined with powerful image processing techniques, allows the combustion status of the solid fuel bed to be determined online. In this way, characteristic quantities can be derived to describe the location of the fire, the extension of the main combustion zone, the temperature distribution over the entire surface of the fuel bed, and the state of grate loading.

Efficient flue gas burnout
Control of secondary air supply/distribution

(3)

Optimized low pollutant combustion

(1)

Efficient fuel bed burnout
INSPECT pro control®

Efficient power generation

(5)

Minimization of
PCDD/F-formation and boiler corrosion
a) Process integrated SO2-cycle and b) Optimized boiler design

(6)

Sulfated ash:
- low TOC, Cl-, PCDD/F

Bottom ash
low TOC, Cl-, PCDD/F

Ash deposit monitoring
Control of:
- a) boiler cleaning
- b) carbon injection

Low emission

< WID 2000/76/EC

No "PCDD/F memory effect" Adiox®

S-Recycling

Low-NOx-combustion and improvement of bottom ash quality
Acid-flue gas mixing and temperature control

(2)

(4)

(7)

No nitrosocompounds

Low NOx-combustion

Efficient fuel bed burnout

(1)

Low emission

< WID 2000/76/EC

No "PCDD/F memory effect" Adiox®

S-Recycling

Simple flue gas cleaning

Dust separator

Wet scrubber

Fly ash

Material recycling

These camera-based characteristic quantities are the basis for an optimum control of the furnace parameters. In this way, the thermal output and fuel throughput can be maximized and, at the same time, formation of pollutants can be reduced on the primary side.

Furthermore, efficient carbon burnout of the remaining slag is guaranteed.

The method can be used universally in all thermal processes, such as grate, rotary kiln, fluidized-bed, and dust furnaces.

The method is marketed by ci-Tec and applied in more than 30 plants worldwide.
In this way, optimum flue gas burnout is achieved even in relatively small combustion chambers. In particular, formation of incompletely burned flue gas streaks under non-steady-state combustion conditions can be prevented largely. CO peaks and elevated concentrations of soot particles are reduced effectively. At low concentrations of soot particles in the ash deposits on the boiler surface, formation of PCDD/F is clearly reduced.

The process (CUTNOx) is applied in technical plants by Götaverken Miljö AB.

Flue Gas Burnout Control (3)

Emission of incomplete combustion products (e.g., CO and hydrocarbons) is limited by legislation (WID 2000/76/EC). Especially heterogeneous fuels, such as domestic waste, may cause local combustion conditions to vary considerably. The flue gases entering the flue gas burnout zone exhibit significant local variations of the calorific value and O₂ concentration over the cross section (flue gas streaks). Globally controlled and homogeneous supply of secondary air over the cross section of the flue gas burnout zone requires relatively large combustion chambers to ensure efficient flue gas burnout.

IR and/or video camera-based online detection of the local burnout status of the flue gas over the entire cross section of the flue gas burnout zone allows the local combustion status to be captured and described by specific characteristic quantities. This information is used for fast control of local demand-oriented secondary air supply.

In this way, optimum flue gas burnout is achieved even in relatively small combustion chambers. In particular, formation of incompletely burned flue gas streaks under non-steady-state combustion conditions can be prevented largely. CO peaks and elevated concentrations of soot particles are reduced effectively. At low concentrations of soot particles in the ash deposits on the boiler surface, formation of PCDD/F is clearly reduced.
Monitoring of Ash Deposits (4)

- Organic pollutants, such as PCDD/F and mercury, can be removed very efficiently from the flue gases with the help of carbon-containing sorbents. In the “carbon entrainment process”, finely dispersed activated carbon dust is added to the flue gas at temperatures <200°C and then separated together with the fly ash in the fabric filter. Adsorptive pollutant separation takes place mainly when the flue gas flow passes the carbon-containing filter dust layer. Concentration of particulate carbon in the filter dust layer correlates with the separation efficiency.

- At temperatures above 200°C, chlorinated organic compounds, such as PCDD/F, are formed when particulate carbon is present in chloride-containing ash deposits (maximum formation at 300–350°C). This formation reaction is known as de-novo synthesis. Minimization of carbon concentration in the ash deposits in the above temperature range therefore is a prerequisite for minimizing the formation of these pollutants in technical furnaces.

- Carbon concentration can be determined by the automatic detection and evaluation of ash deposits based on video-optical measurements (reflectivity). This information can be used to control an automatic boiler or filter cleaning system and/or carbon addition for flue gas cleaning.

Reduction of PCDD/F Formation and Boiler Corrosion (5)

- Formation of chlorine (Cl₂) in chloride-containing ash deposits on the boiler surface of waste combustion plants causes considerable corrosion of the metal boiler material and gives rise to PCDD/F formation via oxychlorination reactions of particulate carbon (soot particles) in the ash. Emission of PCDD/F is limited to <0.1 ng/Nm³ TEQ in the European Waste Incineration Directive 2000/76/EC.

- Sulfation of the fly ash efficiently reduces the formation of Cl₂ and, hence, dioxin formation. PCDD/F concentration in the raw gas drops to values <0.1 ng/Nm³ TEQ. Consequently, there is no need for PCDD/F-specific flue gas cleaning. The residues of flue gas cleaning are practically free of PCDD/F.

- Reduced formation of Cl₂ also decreases chlorine-induced boiler corrosion. Efficiency of electricity generation can be enhanced by elevated steam parameters.

- The SO₂-recirculation-process is applied in technical plants by Götaverken Miljö AB.

- Efficiency of sulfation can be further increased by an improved design of boiler geometry. A longer cooling time of the flue gas from 900 to 700°C results in the formation of a sulfated fly ash with a low chloride content at relatively low SO₂ concentrations.

Recovery of Metals from the Filter Ash (6)

- The fly ash produced by sulfation (5) can be recycled. By a thermal/reductive treatment at defined temperatures (for Pb and Zn about 600°C), heavy metal sulfates are practically quantitatively reduced to metals or metal sulfides. In this form, they are nearly insoluble in water and can be extracted selectively as a solid secondary raw material concentrate by a simple scrubbing process with High SO₂ concentrations reduce chloride concentration in the fly ash and ash deposits.

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2(Na,K)Cl + SO₂ + \frac{1}{2} O₂ + H₂O \rightarrow (Na,K)₂SO₄ + 2 HCl
\]

- Selective separation of SO₂ and recovery as SO₃, H₂SO₄ or (NH₄)₂SO₄ in a modified wet scrubbing process allows for the implementation of a process-integrated SO₂ cycle by recycling into the furnace. Hence, no expensive co-combustion of sulfur, sulfur compounds or sulfur-containing fuels is necessary. The need for neutralizing agents and the residues arising in flue gas cleaning remain unchanged.
subsequent solid/liquid separation. The metals are then transferred to use in metallurgical processes.

**Wet Scrubbing Process with Adiox® (7)**

- PCDD/Fs are absorbed in plastics. After an extended period of operation, a temperature-dependent equilibrium load is established between the flue gas and the polymer. Wet scrubbers that are mostly equipped with polypropylene fillers may release PCDD/F under equilibrium loading because of temperature fluctuations. These “memory effects” of PCDD/F enriched in polymers must be prevented.

- Doping of the polymer matrix with carbon-containing particles (Adiox®) causes efficient irreversible separation of PCDD/F. There is no need for any design changes of existing wet scrubbers. It is sufficient to install the fillers of Adiox® material. The wet scrubbing process modified in this way also has the function of a police filter and ensures reliable compliance with the emission limits even during startup and shutdown or in cases of transient operation. As an option, the wet scrubbing process can be equipped with an additional Hg and fine dust removal function.

- The process is distributed by Götaverken Miljö AB and applied successfully in more than 80 technical reference plants.

The processes can be applied individually or in combination in combustion processes (grate, rotary kiln, fluidized bed). In grate furnaces for waste combustion, all processes can be combined into one optimized overall concept. The use of innovative control strategies, such as fuzzy control, results in high synergy effects. The result is a low-pollutant combustion with simple flue gas cleaning and enhanced efficiency of electricity production. All present environmental standards can be observed or improved in a cost-efficient manner. The processes are implemented technically in cooperation with our competent industrial partners.