Fuel-Specific On-Load Boiler Cleaning Solutions for Waste-to-Energy Plants

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1. Introduction

Ash-related operating troubles caused by slagging, fouling and corrosion are currently the main reason for unscheduled shut downs, both in biomass and waste incineration plants. Strongly influencing factors for fly ash composition and for the fouling tendency
are the quantity and the distribution of ash-forming matter in the fuels as well as the actual operating parameters.

In the past, main interest with regard to slagging and fouling was focused to coal fired plants [3]. Work in this field comprised the conventional analysis of ash generated under laboratory conditions and extracted from plants respectively [8] as well as the development of new methods for ash analysis [2]. Later on, interest extended to analyse ashes originating from combustion of biomass, domestic, industrial and hazardous waste as well as fuel mixtures [4]. The results show a clear difference between the ashes resulting from the latter ones and coal ashes.

Whereas coal ashes are silica rich, causing a high-viscosity silic an melt, which in result in slagging and fouling, is ash from the other group of fuels characterized by a high salt content in the form of alkaline and alkaline earth sulphates, chlorides and carbonates. These salt mixtures build up a melt of very low viscosity that unlike coal ashes have an area of melting temperatures instead of a fixed melting point. Today, it is known that ashes of biomass and waste firing with a weight proportion of 15 to 70 % molten phase are the main cause for slagging and fouling of furnaces, open passes and convective heating surfaces [1, 7].

Every form of uncontrolled slagging and fouling reduces the efficiency of boilers. However, at incineration plants operating performance and boiler operating times are heavily influenced by fouling in open passes. Fouling on the membrane walls of the open passes can lead to significantly reduced heat transfer which consequently increases the flue gas temperature before the super-heaters. This change in the heat transfer ability of a plant can have considerable implications. The increased temperature profile may change the fouling characteristic in the convective part. The weight fraction of the salt melt may rise dramatically depending on the actual fuel characteristics, leading to increasing boiler end temperature and therefore causing unscheduled boiler outages with the effect of production and economic losses. In addition, with rising flue gas temperatures and corresponding chemical composition of the fuel, the risk of high-temperature corrosion increases. Depending on local conditions in the boiler, the wear rate is much higher, which in turn leads to shorter lifetime of the heating surfaces.

The solution for these fuel- and boiler-specific challenges is the absolute adherence to the heat transfer characteristic specified by the boiler manufacturer, independent of load and fuel mixtures.

On-load boiler cleaning systems, which are fuel- and plant-specific designed, contribute a targeted support to cope with this task. Besides efficient on-load boiler cleaning systems by Clyde Bergemann, e.g. the Water Cannon, the Shower Cleaning System (SCS) and the SMART Helix Water, a dedicated automation concept and process engineering know-how complete this approach, which implies detailed knowledge about the process as well as the utilized fuels. The following chapters highlight the fuel-specific challenges and the operating principle of the cleaning systems mentioned above. Finally, with reference to a case study fuel-specific on-load boiler cleaning solutions are presented.
2. Deposit formation during waste and biomass incineration

Gaining detailed knowledge, deposit formation in different large scale boilers is a wide field of research. Besides the direct analysis of boiler deposits, very often indirect analytical methods are applied to obtain information about deposit formation. Fuel analysis as well as flue gas analysis are suitable for this. The fuel analysis does contain several challenges. Firstly, a representative fuel sample with an as homogeneous as possible chemical composition needs to be available. When it comes to analyse fossil fuels, this point is relatively easy to realize and is used in practice. But representative fuel samples of waste are hardly available over a longer period of time, which makes this method difficult to apply. In addition, the results out of fuel samples and laboratory ashes have to be questioned concerning their significance compared with deposit formation under real operation conditions, as laboratory ashes pass a quite different temperature treatment and therefore showing non-comparable chemical and physical properties. Recent approaches to analyse the deposit tendency without thermal treatment of the fuel, e.g. the wet chemical fuel analysis [5], try to accommodate this but are very time- and cost-intensive. The flue gas analysis, which typically includes the evaluation of the chemical components HCl and SO₂, does have merit and can be used as an initial indicator. But it has to be considered, that the chlorine (Cl) in the fuel can occur as HCl in the flue gas and as chloride salt in the deposit, whereas the distribution between these states strongly depends on the operating parameters.

The same is valid for the chemical component sulphur in the fuel, which can be found as oxide in the flue gas and as sulphur in the deposit [9].

Due to these reasons, the most reliable evaluation of deposit is the chemical analysis of the deposit itself. Figure 1 shows the result of an energy-dispersive X-ray spectroscopy with a scanning electron microscope (SEM/EDX) for deposits from an open pass of a plant fed with domestic and industrial waste. Depending on fuel composition, deposits in incineration plants consist of chlorides, sulphates, silicates and alkaline salts. The specific characteristics of a salt mixture in a boiler greatly depends on the distribution of the chemical elements to the salt compounds (e.g. sulphates, chlorides), the ratio of the salt compounds, the temperature distribution in the boiler and therewith the ash particle temperature and further operating parameters, e.g. the local stoichiometry. Ash deposits containing salt mixtures have a specific melting behaviour. Contrary to silicate melts, which are characterised by a defined melting temperature, salt melts have a wide melting range and a very low viscosity. Many years of experience in handling with fuels high in alkaline, primarily in pulp and paper industry, have shown, that ash particles with a liquid content of 15 % of their mass adhere to the furnace walls. This behaviour continues up to a melt fraction of approximately 70 %. Above this limit, the liquid content grows so high and the viscosity gets so low that the ash tends to flow down vertical surfaces. These observations have led to the definition of sticky conditions in terms of the particle temperatures $T_{15}$ and $T_{70}$ (Figure 2). As shown in Figure 2, these melting curves can strongly depend on single chemical elements. An increase of the fraction of such elements in the melt can lead to a dramatically reduced sticky temperature $T_{15}$ and further implications associated to this change.
Figure 1: Elementary analysis of deposits out of an open pass of an incineration plant; oxygen (O) calculated.

Figure 2: Ash melting curve in the equilibrium phase with the characteristic values T15 (temperature at 15 wt. % molten phase) and T70 (temperature at 70 wt. % molten phase).
3. Removal of deposits with water as cleaning medium

The usage of water as cleaning medium in incinerators is a proven technology since many years. The on-load boiler cleaning systems, the Water Cannon, the Shower Cleaning System and the SMART Helix soot blower technology, clean plants with porous silicate deposits according to the same principle. Water introduced into the boiler in sufficient quantity via nozzles intrudes deeply into the pores of the deposits, evaporates immediately due to the direct heat transfer and breaks off the deposits by the subsequent volume extension. For the cleaning success, it is important that the moment of cleaning, water impact and quantity hitting the deposits are plant-specifically adjusted. These factors ensure the optimum penetration of the porous deposits by the water, eliminating any risk for the lifetime of the boiler walls and preventing any damage to materials handling systems due to spare water.

4. Cleaning principle of the water cannon

The cleaning principle of Water Cannons is based on a bundled water jet which crosses an open passes respectively to clean the opposite boiler wall by carrying out individually defined cleaning figures. Central equipment of the Water Cannon is the lance, plugged in a boiler wall opening, which is equipped with a boiler specified nozzle. This nozzle ensures the required formation of the water jet. The lance is supported by a ball joint enabling the targeted move in x- and y-direction (Figure 3).

First implementation of a Water Cannon system at an incineration plant took place more than 20 years ago at the MVA Krefeld [4], Germany, and is since then – with some modifications – used there as reliable on-load boiler cleaning system.

5. Cleaning principle of the shower cleaning system

The Shower Cleaning System has been developed later, specifically designed for the requirements of incineration plants. The beginning of this technology goes back to development works done at the incineration plant MSB Schwandorf, Germany, in 2001. Since then, this technology, where a cleaning nozzle enters the boiler through an opening at the boiler roof, has been further developed (Figure 4). This cleaning nozzle forms a water jet with a defined spectrum of water droplets and with a defined momentum.
The cleaning nozzle is mounted at a flexible, temperature-resistant metal hose, which will be retracted completely and rolled up after the cleaning. The lance enters the boiler guided by a flange, which is opened and closed through an electro-pneumatical valve. Depending on thermal load and flue gas composition, sealing air protects the valve against corrosion. The number and location of the flanges at the boiler roof are constructed according to boiler design and actual deposition tendency. The Shower Cleaning System is mainly used at boilers with a depth of less than 4 m as well as in areas in front of pendant heater exchangers and super-heater surfaces. At boilers with a depth of more than 4 m, the usage of Water Cannons is more efficient when boiler walls can be clearly segmented. With a usage of 0.8 to 1.7 l/s process water, both systems are comparable.

Meanwhile, Shower Cleaning Systems by Clyde Bergemann are implemented at more than 150 incineration plants fed with domestic municipal, hazardous waste as well as RDF. The Shower Cleaning Systems are used in these plants for targeted and selective cleaning of membrane walls, the boiler roof area and even pendent heater and super-heater heating surfaces. In the majority of the cases, the systems showed good cleaning effects after commissioning. In a few cases, plants with design- or fuel-specific features may require an optimization phase after commissioning. If so, the situation is analysed in close cooperation with external experts and works out together with the plant operators necessary optimization actions.

6. Cleaning principle of SMART helix water system

The system has been developed as an innovative on-load cleaning system especially for the convective part in waste and biomass boilers. In order to intensify cleaning efficiency in these areas, water is used as the cleaning medium and a novel water soot blower was introduced, a derivative of a successful steam soot blower. It is based on two motors for flexible lance positioning with independent axial and rotational lance movements. Therefore flexible helical/oscillating blowing figures as well as Go-Stop-Clean-Go blowing mode are possible.

Water as a cleaning medium for convection area is a novel approach, therefore some considerations e.g. thermal impact on the metal surfaces are necessary to prevent surfaces being hit by water too frequently or the soot blowing process being wrongly started too early and already clean heat exchanger tubes being over cleaned.
In order to completely prevent water blowing on metal surfaces, an advanced jet interruption technology was applied in this novel soot blower system. As a result, the Go-Stop-Clean-Go mode ensures, that the soot blower performs water cleaning only in relevant areas like e.g. the space between heat exchanger tubes. Therefore, the water jet hits only the deposits and not the tubes. Another advantage is that less water will be injected into the boiler due to the water flow being interrupted during nozzle head movement from one axial position to the next. During the blowing stop, water returns in a circulating cooling flow back to the water supply station. Due to the technology and the intermittent water jet, almost any thinkable blowing figure is possible in order to perform soft and effective cleaning actions. The new Go-Stop-Clean-Go mode performed by the water soot blower based on this technology allows especially effective, and simultaneously selective and gentle convection area cleaning in waste-, biomass- and RDF fired plants.

The SMART Helix Water system consists out of the innovative soot blower device SMART Helix Water, of the water inlet and water outlet modules to enable Go-Stop-Clean-Go mode and frequency controlled pump module. The whole process and cleaning know how is implemented in the SMART Helix PLC module.

The technology has been successfully installed in more than 40 waste incinerators as well as RDF and biomass fired boilers. Among the positive cleaning effects which were achieved after many years of operation, the following are noteworthy:

- effective convective area on-load cleaning,
- avoiding of unplanned boiler outages due to super-heater plugging,
- long term flue gas temperature stabilization,
- stable boiler operation and extension of boiler operation time before next outage.
7. Operational experience with on-load boiler cleaning systems

The case study described here is based on an incineration plant currently fed with 19 t of domestic waste. The plant is designed as a horizontal pass boiler with three open passes and a boiler depth of 7 m. The plant has been commissioned without appropriate boiler cleaning systems, which shortly after commissioning led to operational constraints due to fouling in the open passes. As a consequence, the flue gas temperature before the super-heater increased to more than 650 °C after less than 2,000 operating hours. In addition, material wear off up to 0.3 mm per 1,000 h caused by corrosion was detected. The domestic waste burnt in this plant is comparatively well sorted. An analysis of the deposits formed during operation in the third pass showed on average a chemical composition that contained low fractions of the elements chlorine and sodium, which are both critical for the salt melt behaviour (Figure 5). This finding was confirmed by the physical structure of the deposits. With regard to these fuel-specific properties, was designed and implemented an on-load boiler cleaning solution.

At the second open pass Water Cannons were mounted opposed to each other in the boiler’s side walls, supported by a Shower Cleaning System on the boiler roof at the third pass. The entire boiler cleaning system works fully automated, controlled from the control room.

![Chemical analysis of a deposit from the third pass of the investigated waste incinerator](image)

Figure 7: Chemical analysis (parts) of a deposit from the third pass of the investigated waste incinerator

Figure 6 shows the development of the flue gas temperature in front of the super-heater after implementation of Clyde Bergemann’s on-load boiler cleaning solution. Even after more than 7,000 hours, the critical flue gas temperature of 650 °C has never been exceeded. The process evaluation, carried out over a period of more than one year, gained following insights:
Scheduled shut down time could be reduced by two days, as the usual cleaning during shut down became redundant after the targeted cleaning of the on-load boiler cleaning systems.

Over a period of more than 7,000 operating hours, the flue gas temperature before the super-heater was constantly kept below 650 °C enabling a reliable plant operation.

Due to the significantly lower flue gas temperature, the corrosion rate could be decreased from 0.3 mm/1,000 h to 0.19 m/1,000 h.

8. Summary and outlook

On-load boiler cleaning systems, comprising Water Cannons, Shower Cleaning Systems and SMART Helix Water Soot blowers, make a lasting contribution to fuel- and plant-specific cleaning of heat exchanger surfaces of incineration plants and biomass fired boilers. Especially for individually designed incineration plants handling varying fuel qualities, the use of these boiler cleaning systems supported by employees’ fuel and process engineering know-how allows a flexible response to different operating conditions. From existing installations, extensive measurement results and experiences with the implementation and operation of this boiler cleaning technology is available, which is archived in the company’s internal database and stored for future applications. Experiences show, that both new-build and retrofitted incineration plants benefit from on-load boiler cleaning solutions due to extended boiler operating times and reduced maintenance costs.

In addition to the on-load boiler cleaning systems presented in this paper, other innovative systems as well as new holistic on-load cleaning concepts for incineration plants are developed that guarantee reliable and efficient plant operation with maximized waste throughput.
Rapping device systems are innovative products for cleaning horizontal superheater paths. Cleaning takes place by means of individually adjustable impact energy for each heating surface. Furthermore the intelligent decision-making product SMART Clean Compact extends the range of innovative products. As in fossil fuel fired boilers, the optimized use of on-load boiler cleaning systems is becoming increasingly important at incineration plants. Optimized use means: when, where and how has the on-load boiler cleaning to be performed with view to actual plant conditions. Based on successfully implemented diagnostics and optimization systems at steam generators, an optimization concept specially designed for the requirements of incineration plants was worked out. Besides an advanced on-line heat and mass balance, this concept considers firing constraints and fuel-specific properties, too.

9. Literature


