Efficient steam-generator concept with external superheater based on the example of the waste-to energy plant in OULU

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1. Waste – energy source of the future

Waste is a global phenomenon and generated from almost everywhere. Consequently, it requires a special treatment because it is potentially harmful to human health and the environment. Nowadays, waste materials are significant energy resources. Their energetic potential is used to produce electricity and heat and consequentially substitutes primary fuels such as coal, oil or gas.

The thermal recycling of the waste materials helps to reduce and avoid greenhouse gas emissions. Reduces, because additional emissions from waste landfills are reduced and avoids, because less fossil fuels are combusted as a result of substitution.

Almost half of the entire German electricity production is based on the use of hard coal and lignite. German lignite has a heating value of something between 6.5 and 10 MJ/kg and thus resides on the same scale as untreated household waste materials.
With heating values ranging from 11 to 18 MJ/kg, the treated household waste materials have an even greater energetic potential.

The electrical energy gained from municipal waste [MSW] – and RDF thermal treatment plants are not subjected to seasonal fluctuations and do not depend on sun or wind energy. Considering the domestic waste’s high biogenic content, it can be classified as biomass.

Both, the municipal and private waste disposal industries have adapted to the changing market conditions, from a disposal market to a recovery/recycling market, and have transformed themselves into energy service providers. Industrial clients, in particular energy-.intensive industries, almost all over the world have discovered that waste materials as a profitable energy source that presents an economic alternative to fossil fuels.

The industrial clients require energy in form of electricity and/or steam to manufacture their products. Since the beginning of the year 2007 the BAUMGARTE RDF plant in STAVENHAGEN [1] has reliably supplied a food producer with steam and electricity gained from refused derived fuels. Another RDF plant situated in the Chemiepark Bitterfeld provides local industrial enterprises [2] with electricity and steam. At the location in BERNBURG [6] 3 lines, each with a thermal combustion capacity of 70 MW, guarantee the supply of energy to a chemical company. Both the Dampfzentrale WEENER [4] and the IGNIS plant [7] operated by the Spree Recycling GmbH residing in Spremberg supply paper mills with process steam generated from domestic and industrial waste materials

Our clients place a very high value on a reliable supply for their processes so that a fully developed and reliable technology needs to be applied. Our experiences we achieved in the field of “Refuse Derived Fuels” provide them with the necessary degree of security.

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2. Introduction

As a traditional boiler manufacturer with more than 78 years of experience, Baumgarte combines its Know-How gained from the installation of more than 100 waste boilers to develop a technological overall concept tailored on the main components in incineration plants.

The BAUMGARTE concept is based on a pusher-type grate, which is preferably used in steam generators having a horizontal convection pass fitted.
Over decades the incineration method using a grate has proven to be the best satisfying the requirements of waste thermal treatment. Consequently, we rely on the BAUMGARTE- pusher-type grate, which can be adapted to the specific fuel requirements either in its air- or water-cooled design..
A conservative design and construction focusing on operational safety are considerable features which we proudly emphasize and which are highly appreciated by our clients. Many of them have not just one BAUMGARTE boiler under „fire“.

Besides our own different patents, a very good example for reliability and innovation represents the plant system AVA – Frankfurt / Main where the third generation of BAUMGARTE boilers is already in operation. The first boiler delivered in 1964 is no longer comparable with the today's standards although the realised main-steam parameters of 5.9 MPa and 500 °C with a steam output of 67,2 Mg/h set standards at that time.

The Baumgarte boiler concept is specially developed for using the waste heat released in the combustion procedure of waste materials and residues.
The heat emitted by the flue-gases is transferred via a „tailend – boiler system“ in a three – or four pass design. The surrounding walls of the two or three vertical radiation passes and of the horizontal convection pass are all provided in a gas-tightly welded tube-fin-tube construction. For the purpose of accommodating negative and positive pressures appearing on the flue-gas side the surrounding walls are reinforced by using expansion joints/buckstays. The entire system with tube walls, headers, downcomers and overflow pipes is designed as a natural circulation system. A generously dimensioned steam drum is arranged crosswise above the second pass and distributes the water via the downcomer system to the wall headers and evaporator heating surfaces. .

3. Influencing variables on the design

The intended use of the plant, in other words the client's requirement, is a basic decision factor which governs all other parameters. While, in the past just the amount of waste to be disposed determined the size of the plant system, the needs for electricity and heat.- such it is always the case within classic power business, define the plant concept for a thermal recovery plant system in these days.

Consequently, the plant concept is decisively influenced not just by the requirements placed in the needs but also by the required availability of electricity and steam to be supplied. Availability is the key to an economic operation and thus the key to project success. Plants with high steam parameters often pay the advantage of a better efficiency range with higher failure rates due to corrosive damages.

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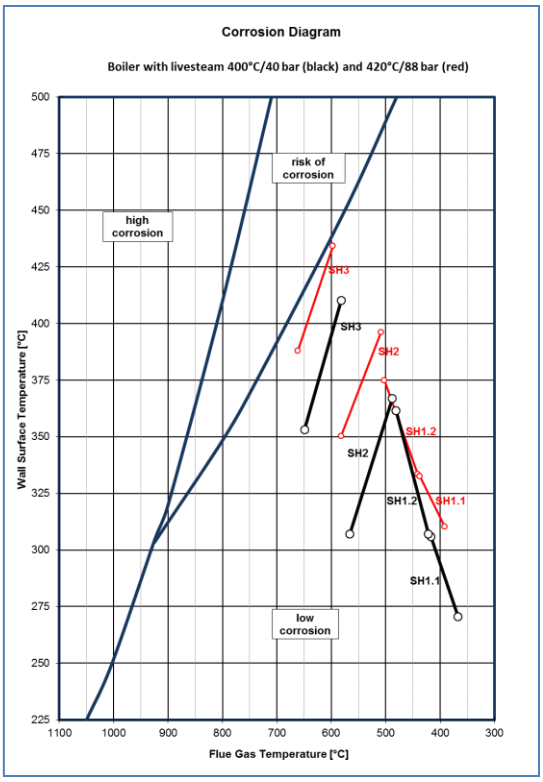
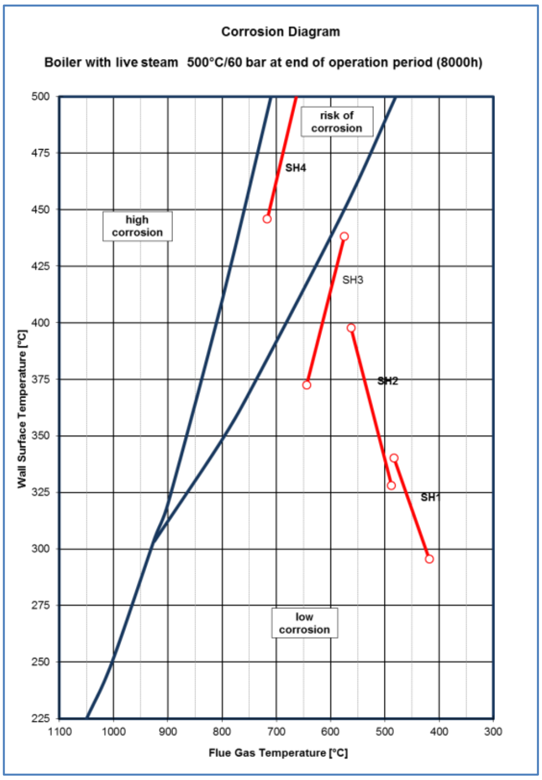
A corrosion diagram is often used to assess the risk of corrosion in superheater areas. This corrosion diagram displays a graphical representation of the heating-surface tubes' temperature in relation to the flue-gas temperatures. The diagram is divided in exposure zones presenting different corrosion risk levels. The corrosion diagram reflecting main-steam temperatures of 400, 420 and 500°C clearly indicates that the final superheater s more readily exposed to severe corrosive attacks than with main-steam temperature ranging above 420°C, provided that the heating surfaces are not attached with expensive protective layers such as cladding or nickel plating. Unlike in the area of the radiation passes, the protective layers on the convective heating surfaces require more expensive and more time-consuming maintenance measures due to their restricted access..





In the light of these principles, in other word having regard to given frame conditions and in consideration of special mechanisms of action of corrosion-promoting flue-gas components, the waste recovery plant system in OULU / Finland was designed on the basis of a special steam boiler concept.

4. The overall concept „OULU“

Our client, the local energy supplier OULUN Energia Oy, is operating different steam generators at the industrial location in the City of Oulu in Finland, to produce electricity and district heat for people and enterprises in the Oulun region. The plant system incorporates two steam turbine units with a total electrical output of 25 MW. The live steam generated in the system is used to drive the turbines. For this purpose the live steam flow is conveyed with a pressure of 8.3 MPa and temperature of 515 °C via a common steam pipe to the turbines. 100 MW from this process are fed thermally into the local district heating network.

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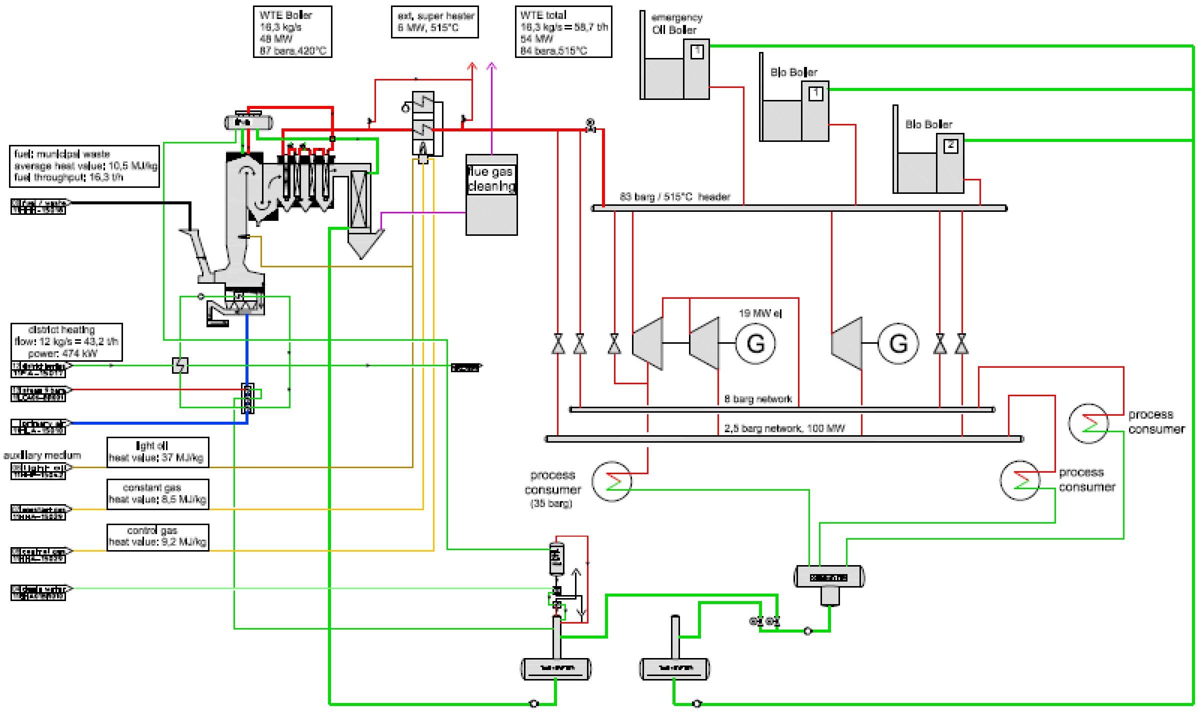
So as to ensure the adequate and safe disposal of domestic waste materials, a waste-to-energy plant capable of processing a significant portion of burnable waste - 130,000 tons per year had to be conceived. Considering the tasks at hand, a special challenge was to integrate the high steam parameters into the existing system.

In order to design the steam generator unit appropriate for the requirements in hand this special concept was developed using moderate steam temperature (420 °C) at the waste boiler's final superheater and considering an external superheater for further superheating up to 515 °C.. This external superheater is fired using lean gas, a waste product from chemical production, which is flared off before.



5. The steam generator concept „OULU“

The influence of steam parameters on the corrosion behaviour is well known. In consequence moderate steam temperatures and moderate pressure rates were used in many projects. Also the boiler plant in OULU is operated at well proven comparably moderate steam temperatures. Merely the steam pressure had to be raised.

The high pressure rate prevailing inside the boiler causes the saturating temperature in the evaporator walls to increase what consequently promotes the risk of corrosion in areas exposed to high flue-gas temperatures. To counteract this unfavourable effect the membrane walls positioned in the first boiler pass were generously attached with a ceramic lining or protected against corrosive attacks by means of weld cladding on nickel-basis alloys.

The steam generator had been conceived in the well-known tailend- boiler design, in other words featuring the combination of vertical radiation passes and a horizontal flue-gas pass with installed convective heating surfaces. The downstream economiser is positioned in a vertical pass.

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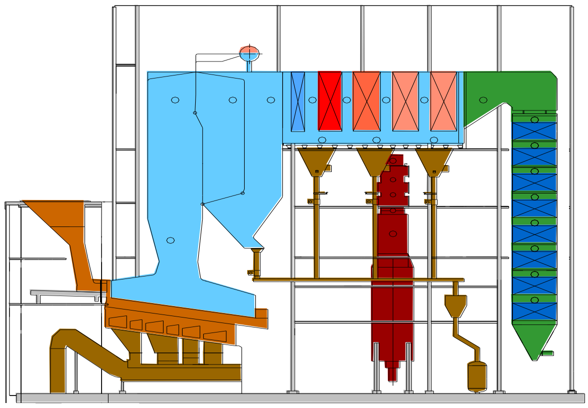
The tailend construction allows the cleaning of the convective evaporator and superheater surfaces located inside the horizontal pass by the application of a rapping system, without needing steam for sootblowers. In this way, the steam can be made completely available to the client's process what in turn improves the plant efficiency and the profit. This type of heating-surface construction proves to be economically also in view to the implementation of maintenance services. The harps are suspended independently of one another superheater bank are easy to access.

This construction has beneficial effects on the availability period - that means the economic efficiency of plant operation is positively influenced not just by lower start-up and shutdown costs and times but also by attainable higher fuel throughput rates. The vertical passes are free of installations. The blank passes are cleaned by applying the water-spraying method. This cleaning measure has two important effects –adhesive foulng on the walls of the radiation passes are regularly removed while the boiler is in operation - what, on one hand, avoids the formation of extensive slag cornices and, on the other hand, allows a considerably simplified and faster cleaning of the radiation passes during boiler standstill and inspection periods. However, of greater significance is the positive influence on the flue-gas temperature when entering the convection pass and the corrosion behaviour of the superheaters, which experience show is less intensive by reducing the flue-gas temperature.



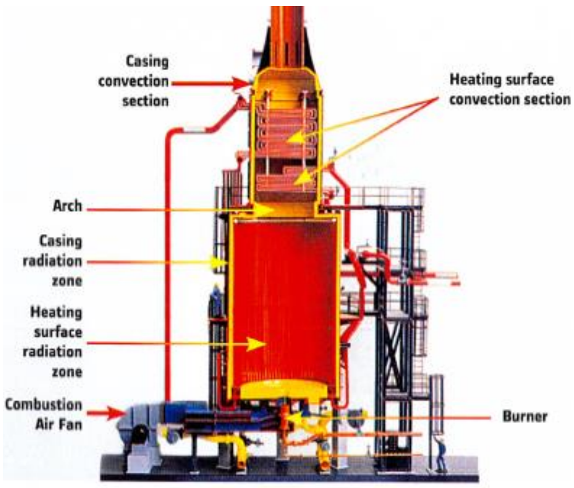
Arrangement o the external supoerheate (red) beside the waste boiler

Unlike the superheaters, the economiser has a vertical sheet metal duct fitted. The fly-ash particlespassing through this area are very fine and non-adhesive, so that cleaning can be effected by using the steel-shot-ball cleaning system. These heating surfaces are relatively low-priced in manufacture and prove to be very effective due to the higher flue-gas velocities. For all these reasons it was possible to design the boiler with extremely low exhaust-gas temperatures ranging from 150 to 160 °C and to achieve in this way a very high boiler efficiency.

6. The external superheater

The external superheater is equipped with a bottom firing system. Lean gas from chemical production processes is mainly combusted. Heating oil or natural gas can be used in the start-up operation. In order to better utilise the heat emitted by the flue-gases and for the purpose of preheating the own combustion air, air preheaters are installed right beside the convective heating surfaces serving the superheating of steam in the upper section.

To operate the system using this combined technology turned out to be absolute uncomplicated. The exhaust gases from the final superheater are introduced into the boiler's furnace area for further use of the contained heat. The combustion air flow proceeding into the direction of the boiler is reduced in a way, to remain the waste-gas loss of the boiler at a low level.



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7. Comparison of efficiency

To demonstrate the efficiency improvement obtained by the installation of an external superheater, We have compared three different variants in the following:

As basis of this comparison we have chosen the standard parameters, i.e. a superheated-steam pressure of 40 bar and a superheated steam temperature of 400 °C. These parameters have then been varied to 62 bar / 420 °C without external superheating and were finally compared with the operating parameters 84 bar / 515°C used in the OULU plant.

The improved efficiency range and, in particular, the extremely high utilisation rate – more than 53 ,% - of the refuse derived fuels in the external superheater clearly speak for the high efficiency of such a system.

	Unit	Standard	OULUN without ext.SH	OULUN with ext. SH
Steam pressure	MPa	4.0	6.2 [1]	8.4
Seam temperature	°C	400	420	515
Thermal capacity DE	MWth	48.0	48.0	48.0
Thermal capacity ext. SH	MWth	0	0	4.7
Electrical output	MWel	12.5	13.3	15.8
Efficiency range	%	25.5	27.2	29.3
Electr. efficiency range of the ext.SH	%	0.0	0.0	53.2

8. Summary

The optimal design of a plant system supplying energy produced from waste materials and residues is determined by the economic parameters, in other words investment and operational costs, maintenance costs and the overall financial impact. Focusing only on one criterion, for example on the lowest investment costs possible, is inevitably condemned to failure. The optimal design begins with the selection of the plant concept in view to economic success and in consideration of all parameters. In doing so, the availability of the plant is of great importance. The construction type of the steam generator and the steam parameters have a significant influence on the availability and maintenance costs. A high degree of flexibility with regard to usable fuels enables intermediate response to changing market conditions. The correct choice of the components to be used paves the way for success at an early stage.

The steam generator plant in in OULU has reached an availability of 99 % over more than 20,000 operating hours. After having adjusted the external superheater with heating oil it was possible to run the unit exclusively with the remnant lean gas. All of the promised characteristics were achieved without exception and could be proved on the basis of a performance test.

This represents a further success story not just for our clients but also for us. As it was in the case with the power plant in Frankfurt am Main in the year 1964, here again, this is another pioneering step in our industrial sector.

[1] The steam, pressure is defined by the steam moisture in final turbine sage, with a temperature of 420°C a steam pressure of 8.4 MPa cannot be achieved.

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9. Technical data of selected reference plants

	Country- location	Thermal capacity	Steam pressure-	Steam temperature
[1]	GER- Stavenhagen	1 x 47.5 MWth	43 bar	400°C
[2]	GER- Bitterfeld	1 x 56 MWth	43 bar	400°C
[3]	GER- Weener	1 x 70 MWth	27 bar	320 °C
[4]	BE- Oostende	1 x 70 MWth	42 bar	402 °C
[5]	GER- Frankfurt/Main	1 x 60 MWth	59 bar	500 °C
[6]	GER- EAB Bernburg	3 x 70 MWth	42 bar	412 °C
[7]	GER IGNIS Spremberg	1 x 110 MWth	40 bar	400 °C
[8]	FIN- OULU	1 x 48 MWth	84 bar	420 / 515°C
[9]	UK- MVA Plymouth	1 x 84 MWth	60 bar	420 °C