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FUEL-SPECIFIC ON-LOAD BOILER CLEANING SOLUTIONS IN WASTE INCINERATION PLANTS – CHALLENGES; CONCEPTS, EXPERIENCES

Christian Mueller
Clyde Bergemann GmbH
Wesel, Germany

Manfred Frach
Clyde Bergemann GmbH
Wesel, Germany

Marc Tirkschleit
Clyde Bergemann GmbH
Wesel, Germany

Danny Tandra
Clyde Bergemann Inc.
Atlanta, GA, USA

Charlie Breeding
Clyde Bergemann Inc.
Atlanta, GA, USA

ABSTRACT

The range of fuels fed to waste incineration plants extends from well-sorted domestic refuse through mixed waste fractions to fuel mixtures that may additionally contain various types of hazardous waste and biomass. This diversity results in a great number of fuel and ash compositions. Among these are fuels with a high calorific value as well as with a low calorific value and simple fuel ashes just as highly problematic fuel ashes. The latter can lead to increased slagging in the combustion chamber and fouling in the open passes of waste incineration plants as well as accelerated corrosion. The plant operator is consequently faced with considerable challenges associated with unscheduled boiler downtime and production losses.

The paper describes how fuel specific process know-how is applied in combination with fully automated, efficient on-load boiler cleaning systems to control the slagging issues. The paper describes a system which utilizes water as the cleaning medium. The system allows the targeted cleaning of waste incinerators during operation.

This paper points out challenges faced by plant operators and suppliers of boiler cleaning technology caused by the heterogeneous fuel composition, and describes in well monitored case studies how these challenges can be successfully met.

INTRODUCTION

Ash-related operating challenges caused by slagging, fouling and corrosion are currently the main reason for unscheduled shutdowns, both in fossil fired power boilers and in biomass and waste incineration plants. Strongly influencing factors for fly ash composition and therefore 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 came from coal fired plants [1]. Work in this field comprised the conventional analysis of ash generated under laboratory conditions and extracted from plants respectively [2] as well as the development of new methods for ash analysis [3]. In addition to this experimental research, mathematical models of different complexity and purpose have been developed and applied. These include both, complex thermodynamic calculations to determine multiphase equilibria [4] and boiler balances as well as flow simulations to determine the physical and chemical conditions in large-scale boilers [5, 6, 7].

In recent years, interest extended to analyse ashes originating from combustion of biomass, domestic, industrial and hazardous waste as well as fuel mixtures. 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 silica melt, which in turn results in slagging and fouling, ash from the other group of fuels are 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 a melting temperature range instead of a fixed melting point. Today, it is known that ashes of biomass and waste firing with a weight fraction of 15-70% molten phase are the main cause for slagging and fouling of furnaces, open passes and convective heating surfaces [8, 9].

Every form of uncontrolled slagging and fouling reduces the efficiency of large-scale boilers. However, at incineration plants operating performance and boiler operating times are heavily influenced by fouling in open passes. Fouling of the membrane walls of the open passes can lead to significantly reduced heat transfer which consequently increases the flue gas temperature in front of the superheaters. This change in the heat transfer ability of a plant can have considerable implications. The increased temperature profile may change the fouling characteristics in the convective pass. The amount of salt melt may increase dramatically depending on the actual fuel characteristics, leading to an 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 strict operation of the boiler according to design parameters, independent of load and fuel mixtures. On-load boiler cleaning systems, which are designed fuel- and plant-specific, contribute to achieve this task. Besides efficient on-load boiler cleaning devices, such as the Water Cannon and the Shower Cleaning System, a dedicated automation concept and detailed process know-how belong to such an on-load boiler cleaning system.

The following chapters highlight the fuel-specific challenges and the operating principle of the cleaning systems mentioned above, both operated with water as cleaning medium. Finally, with reference to two case studies with very different chemical composition of the ashes, fuel-specific on-load boiler cleaning solutions are presented.

DEPOSIT FORMATION DURING WASTE AND BIOMASS INCINERATION

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 a homogeneous chemical composition needs to be available. When it comes to analysis of 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, since 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, try to accommodate this but are very time consuming and cost-intensive.

The flue gas analysis, which typically includes the evaluation of the chemical components HCI and SO2, does have merit and can be used as an initial indicator. But it has to be considered, that the chlorine (CI) in the fuel can be presented as HCI 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 sulphur in the fuel, which can be found as oxide in the flue gas and as sulphate in the deposit.

Due to these reasons, the most reliable evaluation of a deposit is the chemical analysis of the deposit itself. Usually a SEM-EDS analysis of the deposit is performed, followed by elemental mapping (Fig. 1).

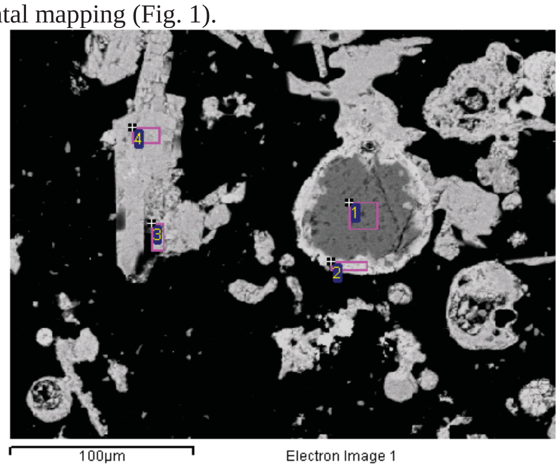

Figure 1 BSE-image with identified spots for elemental mapping.

Figure 2 shows the elemental mapping results for deposits from 11 boilers fed with domestic and industrial waste. The great diversity of chemical compositions of the deposits becomes obvious.

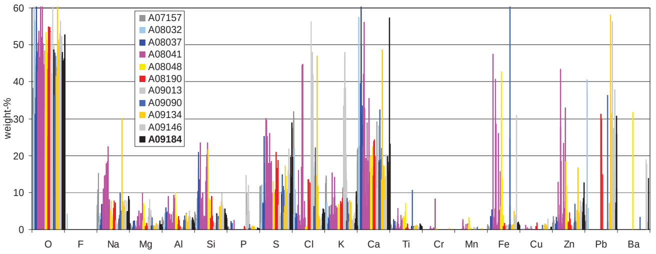

Figure 2 Elementary analysis of representative deposits out of 11 waste incineration plants. Oxygen (O) calculated.

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 depend on the chemical composition (e.g. sulphates, chlorides), the ratio of the salt compounds, the temperature distribution in the boiler and related the ash particle temperature and other operating parameters, e.g. the local stoichiometry. Ash deposits containing salt mixtures have a specific melting behaviour. Contrary to silicate melts, which are characterized by a defined melting temperature, salt melts have a wide melting range and a very low viscosity. Many years of experience in handling fuels high in alkaline, primarily in the pulp and paper industry, have shown, that ash particles with a liquid content of 15% of their mass stick to the furnace walls. This behaviour continues up to a melt fraction of approx. 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 T15 and T70 (Fig. 3).

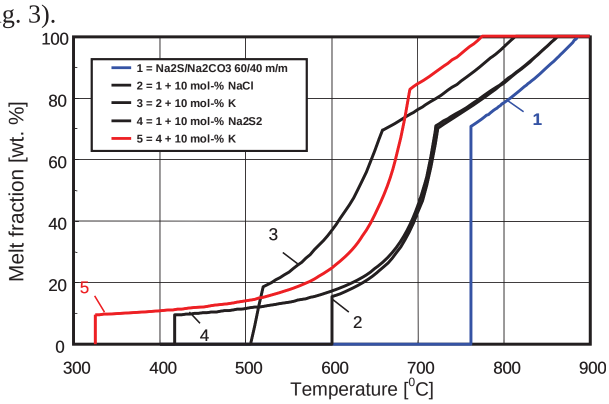

Figure 3 Ash melting curves with the characteristic values T15 (temperature at 15 wt. % melt) and T70 (temperature at 70 wt. % melt)

As shown in Fig. 3, these melt curves can strongly depend on single chemical elements. An increase of the fraction of such elements like chlorine (Cl) in the fuel and therefore in the melt can lead to a dramatically reduced sticky temperature T15 and further implications associated to this change.

REMOVAL OF DEPOSITS WITH WATER AS CLEANING MEDIUM

The use of water as cleaning medium in coal fired utility boilers is proven technology since decades. Both on-load boiler cleaning systems, the Water Cannon and the Shower Cleaning System, clean plants with porous silica deposits according to the same principle. Water brought onto the deposit through the cleaning system deeply penetrates into the pores of the deposits, evaporates very fast 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 point in time, the water impact pressure and the water quantity hitting the deposit are plant-specific. 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 excess water.

The use of certain wastes and biomasses as well as certain firing conditions, leads to the build-up of both porous deposits and dense, non-porous deposits. These dense, non-porous deposits are characterized by a closed surface and contain a high fraction of alkali salts. The salt mixture starts melting at comparably low temperatures so that an alternative cleaning strategy is required. In such cases, contrary to the approach described above, controlled cleaning based on water jets with a higher momentum needs to be applied.

CLEANING PRINCIPLE OF THE WATER CANNON

The cleaning principle of Water Cannons is based on a concentrated water jet which crosses a furnace or open pass, respectively to clean the opposite boiler wall by carrying out defined cleaning patterns. The central piece of equipment of the Water Cannon is the water lance equipped with a boiler specific nozzle. This nozzle ensures the required formation of the water jet. The lance is supported by a ball joint enabling the targeted movement in x- and y-direction (Fig. 4).

First implementation of a Water Cannon system at an incineration plant took place in 1998 at the waste incinerator Krefeld, Germany, and is since then – with minor modifications – in use as reliable on-load boiler cleaning system.

Figure 4 SMART Cannon CB 100 with ball joint supported lance and two servo-modules for movement in x- and y-direction

CLEANING PRINCIPLE OF THE SHOWER CLEANING SYSTEM

The Shower Cleaning System has been developed later and is especially designed for the requirements of incineration plants (Fig. 5). The beginning of this technology goes back to development works done at the incineration plant Schwandorf, Germany, in 2001.

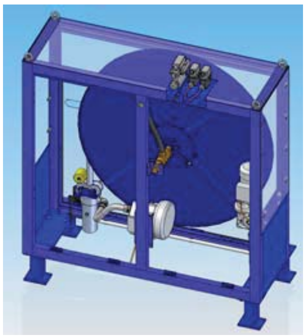

Figure 5 Shower Cleaning System as a stand-alone module

In this cleaning concept a cleaning nozzle is mounted at a flexible, temperature-resistant hose, which will be inserted and retracted to and from the boiler and rolled up after the cleaning. The cleaning nozzle forms a water jet with a defined spectrum of water droplets and with a defined momentum. The hose enters the boiler through a flange, which is opened and closed through an electro-pneumatic valve. Depending on thermal load and flue gas composition, sealing air protects the valve against corrosion. The number and location of the flanges on the boiler roof is designed according to boiler design and actual deposition tendency (Fig. 6).

Meanwhile, Shower Cleaning Systems by Clyde Bergemann are implemented at more than 70 incinerator plants fed with biomass, domestic and hazardous waste. The Shower Cleaning Systems are used in these plants for targeted and selective cleaning of membrane walls, the boiler roof area and even pendent heat exchanger surfaces. In the majority of the cases, the systems showed very good cleaning effects after commissioning. In a few cases, plants with design- or fuel-specific features may require an optimisation phase after commissioning. In such cases Clyde Bergemann analyses the situation and works out together with the plant operator necessary optimisation actions.

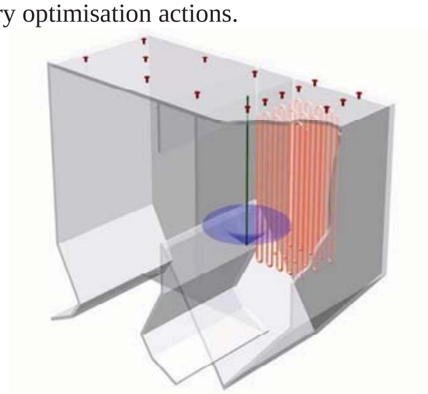

Figure 6 Arrangement of flanges at the boiler roof and schematic presentation of flexible hose and water spray.

The Shower Cleaning System is mainly used at boiler passes with a width of less than 4 m as well as in areas in front of pendant heater exchangers and superheater surfaces. At passes with a larger width than 4 m, the use of Water Cannons turned out to be more efficient. With the consumption of 0.8-1.7 l/s process water, both systems are comparable at incinerator conditions.

OPERATIONAL EXPERIENCE WITH ON-LOAD BOILER CLEANING SYSTEMS

CASE A – The case study presented here describes an incineration plant operated with 19 t/h of domestic waste. The plant is designed as a horizontal pass boiler with 3 open passes and a pass width 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 in front of the superheater increased to more than 650°C after less than 2000 hours of operation. As a consequence material wear of up to 0.3 mm/1000 h caused by corrosion was detected.

The domestic waste burnt in this plant is comparably 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 (Fig. 7). This finding was confirmed by the porous structure of the deposits. With regard to these fuel-specific characteristics, an on-load boiler cleaning solution was designed and implemented. At the second open pass Water Cannons were mounted opposite to each other in the boiler side walls, supported by a Shower Cleaning Systems on the boiler roof of the third pass. The entire boiler cleaning system works fully automated from the control room.

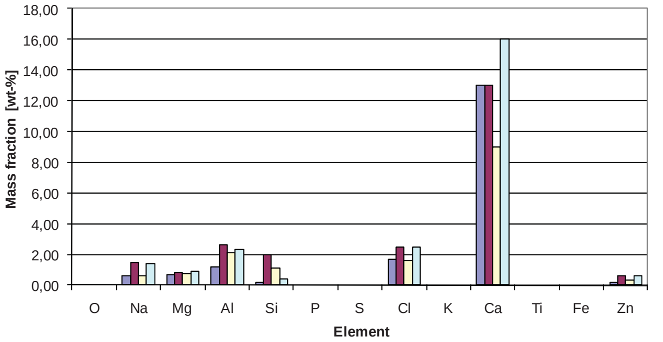

Figure 7 Chemical analysis of four deposits from the third pass of the investigated waste incinerator.

Fig. 8 shows the development of the flue gas temperature in front of the superheater after implementation of the on-load boiler cleaning solution. Even after more than 7000 hours, the critical flue gas temperature of 650°C has not been exceeded.

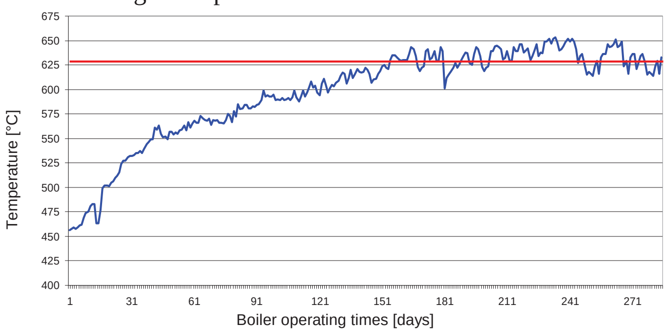

Figure 8 Flue gas temperature in front of the superheater of the analysed incineration plant.

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 shutdown became redundant after the targeted cleaning with the on-load boiler cleaning systems
- Over a period of more than 7000 operating hours, the flue gas temperature in front of the superheater was 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/1000 h to 0.19 mm/1000 h

CASE B – The incineration plant described in the following is also designed as a three pass boiler and has suffered from severe fouling in all three passes since commissioning several years ago. The fouling frequently leads to unscheduled boiler shutdowns, which is not acceptable for the operator in the long run. The planning of an adequate on-load boiler cleaning solution is still ongoing. A special challenge here is the inhomogeneous fuel composition. In addition, detailed analysis of the deposits along the flue gas pass revealed a complex chemical composition of the deposits that are high in sodium, sulphur, chlorine, potassium and calcium (Fig. 9). This composition is an indicator for a high salt content in the form of alkaline and alkaline earth sulphates, chlorides and carbonates in the deposits as well as for a non-porous and dense deposit surfaces.

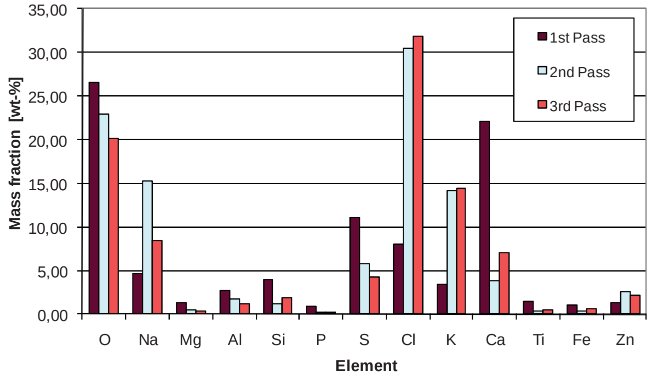

Figure 9 Chemical analysis of the deposits along the flue gas pass of the investigated waste incinerator. Oxygen (O) calculated.

With regard to boiler design and the fuel-specific properties, a combination of several Water Cannons and Shower Cleaning Systems along the first two open passes is intended as cleaning concept for this plant. Initial test results indicate that different positions along the flue gas stream require the selection of different cleaning parameters to successfully overcome the specific characteristics of the deposit surfaces (Fig. 10). Prior to the final decision, on-site tests have to be conducted, evaluating most suitable fuel- and plant-specific cleaning parameters and in addition process know-how needs to be collected to design a fully automated system.

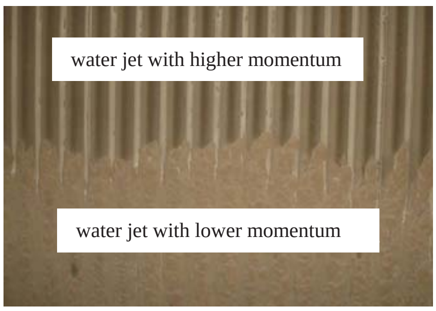

Figure 10 Membrane wall with dense deposits at the beginning of the second pass treated with water. The use of water jets with varying momentum resulting in different cleaning efficiencies.

SUMMARY AND OUTLOOK

On-load boiler cleaning systems by Clyde Bergemann, comprising Water Cannons and Shower Cleaning Systems, 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 fuel and process know-how allows a flexible response to different operating conditions.

From existing installations, measurement results and experiences with the implementation and operation of boiler cleaning technology is collected in a database for future applications. Experiences show, that both new-build and retrofitted incineration plants benefit from on-load boiler cleaning solutions by Clyde Bergemann due to extended boiler operating times and reduced maintenance costs.

In addition to the on-load boiler cleaning systems presented in this paper, Clyde Bergemann is working on optimized on-load cleaning concepts for incineration plants that guarantee reliable and efficient plant operation with maximized waste throughput. As with utility boilers also here the WHEN, WHERE and HOW to start on-load boiler cleaning considering actual plant conditions is the key to success.

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