Practical test of ACC systems for Waste to Energy plants

Ole Hedegaard Madsen* and Jacob Munch Jensen**
* Babcock & Wilcox Vølund, Odinsvej 19, DK-2600 Glostrup, Denmark
(E-mail: ohm@volund.dk)
** Babcock & Wilcox Vølund, Odinsvej 19, DK-2600 Glostrup, Denmark
(E-mail: jmj@volund.dk)

Abstract: The first operating advanced combustion control (***ACC***) system in Denmark has been installed at the L90 plant and has been in operation for more than one year. The L90 plant is a waste fired power plant burning 24 tonnes of waste per hour. The waste is a mixture of household and industrial waste. This paper will present some of the test results from operating the plant with and without the ACC system. The major findings were a reduction of 40% in the scattering of the steam flow and a reduction of 17% in the scattering of the oxygen level.

Keywords: ACC, Combustion, Control, Waste

1. INTRODUCTION

The demands made 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 tighten EU legislation. These requests have resulted in a new technology such as the Advanced Combustion Control systems (***ACC***), which is an extension of the traditional control system – see References [1]. The main objectives by using ACC systems are:

- Reduce the operational cost
- Less operational people on each working shift
- Reduce maintenance cost and operational mistakes
- Reduce consumables
- Improve process stability
- Automatical 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 first operating ACC system in Denmark has been installed at the L90 plant and has been in operation for more than one year. The L90 plant is a waste fired power plant (***WFPP***) burning a mixture of household and industrial waste – see Table 1 for process data.

Table 1 – Technical data for the L90 WFPP.

Process Parameter L90	**Unit**	**Value**
Capacity MSW	tonne/hour	24
Thermal efficiency	%	89
Electrical production	MW	18
District heating production	MW	54
Combustion process:		
Temperature flue gas	ºC	165
O_2	vol% $_{[wet]}$	4.5
H_2O	vol% $_{[wet]}$	17.9
CO	mg/Nm^3	6
TOC gas	mg/Nm^3	2
LOI ash	%	2.1
Average heating value	MJ/kg	10.6

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

2. COMBUSTION CONTROL

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 an 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 bound 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 through 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 [2]. 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 is 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 aim of several research projects and development activities during the latest 10 years – References [3, 4 & 5]. 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 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.

3. ACC SYSTEM

Babcock & Wilcox Vølund's ACC system is supplied in cooperation with the German company Powitec. 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 for camera positions. The neural network is generating remote set point corrections to the energy controller, the grate velocity controller and the combustion air controllers. The ACC system will continuously adjust the primary air distribution, the primary and secondary air amount and the grate velocity in order to achieve a stable and good combustion and to ensure that the different combustion processes on the grate are correctly located.

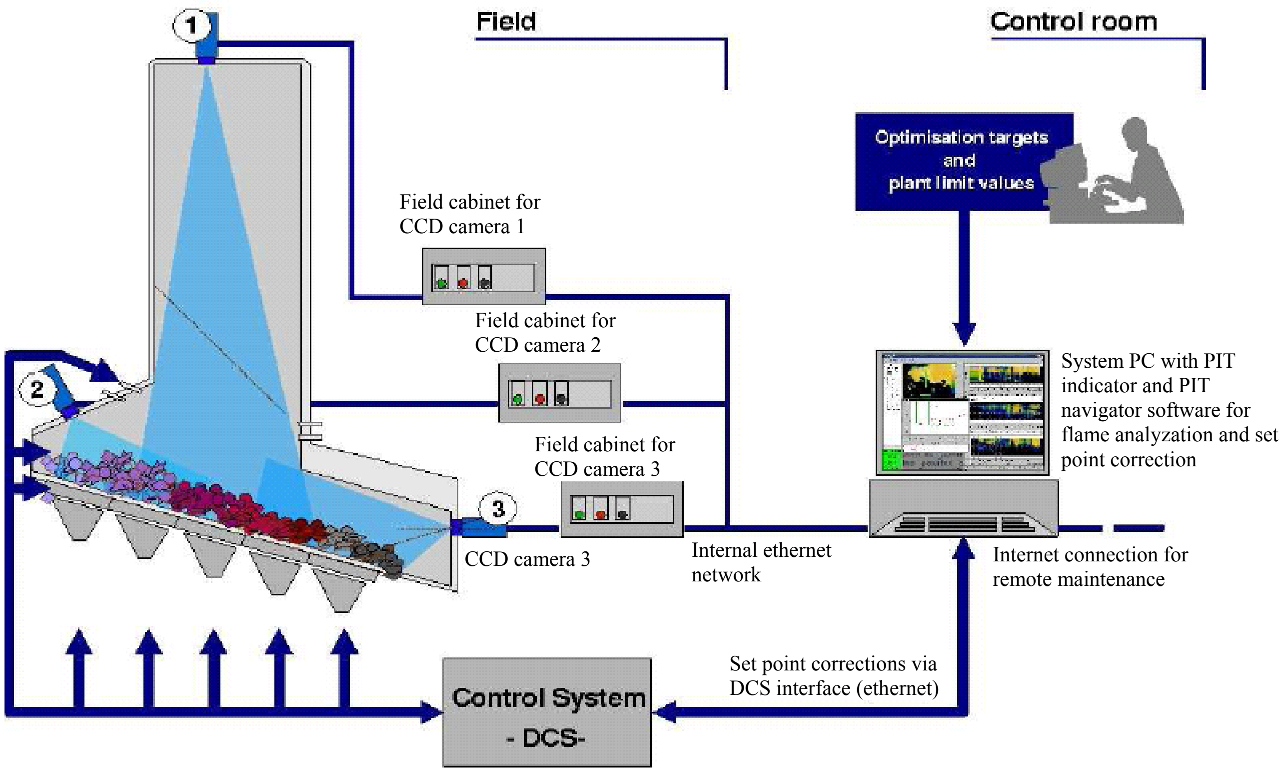

Fig. 1 Position of CCD camera at the L90 plant.
(Courtesy of Powitec)

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. NOx, etc. The neural network is able to learn the behavior 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 contrary to the fuzzy system which is an expert system based on operational rules.

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. The ACC system will continuously adjust the primary air distribution, the primary and secondary air amount, the primary air temperature and the grate velocity in order to achieve a stable and good combustion and to ensure that the different combustion processes on the grate are correctly located.

The advantage of the new technology from Powitec is based on the consistent use of the three camera pictures of the 3−chip−CCD−camera, which are available at the same time. This camera provides a picture of its own for the red as well as the green and the blue (RGB) wavelength range of the visual light. The result is a robust and exact temperature determination, also at different remote objects and at disturbing influences such as cyclical dust development. Next to a new camera technology, the image processing software was also developed further in essential points for the RGB−thermography.

The PIT process navigation system has an optimizer on neuro/fuzzy basis calculating online and self-learning the optimizing control actions. These actions are directly fed into the control system via an interface module as desired set−point corrections. The PIT navigator software is structured in a manner that it is adapting itself automatically to the continuously changing process conditions (adaptivity). Conventional neural/fuzzy optimizers are being generated once during a training phase. The PIT navigator, contrary to this, continues to learn steadily. It recognizes, amongst others, the wear of machinery and plant parts, and also the changes of charge materials, and is readapting its optimization strategy continuously.

4. TEST AND RESULTS

4.1 Data acquisition

In the following, some of the results are presented from the guarantee test of the ACC system. The guarantee test is performed for 23 hours with the ACC system in operation, then 2 hours of change followed by 24 hours without the ACC system in operation, in the period from the 4 May to the 6 of May 2004. All data points are plant measurements which are recorded by the control system. The fuel in the test period was household waste with a composition typical of the surrounding area.

4.2 Measurement data:

The average variation V is calculated as:

$$V = \frac{\sum_n |PV - SP|}{n} \quad (1)$$

where PV is the process value, SP is the set point and n is the number of measurement points.

4.3 The steam flow

The master set point for the production of the plant is the desired steam flow. The steam flow is thereby the parameter of main interest when evaluating the performance of the control system. Figure 2 shows the steam flow as well as the variations for a test period with the ACC system active, followed by a test period without the ACC system being active. The two test periods are separated by a switch-over period, which is not shown. The steam set point is 95 t/h.

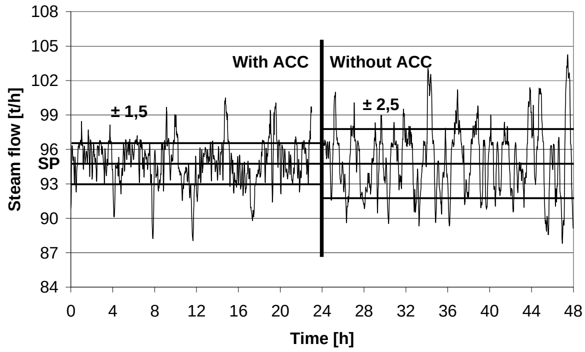

Fig. 2 Steam flow with and without the ACC system active.

The average variations are +/- 1.5 t/h with the ACC system and +/- 2.5 t/h without the ACC system. The ACC system decreases both the variations of the steam flow and the maximum amplitude of the oscillations. Thus, the combustion process has been stabilized by means of relatively small set point corrections. Particularly, the decrease of the maximum amplitude of oscillations is of commercial interest, as a plant may be operated closer to the maximum capacity. Usually, the set point for the steam flow is limited to a certain range below the actual peak load of which the plant is capable of running in order to manage the oscillations. Using the ACC system, the oscillations are decreased and the set point may be set closer to the actual peak load thus increasing the capacity of the plant using the same components.

4.4 The oxygen content

The oxygen content is important in terms of plant efficiency and for environmental reasons. A high oxygen content shows that too much combustion air is added to the process resulting in cold areas giving an increase in the CO emission and a decrease in the plant efficiency. A low oxygen content may result in a high CO emission, too, due to insufficient combustion air. Thus, the combination of the oxygen content (see Figure 3) and the CO content (see Figure 4) shows if the combustion air flow is adequate and added at the appropriate locations. The values of "high" and "low" depend on the furnace/boiler configuration (counter flow, concurrent flow or parallel flow) and of the specific plant. Usually “high” will be in the range above 10-12% (wet) and “low” will be in the range below 2-3% (wet). The oxygen set point is 4.5% (wet).

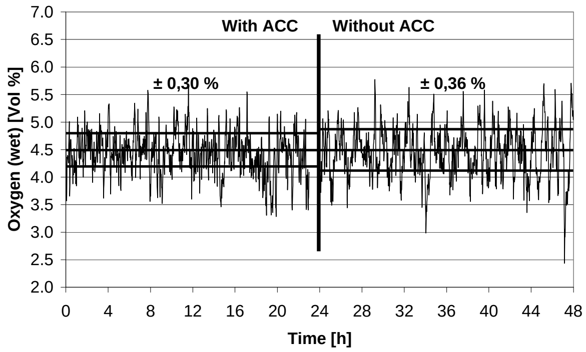

Fig. 3 Oxygen$_{(wet)}$ content with and without the ACC system.

The oxygen content is decreased to +/- 0.30 % with the ACC system from +/- 0.36 % without the ACC system. Also the amplitude of the oscillations is decreased using the ACC system. The decrease is due to the before-mentioned stabilization of the combustion process, which also affects the oxygen content. Comparing the steam flow and the oxygen content, the influence of the ACC system is most clearly seen in the variations of the steam flow.

4.5 The CO content

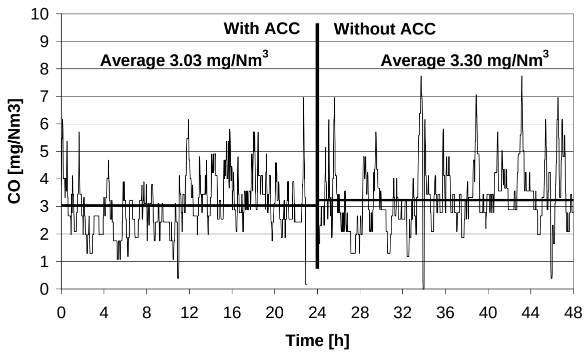

Fig. 4 CO content with and without the ACC system.

The EU directive requires a CO content below 50 mg/Nm3 measured as half-hourly average values. The average over the two test periods is 3.03 mg/Nm3 with the ACC system and 3.30 mg/Nm3 without the ACC system, respectively, which in both cases are negligibly small amounts well below the requirements. No significant effect of the ACC system can be seen, which may be due to the particularly low CO content. This is due to the BWV design of the secondary air system using a Rotamix system based on CFD simulations [6].

4.6 Example of ACC set point correction

When the ACC system is active, a correction term is generated, which is added to set points of the slave controllers in the traditional BWV control concept. As an example, the resulting control signal to the grate speed controller (grate 3) is shown in Figure 5.

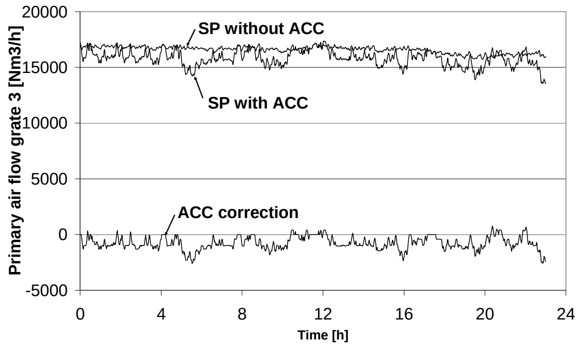

Fig. 5 Set point for the primary air grate 3.

The ACC correction term is added to the set point generated by the traditional BWV control concept (SP without ACC) giving the actual set point to the grate speed controller (SP with ACC). The corresponding control signal (SP with ACC) is seen to be more varying, which is expected, as the ACC system is capable of reacting to small visual changes in the combustion process as well as changes in the traditional plant measurements.

5. DISCUSSION

The results are summarized in Table 2. The data sets show a clear improvement of the operation of the plant using the ACC system. The variations in the steam flow are reduced by 40 % and the variations in the oxygen content are reduced by 17 % using the ACC system. The reduction of the CO content is negligible due to a very low CO content in general, and the effect of the ACC system on the CO content is therefore not relevant.

Table 2 - Summary of results.

Parameter	+ ACC	- ACC	Reduction
Steam variations [t/h]	1.5	2.5	40 %
O_2 variations $[\%]_{wet}$	30	36	17 %
CO content [mg/Nm^3]	3.03	3.30	-

In general, the personnel at the plant reported of improvements in the daily operation when the ACC system was included in the control system. An important experience is that the tendency of uneven combustion on the two grate runs (two parallel grates) is considerably decreased by the ACC system.

6. CONCLUSION

This paper showed some of the test results from operating the L90 plant with and without the ACC system. The major findings were a reduction of 40% in the scattering of the steam flow and a reduction of 17% in the scattering of the oxygen level. The comparison of the CO content is not relevant as the level is very low.

7. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contribution and help from the staff of L90 and especially Mr. Jan Hansen, Operating Manager.

8. REFERENCES

[1] Madsen O.H.; New technologies for Waste to Energy plants, *4th International Symposium on Waste Treatment Technologies*, Sheffield University, UK, 29 June – 2 July, 2003.

[2] Rogers J.E.L., Sarofim A.F. and Howard J.B.; Effect of underfire air rate on a burning simulated refuse bed, *Proceedings 1972 National Incinerator Conference,* New York.

[3] Schuler F., Rampp F., Martin J., Wolfrum J.; TACCOS – A Thermography Assisted Combustion Controlled System for Waste Incinerators*, Combustion & Flame* 99, p 431-439, 1994.

[4] Hiller W., Neukirchen B., Wintrich F.; Überprüfung einer Müllfeuerung mit innovativer Messtechnik – auch ein Weg zur Simulationskontrolle, *Müll und Abfall*, 12, 1996.

[5] Jørgensen K., Madsen O.H.; Modern control systems for MSW plants, *Second International Symposium on Incineration and Flue Gas Treatment Technologies*, Sheffield University, UK, 4-6 July 1999.

[6] Madsen O.H., Binner S., Jørgensen K.; Thermal Optimization and Pollutant Control in MSW Incineration Plants, *4th European Conference on Industrial Furnaces and Boilers*, Espinho Porto, Portugal, 1-4 April 1997.