KIT
Karlsruhe Institute of Technology

KIT Energy Center

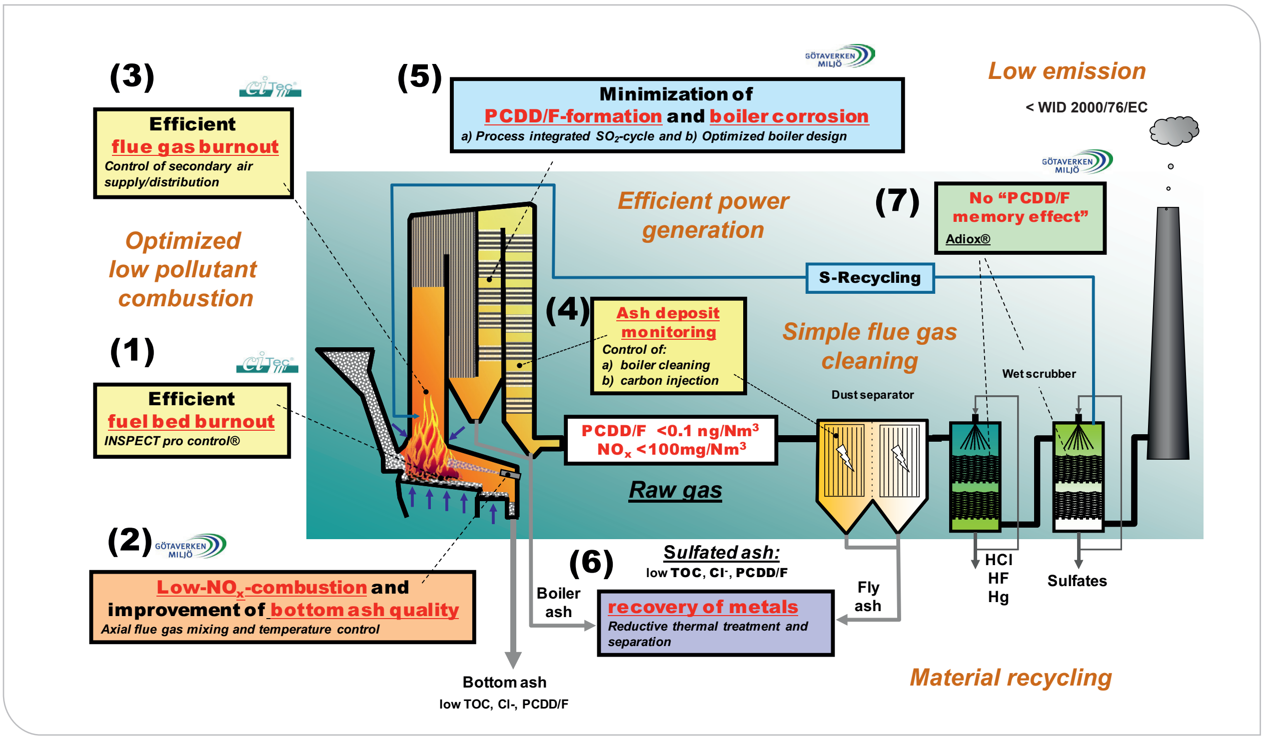
Institute of Applied Computer Science/
Institute for Technical Chemistry

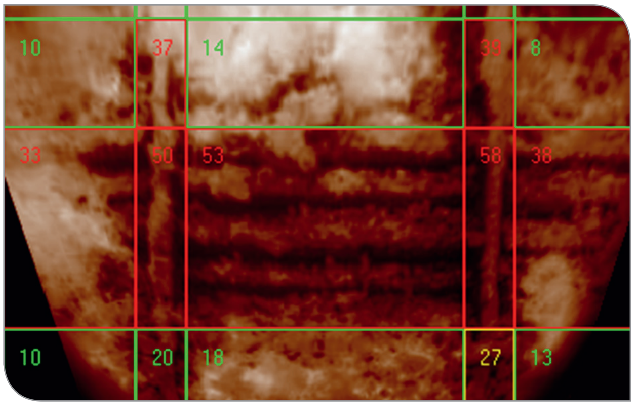
Innovative Methods of Low-pollutant and Economically Efficient (Waste) Combustion

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)

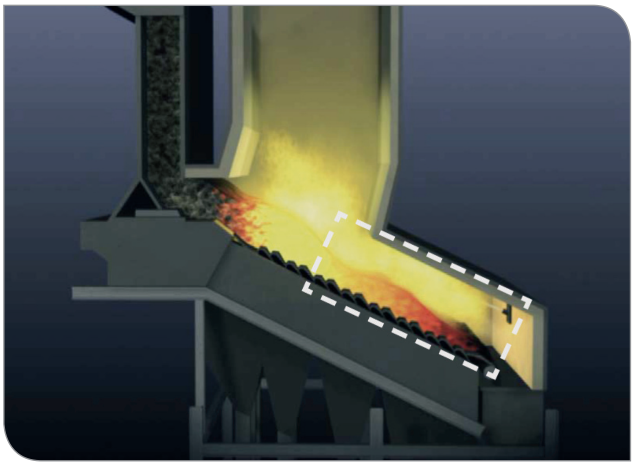
- Heterogeneous fuels, such as domestic waste, vary considerably in their burnout behavior.
- Use of special infrared and/or video camera systems, combined with powerful image processing techniques, allows the combustion status of the solid fuel bed to be determined online. In this way, characteristic 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.
- 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.





Low-NOx Combustion and Slag Improvement (2)

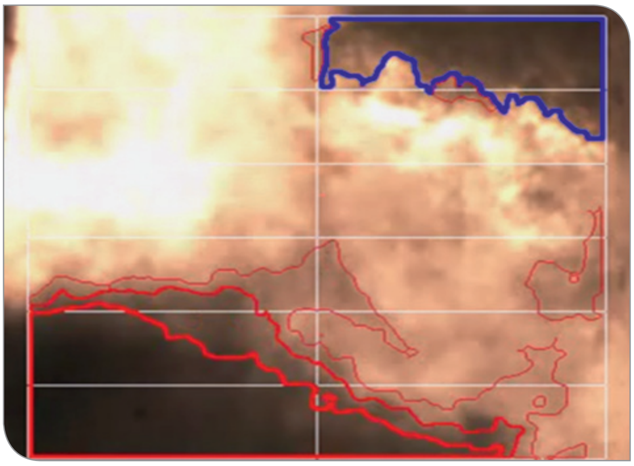
- Emission of nitrogen oxides (NO_x) from combustion processes is limited by the European Waste Incineration Directive 2000/76/EC (WID 2000/76/EC). NO_x reduction in flue gases requires the use of sophisticated secondary processes, such as SCR or SNCR, and the addition of reducing agents (e. g. NH_3).
- In waste and biomass furnaces, NO_x is generated almost completely from the nitrogen contained in the fuel. Fixed-bed burnout primarily causes the formation of NH_3 and NO. Under modified operating conditions, these nitrogen compounds may preferably react to nitrogen (N_2) during flue gas burnout in an autogenous SNCR process, while NH_3 emissions and N_2O production are prevented.
  $4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$
- Axial mixing of all flue gas flows emanating from the fuel bed and simultaneous combustion chamber temperature control by means of a controlled gas/water free jet allow the combustion process to be set such that the resultant NO_x concentration in the raw gas drops to values < 100 mg/Nm³. Consequently, there is no need for secondary flue gas cleaning processes to reduce NO_x or for the addition of reducing agents (NH_3).



- Flue gas mixing above the fuel bed clearly raises the temperature in the fuel bed at the end of the grate, which results in both NO_x minimization and a considerable improvement of the slag quality (TOC, Cl, PCDD/F). Apart from better utilization options of the slag, plant-specific fuel throughput can be increased.
- 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 O_2 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.



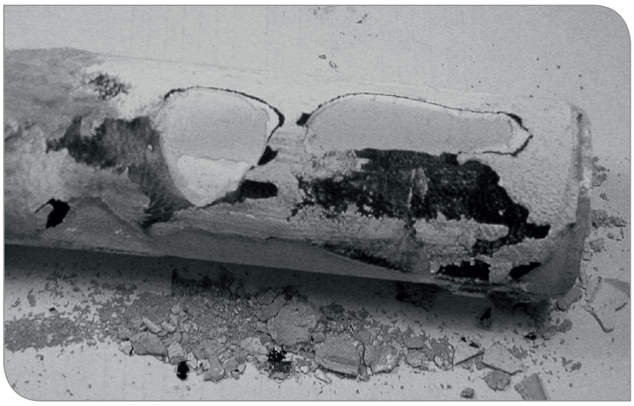
- In this way, optimum flue gas burnout is achieved even in relatively small combustion chambers. In particular, formation of incompletely burned flue gas streaks under non-steady-state combustion conditions can be prevented largely. CO peaks and elevated concentrations of soot particles are reduced 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 (Cl_2) 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/Nm^3 TEQ in the European Waste Incineration Directive 2000/76/EC.



- Sulfation of the fly ash and ash deposits on the boiler surface can reduce chloride concentration and, hence, formation of Cl_2. The Cl/S ratio of the fly ash and ash deposits correlates with the HCl/SO_2 ratio of the flue gas. High SO_2 concentrations reduce chloride concentration in the fly ash and ash deposits.

$2(Na,K)Cl + SO_2 + ½\ O_2 + H_2O \rightarrow (Na,K)_2SO_4 + 2\ HCl$

- Selective separation of SO_2 and recovery as SO_2, H_2SO_4 or $(NH_4)_2SO_4$ in a modified wet scrubbing process allows for the implementation of a process-integrated SO_2 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.

- Sulfation of the fly ash efficiently reduces the formation of Cl_2 and, hence, dioxin formation. PCDD/F concentration in the raw gas drops to values <0.1 ng/Nm^3 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 Cl_2 also decreases chlorine-induced boiler corrosion. Efficiency of electricity generation can be enhanced by elevated steam parameters.
- The SO_2-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 SO_2 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 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.

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