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New technologies for Waste to Energy plants

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Abstract

The demands on modern waste to energy plants very much focus on high energy efficiency, long continuous availability and low maintenance and operational cost. At the same time, the plant has to live up to a new, strict EU legislation. These requests result in new technologies such as Advanced Combustion Control (ACC), use of Inconel® protection in boilers, boiler cleaning, water cooled combustion grates and wear zones. This paper will describe how Babcock & Wilcox Vølund (BWV) is improving the design of waste to energy plants by implementing these new technologies.

Introduction

Design and production of waste incinerators comprise many parameters, and it is a very complex analysis to optimise the final design. A number of possible plant designs can be made that are combinations of the same main components and processes. However, each design shall be evaluated from the customer's requirements on that particular market. The table below contains a list of the most essential parameters which are to be included in the analysis of the boiler.

- Weight
  - Size
  - Fin division
- Production price
- Efficiency
  - Outlet temperature
  - λ - O_2
  - Loss
  - Air preheating
  - Operating hours > 8000
- Integration of furnace
  - Combustion quality
  - Flue gas temperatures
  - Flue gas flow
  - Suspension
- Design furnace configuration
  - Counter flow
  - Centre flow
  - Parallel flow
- Design boiler layout
  - Number of empty radiation drafts
  - Horizontal/vertical conv. part
  - Baffle wall / evaporator tube
  - Superheater / parallel flow or counter flow
  - Soot blowing / rapping gear
- Heat transmission
  - Radiation part
  - Surface heat load
  - Convection part - economiser
  - Tube configuration
  - Fouling
- Materials
  - Inconel®
  - Refractory lining
  - Corrosion
- Water / steam circulation
- Erection & Service

Table 1 Design parameters for waste to energy boilers

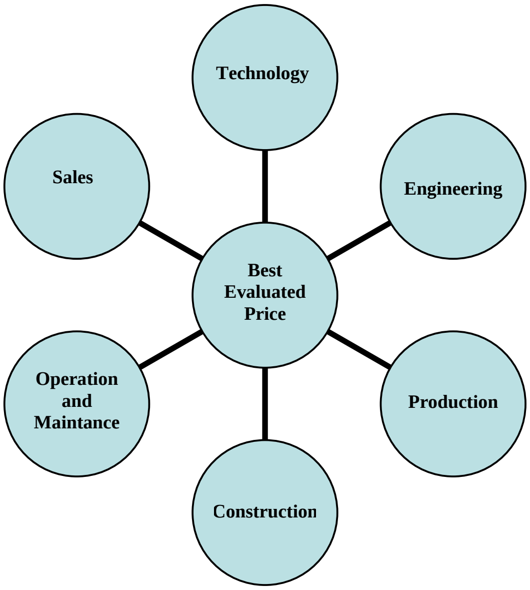
Today, the furnace has become an integrated part of the boiler design. In general, there are 3 different furnace/boiler layouts; counter, centre and parallel flow. It is important to consider advantages against disadvantages. We know for instance that the parallel flow principle offers a number of advantages with regard to combustion, including a low NO_x emission. The latter is important because of the new EU emission limits for NO_x. On the other hand, the parallel flow furnace has some disadvantages concerning heat transmission and water/steam flow conditions. The centre flow configuration is a less complicated design and gives a simple and better water circulation system and thereby a lower price for the construction of the boiler. Moreover, the size of the furnace wall area is minimised and thereby the cost of refractory or Inconel® is less, see below.

The past few years we have focused on improving the thermal efficiency of the plants and thereby the steam and energy production, as these are weighty parameters for the estimated project price. Experience from this work shows that most modern waste to energy plants has very high energy efficiency. However, an optimized thermal process is only half of the competition parameter, and it does not necessarily take the price and function of the equipment into account.

It is important to focus on the weight / price of the boiler and on how complicated it will be to design and erect the boiler. In this connection it is essential to identify expensive / inexpensive design details for the boiler as well as conditions that might have influence on the erection of the boiler. The construction time for the project is typical a very important parameter in the evaluated price.

Another very important and competitive parameter is the plant availability. Today, we face requirements for plant availability of typically 8000 hours per year. The operation hours are, of course, one of the most important factors for the plant owner, because that is the basis for his yearly income and thereby if it is profitable business. This fact results in very conservative development where the investors tend to choose well-proven technology in order to minimise the economical risk.

In order to achieve the plant availability and reduce operation and maintenance cost, there has recently been focused on a number of new technologies. These technical solutions have to be in compliance with the conditions stipulated by the market.



New design elements:

- Advanced combustion control systems
- Inconel® ® alloy 625 instead of refractory
    - Overlay welding
    - Compound tubes
- New boiler cleaning systems
- Water cooled combustion grate
- A water cooled wear zone above the grate

ACC – Advanced Combustion Control

In some cases it can be useful to expand the normal control concept by an ACC system – **A**dvanced **C**ombustion **C**ontrol system. The main objectives by using ACC systems are:

- **Reducing operation cost**
  - Less operation people on each working shift – even unmanned in night time
  - Reduce maintenance cost and operational mistakes
  - Reduce consumables

- **Improve process stability**
  - Automatically handling of major steps or change of the heating value
  - Fixed position of main combustion and burnout zone
  - Reduction in variation of process parameters as steam flow, temperatures, CO etc.

The standard DCS systems are fully capable of controlling the plant and maintain stable operation. In normal operation and with homogeneous flow of waste and thereby heat input, the benefit of an ACC system is quite limited, and a well-skilled operation staff can run the plant without any problems.

A new EU legislation for landfills will reduce and finally forbid the amount of burnable waste that goes to landfill. The consequence is more variation in the heating value of the waste going to combustion. Furthermore, there will be increased focus on reducing the operating cost in order to be competitive and reduce the cost per tonne burned waste. All in all, these tendencies will increase the demand for ACC systems.

The chemically bounded energy in the waste is released partly in the fuel layer and partly in the furnace room. Even though a certain surplus of primary air is led to the combustion process in the waste on the grate under normal conditions, a local gasification of the waste will take place. This is among other things due to the fact that the waste layer is very inhomogeneous, and some of the combustion air can penetrate channels created in the waste layer. Furthermore, pyrolysis gases will be released in the ignition zone due to a fast heating up of the upper waste layer before the combustion begins. These burnable gases flow up into the furnace room where they are mixed with surplus primary air from other parts of the grate and with secondary air. Thus, a pure gas phase combustion right above the fuel layer is created, whereby a relatively large part of the waste energy is released, typically 30% to 50% of the energy input - references 1. Finally, some particles will “leave” the grate and burn in the furnace room and in the post combustion chamber.

The combustion reaction rate is very difficult to determine as the controlling partial processes are heterogeneous solid gasification and combustion, and homogeneous gas phase combustion in and above the fuel layer. Generally, the processes between the oxygen in the combustion air and the solid waste are diffusion controlled and thereby relatively slow, whereas the gas phase combustion is controlled by temperature and concentrations and the rate of reaction relatively high. In practice, this means that the reaction rate of the whole process is mainly controlled by the mass flow of primary combustion air and its temperature.

Knowledge of all the above processes is very important in relation to design and operation of a waste incineration system. Some important design parameters to be considered are: Type of grate, excess air flow, primary and secondary air distribution, waste bed height, grate speed, etc.

As previously mentioned, there is a strong connection between the burning rate and the amount of primary air, both the total amount and the distribution along the grate. As regards control and operation, the major difficulties appear to be:

- Adjustment of operating conditions to compensate for changes in the waste quality and quantity.
- The lack of measurement techniques available for rapid evaluation of the combustion processes in the fuel bed.

The latest problem has been the occasion of several research projects and development activities during the latest 10 years – references 2, 3 & 4. They have developed measurement and monitoring systems based on an IR camera, capable of providing a thermal mapping across the fuel bed. The thermal image is used to calculate mean temperatures for a number of locations across the grate corresponding to the individual primary air zones. The thermal image is evaluated to give an indirect indication of the intensity of the combustion on the grate.

The advantage of the camera measurement system is detailed information in 2-dimensions about the surface temperature of the fuel bed. The main weakness of this technique is the interpretation of the data and influence of solid particles on the thermal image. Recording of high radiation in one area could be a result of a high concentration of burning particles and soot instead of a hot spot on the

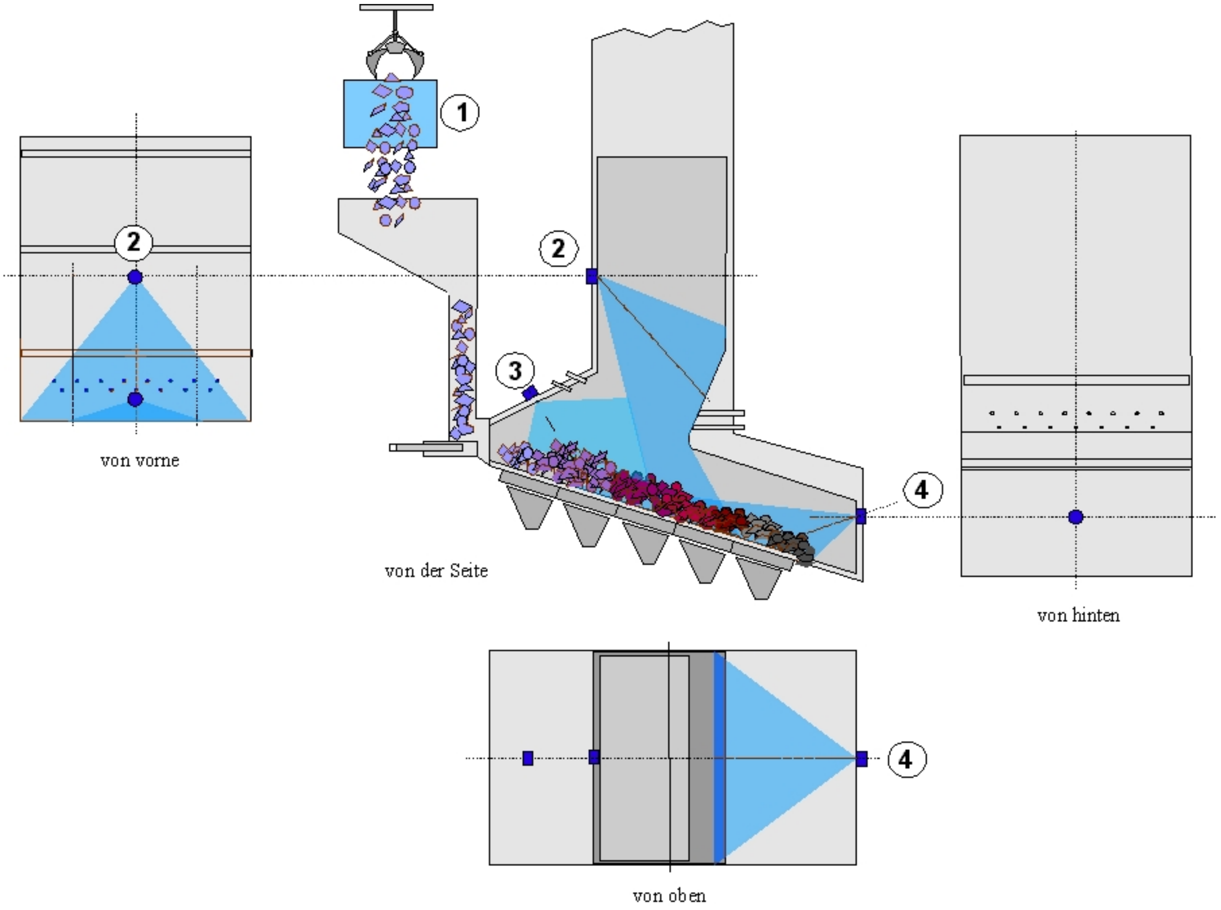


Figure 1 Position of CCD camera at the L90 plant. (Courtesy of powitec)

fuel bed. It is well-known that in some parts of the fuel bed gasification is more pronounced than combustion. The thermal image cannot give information about the type of process going on in the fuel bed.

BWV’s ACC system is supplied in cooperation with the companies Powitec and ABB. The ACC system consists of a number of CCD cameras and a control unit built up around the neural network. The CCD cameras give temperature images of the burning waste on the grate, and these images will show where the ignition and burnout zones are placed on the grate – see figure 1. The ACC system uses neural networks to determine the temperature distribution from the digital pictures obtained from the CCD cameras.

As shown in figure 1, camera number 1 is monitoring the waste coming in to the furnace and combined with crane weight (density) a correlation will be made to the heating value of the incoming waste and thereby a feed forward signal.

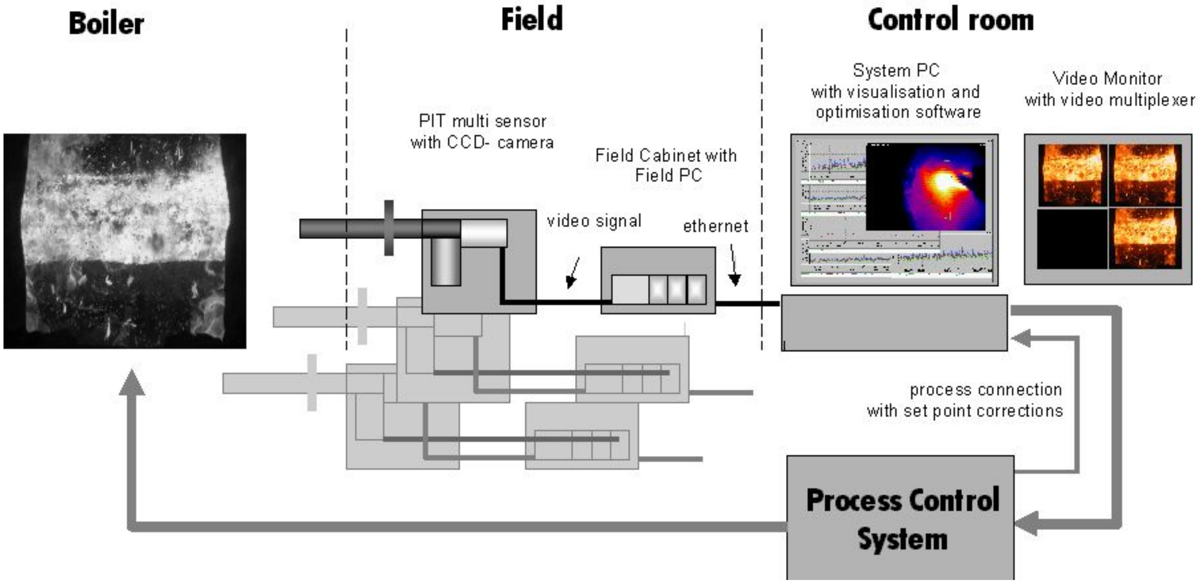


Figure 2 ACC system based on CCD camera and set point correction.

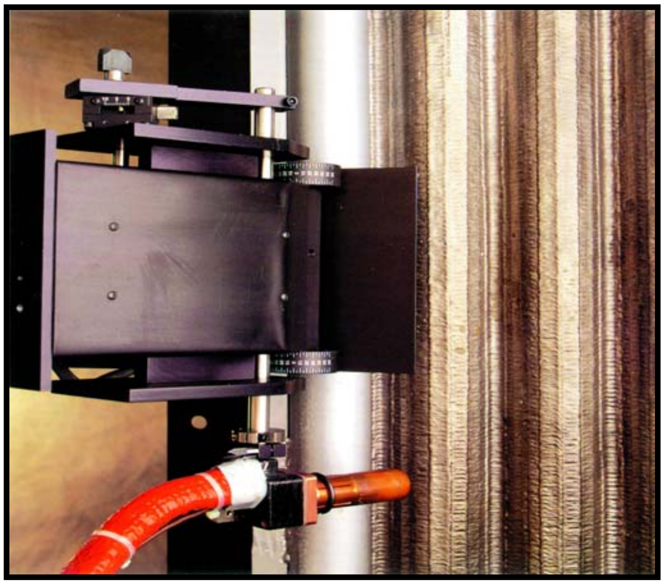
(Courtesy of powitec)

Being in operation, the neural network generates remote set points to the energy controller, the grate velocity controller and the combustion air controllers. Each of these controllers’ set points can be individually chosen to run at either a remote set point from the neural network or from a set point chosen by the operator – see figure 2. The ACC system will continuously adjust the primary air distribution, primary- and secondary air amount, primary air temperature and grate velocity in order to achieve a stable and good combustion and ensure that the different combustion processes on the grate is correctly located.

The neural network part of the ACC system is open to all signals of the plant. The neural network will find coherences of the parameters and adjust the control accordingly for example the secondary air vs. oxygen, secondary air vs. NO_x, etc. The neural network is able to learn the behaviour of a plant by looking at the process parameters and as a result the ACC system will be able to manage much of the operator's work. This is in contrary to fuzzy system which is an expert system based on operation rules.

Inconel® alloy 625 cladding and composite tubes

During the years, many plants have reported of problems when using ceramic tiles as corrosion protection in the boiler. It is therefore considered a large advantage to use Inconel® 625 instead of refractory as protection. For a number of years, this technique has been used successfully in the upper part of the post combustion chamber of the boiler. The new element is to replace as much as possible of the refractory in the boiler by Inconel®.



The use of Inconel® as protective material against corrosion is coming from the pulp & paper industry. Besides avoiding refractory in the boiler there are other advantages such as a smaller and more compact boiler design. Moreover, there is no need for a flue gas recirculation system to cool the furnace and refractory, even with the high heating values that are characteristic of the waste in Scandinavia. The flue gas recirculation (FGR) system is a technically complicated system with high maintenance costs.

The FGR system has often been mentioned in the literature as a primary measure for NO_x reduction, because of the lower temperature in the combustion zone and thereby less formation of thermal NO, reference 5 & 6. As concluded in reference 6, the contribution of thermal NO_x in waste combustion is very small, and the controlling parameter is the excess air number for the fuel bed. Using Inconel® in the furnace makes it possible to operate the plant at lower oxygen levels and thereby reduce the NO_x emission and increase the thermal efficiency.

Despite the savings of omitting refractory and flue gas recirculation system, the direct total price of an Inconel® boiler is higher than the classic set-up. The extra price of the Inconel® /compound tubes will partly be compensated for in the evaluated plant price avoiding the cost of refractory maintenance.

In general, there are two methods of applying Inconel® in a boiler, either using composite tubes or using Inconel® cladding. The Swedish company Sandvik is producing a two-layer tube also called a composite tube. The tubes consist of two components, metallurgically bonded together. The inner tube is a carbon steel tube able to meet the requirement for pressure vessel approval. The outer tube is made by a corrosion resistant alloy, as for example Inconel® 625. Sandvik has many years of experience with composite tubes used for black liquid recovery boilers for the pulp and paper industry. Over the last years they have tested compound tubes in different positions in waste boilers and achieved a very promising improvement of lifetime.

The most used technique is Inconel® cladding which is an overlay welding using Inconel® 625 as filler material. Babcock & Wilcox Vølund has worked with this concept for more than 5 years and is specialised in corrosion protection of boilers. The combination of welding technology, welding gas and filler material has been determined and developed by Babcock & Wilcox Vølund in close cooperation with the leading laboratories within the field. For new application, in-shop cladding is the most used method. During manufacture all welding parameters are continuously checked and controlled following extensive QA/QC procedures. The Inconel® components are delivered to the customer's site for final assembly. This concept gives a guarantee of high quality of the Inconel® cladding and minimum erection time. The Fe-content of the Inconel® cladding will typically not exceed 6 %; this result is achieved by a cladding concept with two separate layers of Inconel®. The finished, sandblasted Inconel® panels are delivered with dimension tolerance rates in line with our general manufacturing standards.

In some cases, it is recommended to carry out the Inconel® cladding on site. Babcock & Wilcox Vølund has extensive expertise in this area and performs on-site semi-automatic or manual application. The guarantee time for on-site Inconel® works on corroded boiler walls is somewhat reduced in comparison with the guarantee time for in-shop manufactured boiler walls.For new in-shop manufactured panel walls it is possible to provide a five-year warranty, depending on incineration conditions, pressure and temperature. Such a warranty is based on annual inspections and adjustments, where required. Babcock & Wilcox Vølund provides a full warranty service concept, under which down-time caused by corrosion is reduced to a minimum and unscheduled standstills are avoided.

The material loss rates have been measured and compared for the Sandvik composite tubes and the overlay cladding and the average metal loss is the same, reference 7. Moreover, the majority of experiments reported in reference 7, identifies Inconel® 625 as the most corrosion resistant alloy at conditions known from waste combustion.

The lifetime of superheater tubes is often a critical parameter, and today the main trend is a 5 years operation guarantee based on rather conservative steam data as for example 400 °C and 45 bars. New materials as Inconel® and design tools as CFD modelling, reference 8, will probably result in more progressive steam data and thereby increasing electrical efficiency.

New boiler cleaning systems

In the convection sections it has been normal practice to remove ash deposits by use of sootblowers and mechanical rapping devices. On the other hand, it is a fairly new practice to clean the radiation part of the boiler. The extensive use of refractory in both the first and second radiant drafts has made it impossible to clean these areas in the past. Introducing Inconel® instead of refractory for corrosion protection has changed the situation and a number of cleaning systems have been tested in the radiant part of the boiler.

In some cases high fouling rates, not expected at the planning stage of the waste to energy plant, result in high demands on the cleaning systems. Unexpected fouling in the radiant part of the boiler will result in higher inlet temperatures to the convection part. In order to control corrosion and fouling in the superheater section it is normal practice to design for a maximum temperature before the superheaters at 650 °C. A new cleaning method has been developed which considerably reduces the undesired downtimes with the cost-intensive manual cleaning of the boiler plants. As a result, the boiler operating periods specified at the planning stage can be realized.

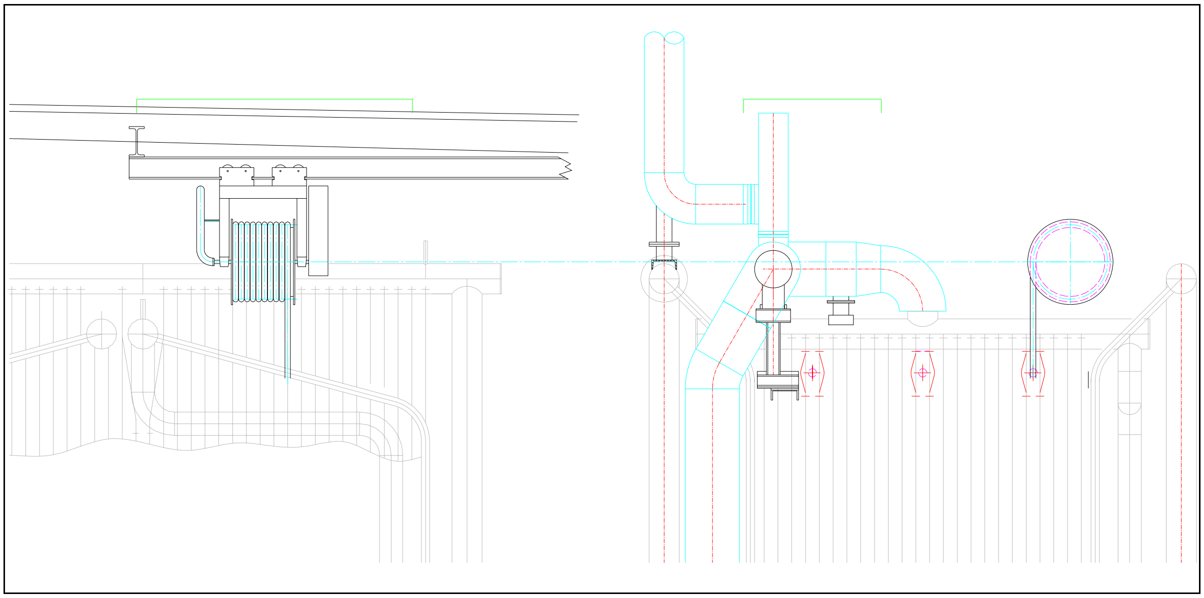


Figure 3 Automatically controlled water hose and rotating nozzle cleaning system

The cleaning system consists of a hose which is lowered into the boiler through the ceiling, see figure 3. At the end of the pipe, a rotating nozzle is mounted, which operates with water as blowing agent. The water jet penetrates, with high kinetic energy, the pores of the slag coat on the tube walls, evaporates and causes the tenacious slag to flake off as a result of the abrupt increases of the volume produced.

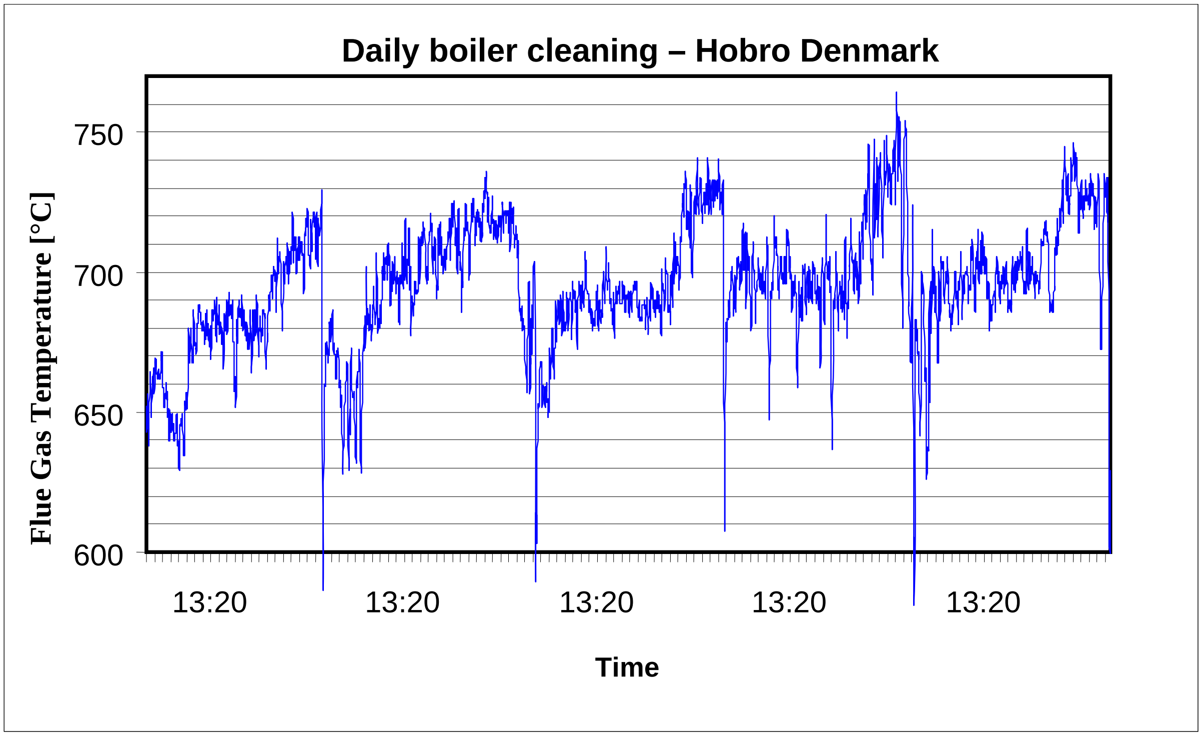


Figure 4 Daily cleaning of the second radiant draft

The technology of water hose and rotating nozzle cleaning system is particularly suited for cleaning the radiant part of the boiler and thereby control the inlet temperature to the convection part. It enables an effective cleaning performance at low operating costs.

Cleaning of the evaporator walls by means of water yields a very good result. In figure 4 the outlet temperature of the second draft is shown as function of time. A daily cleaning sequence gives a temperature reduction of 60 °C to 70 °C.

Water cooled combustion grate and wear zone above the grate

There is an increasing market demand in Europe for a water cooled combustion grate which is able to burn waste with high heating values. In Scandinavia it is normal to burn quite big fractions of industrial waste as for example demolition wood and different types of biomass resulting in periodically very high heating values. Moreover, water cooled combustion grates give a number of other advantages, such as lower maintenance cost, reduced amount of grate riddling and less problems with melted metal.

Finally, the primary combustion air can be controlled without consideration to cooling of the grate bars. In that way, it is possible to stage the combustion process and reduce the NO_x formation. Lately, BWV has made tests with operation at oxygen levels around 4½ % - 5 % resulting in NO levels in the range 150 – 200 mg/Nm^3. If these results can be confirmed in long term tests it would be possible to meet the NO_x emission limit without a de-NO_x system.

Combustion grates for waste have been gradually modified over time. The historical development started from a relatively open low pressure air cooled grate, ending with high pressure water cooled grate. The development has been determined by circumstances in the surrounding world, such as increased amounts of metals in the waste and increasing heating values. Today, the water-cooled grate at high pressure drop has become state-of-the-art technology. The major disadvantage of the grate, however, is the complicated cooling system which is expensive and a sensitive process which in case of failure can stop the complete plant.

The w-grate resembles a staircase. The individual steps – the grate bar – are alternately placed horizontally and vertically. These grate bars are mounted on axles and, as the grate bars of one axle interfere with the bars of the adjoining axle, a continuous grate carpet is formed. When the axles turn 60 degrees in the opposite direction during the movement of the grate, the steps are changing from vertical to horizontal and from horizontal to vertical. The changing of the steps from horizontal to vertical and vice versa produces a waving longitudinal optimum turnover and distribution which ensures the drying, conveying, and combustion of the waste bed.

The cooling water is led to and from the grate through the shaft ends and to the middle sections of the shafts through firm pipe connections, see figure 5. There are no sensitive hose connections inside the furnace. Damages due to grate siftings, melting tin, aluminum, etc. are efficiently prevented.

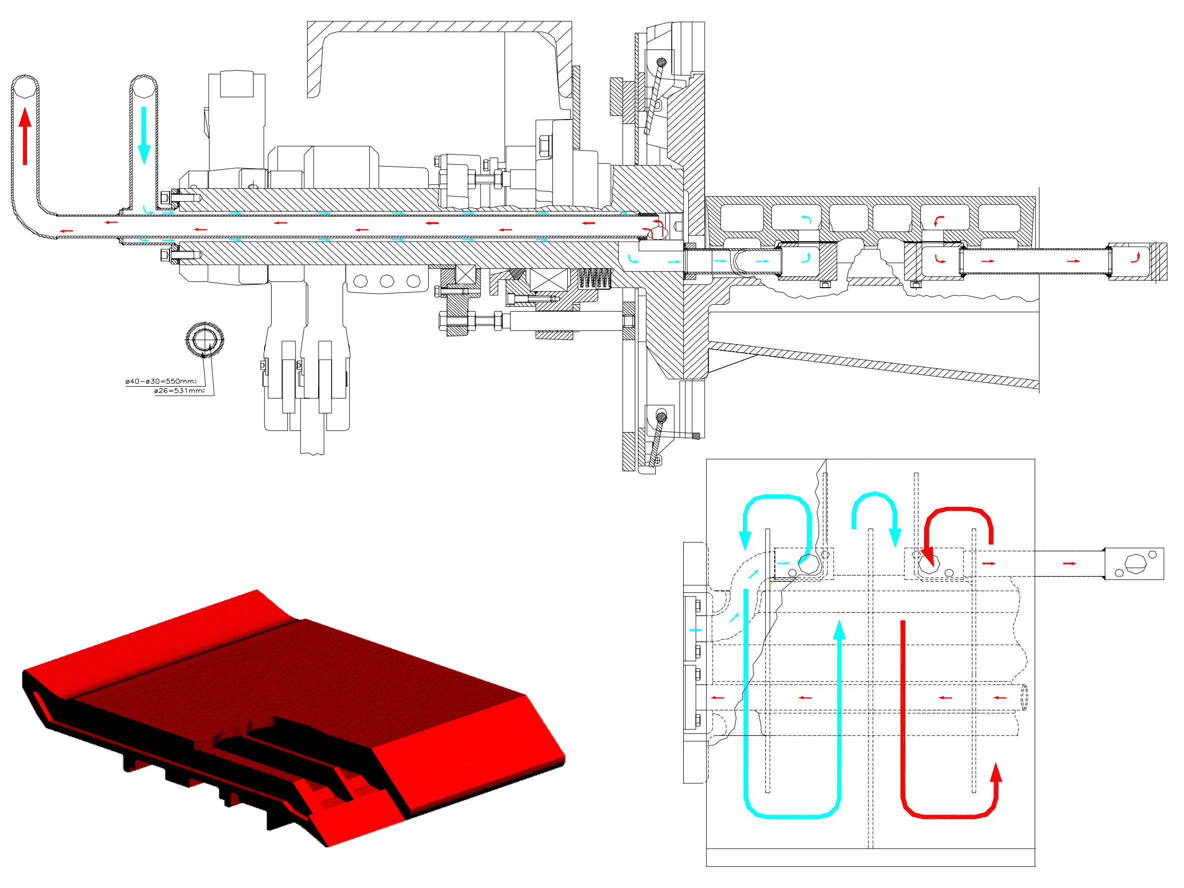


Figure 5 The new water-cooled BS w-grate Mark 6

The cooling circuit is dimensioned for the maximum possible heat flux from the hot flue gasses. The normal heat transfer lies between 15-20 kW per square meter. During normal operation, the entire transferred energy from the grate can be returned to the combustion process because the energy can be used for heating of the combustion air. The boiler efficiency and electricity production will thus be maintained when using a water-cooled grate.

A water cooled wear zone above the grate

It is a common problem that clinker is building up just above the burning waste layer. The main reason is a high surface temperature at the refractory wear zone causing the ash to stick to the wall. In severe cases, the clinker will disturb the combustion process and the plant has to be taken out of operation for cleaning. This can be avoided by using a low temperature wear zone. The new wear zone is made by a number of heavy steel tubes cooled by a closed water cycle, and the absorbed energy is led back into the boiler by preheating the primary air. In this case the burning fuel layer is gliding across the unprotected steel surface without any wear or other problems – see figure 6.

The idea can be compared with our water cooled vibration grate, which in principle is a membrane boiler wall. In this case the burning fuel layer is gliding across the unprotected steel surface without any wear or other problems.

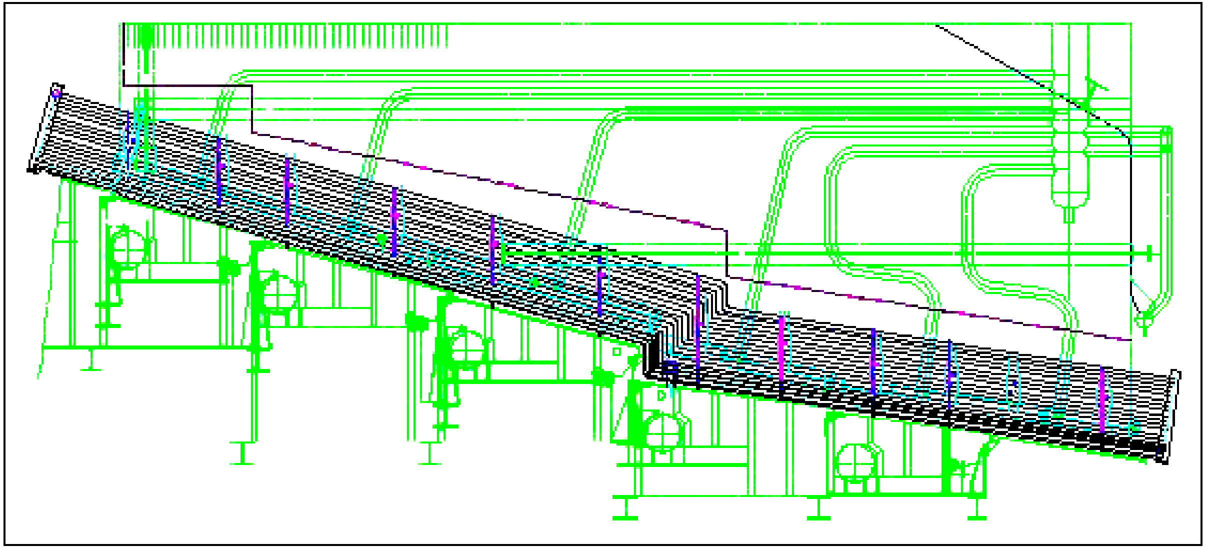


Figure 6 Water cooled wear zone at the L90 plant

The material temperature is at the same level as in the old hot water boilers for waste incineration. These plants are still running and there have never been any corrosion problems. This is confirmed by the fact, that this technology has been used in connexion with upgrading a number of exciting plants in Italy with good results.

Conclusions

Waste to energy plants are an important part of the European waste management system and the new European Commission legislation have influenced the design and planning of new plants. Moreover, new trends in the common market as harmonisation and liberalisation will create even more focus on costs. In order to comply with these demands, new technical developments are focused on improving the plant availability and reducing operating and maintenance cost.

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