DUNBAR ENERGY FROM WASTE WITH COMBINED HEAT AND POWER FACILITY, OXWELLMAINS

Example Keppel Seghers CFD Modelling

Viridor Waste Management Limited

Summary

This report provides details of a demonstration of CFD modelling undertaken by Keppel Seghers.

In the report two examples are given:

1) 66,7 MWth, 9,6 MJ/kg, 25 t/h throughput with a prism
2) 27,8 MWth, 10 MJ/kg, 10 t/h throughput without a prism

Dunbar has 49,1 MWth, 9,2 MJ/kg, 19,2 t/h throughput. : The calorific value of waste input at the Dunbar facility will be similar to both examples given; the waste throughput will be less than example one given; and the thermal capacity of Dunbar is in between two examples. Dunbar has a Prism because the plant's thermal capacity will be higher than 40 MWth.

In the first example, the temperature and velocity profiles are shown but the residence time plot is not given. The residence time plot can be calculated from the vertical velocity profile and the distance, as a result it can be proved that the example plant will comply with 850°C, 2 second rule.

The residence time is plotted for the second example.

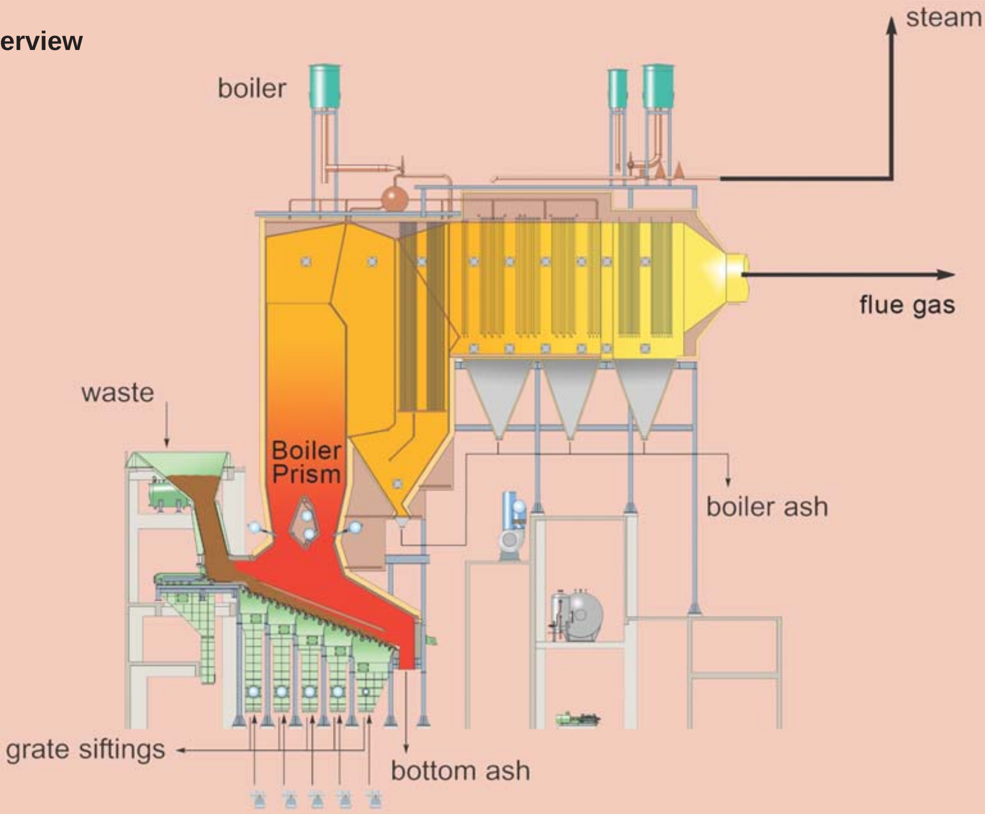
CFD modelling will be performed using Dunbar EfW Plant design data and will be reported in more details at the detailed engineering stage of the Project.

Keppel Seghers Boiler PRISM

Waste-to-Energy

Keppel Seghers BOILER PRISM

Process Overview



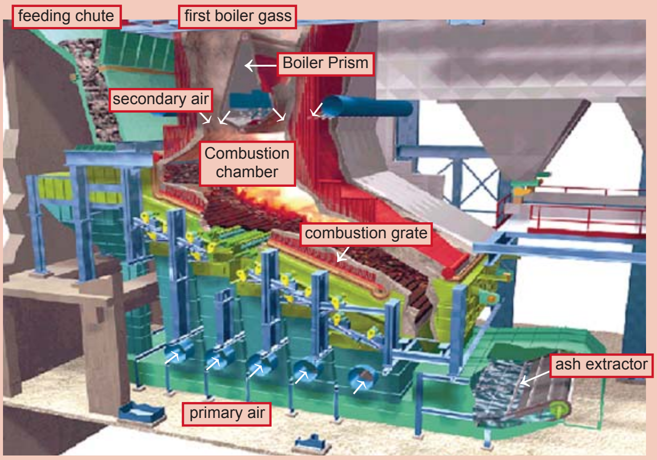
Waste incineration plants have evolved from pure incineration plants to state-of-the-art installations with minimal environmental impact. The interest is no longer exclusively on the thermal treatment of solid waste, but also the recovery of energy available in the waste.

In the energy recovery process, the steam boiler transfers heat present in the flue gas to the water/steam circuit. When leaving the furnace the flue gas flows through the empty passages of the boiler, releasing heat so that the temperature at the inlet of the convection section (final superheater) is less than 650°C. In the convection section, the flue gas further releases its heat such that its temperature at the outlet of the boiler is 200°C or less. Meanwhile, the water inside the boiler pipes is converted into superheated steam.

Principle

Flue gas from waste incineration contains very aggressive components. The combination of these pollutants and the temperature result in a high risk for corrosion. Therefore, one of the major problems with boilers of waste-to-energy plants is high-temperature corrosion.

Since its first installation in 1997, the Keppel Seghers Boiler Prism has proved to be an excellent primary measure against high-temperature corrosion in the empty boiler passages. The Boiler Prism is located at the transition of the combustion chamber to the first boiler passage and acts as a dynamic mixer due to the injection of secondary air. The device is water-cooled, refractory-lined and integrated with the natural circulation system of the boiler.



Application

The Keppel Seghers Boiler Prism is applied in medium to large waste-to-energy plants. The Boiler Prism can be installed in new plants and can also be retrofitted to existing plants.

The Boiler Prism divides the flue gas flow into two sections, into which secondary air is injected from four different locations.

Compared with a design without a Boiler Prism, this approach enables a more uniform injection of secondary air (ensuring high turbulence and optimal mixing) and superior process control.

Process Description

The Keppel Seghers Boiler Prism is an integrated boiler component positioned at the exit of the combustion chamber. It is prism-shaped and contains two internal collectors with nozzles for the injection of secondary combustion air. As such, it ensures a swift post-combustion of the flue gas along with an optimal flow-, temperature- and oxygen-distribution.

The improvements on the combustion and post-combustion process result in a much shorter and clearly defined burn-out of the flue gas just above the Boiler Prism. This achievement is based on following facts:

- Improvement of the flue gas mixing due to the reduction of the necessary penetration depth of the secondary air jet to nearly ¼ of the original furnace depth
- Injection through a large number of “smaller” nozzles with lower individual air flow, permitting a much quicker heating of the secondary air to the required reaction temperature for CO-oxidation (ca. 600°C)
- Creation of an optimal post-combustion reaction chamber with targeted oxygen supply in a highly turbulent stream

Just above the outlet of the two gas flow sections “A” and “B”, in the shape of a venturi, a flue gas temperature measurement gadget is installed to measure the actual temperature for each flow section. The purpose of this temperature measurement gadget is to maintain, through the combustion control system, almost the same flue gas temperature (ca. 1.000°C) in both sections by means of the variable secondary air flow.

Dust, trapped by the flue gas stream, causes erosion and pollution of the boiler walls and pipes, resulting in less efficient heat transfer. An efficient cleaning system is of great importance to guarantee a long operation time of the boiler. Typically, an operation time of 8000 hours without stoppage for manual cleaning can be guaranteed.

Features:

- Optimised injection of secondary air, resulting in a highly uniform distribution of the flue gas flow in terms of velocity, temperature and oxygen content
- Designed according to the customer's needs for heat recovery, using computational fluid dynamics (CFD)
- Unique and proprietary technology
- Proven primary measure against high-temperature boiler corrosion
- Leading to higher throughput and higher availability of the waste-to-energy plant, increased operation time between manual boiler cleanings and a lower reagent consumption of the SNCR system (if applicable)
- Also available as retrofit

CFD Simulation – Using Keppel Seghers PRISM

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BELGIUM

CFD simulation with SEGHERS Prism

The simulations are done with different boundary conditions provided by SEGHERSBetter technology.

On visual basis a certain selection can be made based on velocity vectors, flow lines and oxygen distribution over the furnace volume and also based on experience.

To make a more rational comparison, a number of criteria were used, quantifying the quality of the flow pattern. These criteria are summarised hereafter:

Homogenisation of the temperature (T criterion)

This is characterised by the deviation from the average **T**emperature on different levels.

Homogenisation of the oxygen (M criterion)

For a completed post combustion, the oxygen brought in with the secondary air should be as well as possible distributed over the entire furnace section.

Homogeneity of the vertical velocity profile (S criterion)

A high minimal residence time of the flue gases is achieved by obtaining an as far as possible uniform vertical velocity profile in the furnace. This is characterised by the deviation from the average vertical velocity.

The more uniform these profiles, the higher the minimal residence time of the flue gasses in the furnace.

• First intermediate results

The deviation in temperature, velocity and O2 are calculated on 3 different levels:

1) On 16m level = just at the outlet of the S.A. Prism
2) On 19m level = just above the burners
3) On 27m level = slightly above the refractory lining limit of the first empty pass

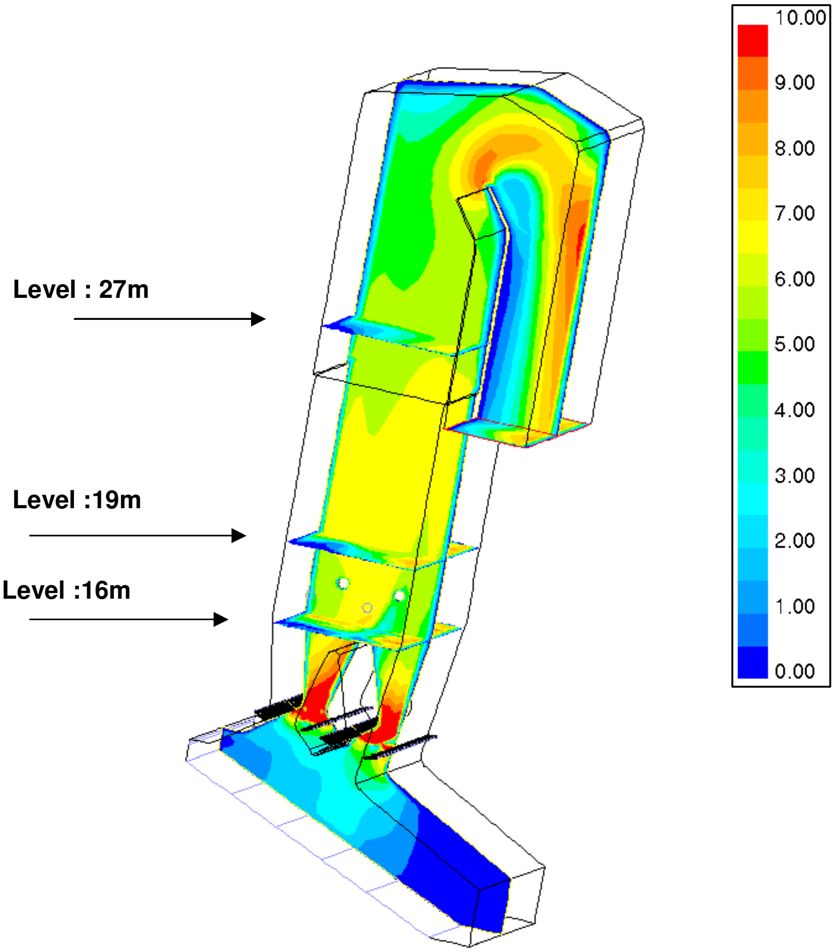


Figure 1: Velocity profiles (0-10 m/s)

First trials to optimise the secondary air mixing were performed with the geometry and nozzles positioned as shown in fig.1. All these first simulations were performed with a combustion process on the grate, based on our experience over many years on our multi-grate system and combustion air distribution.

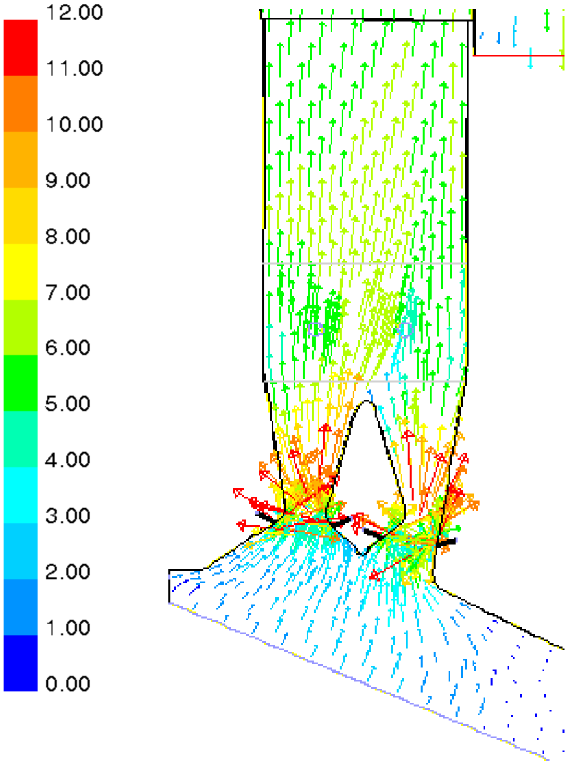


Figure 2: Velocity vectors

Remark: All simulation calculations are based on flue gas temperatures for a fouled boiler condition (after 8000h operation)

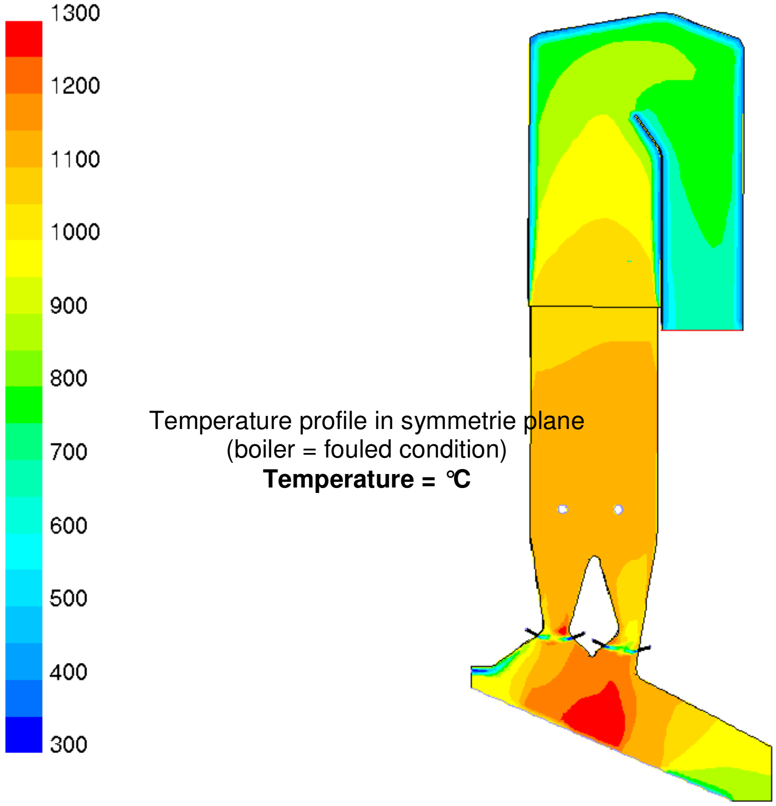


Figure 3: Temperature profiles

Second intermediate calculations

Some adaptations further into the empty passes of the boiler and a slight refinement of the boundary conditions resulted in a new series of intermediate calculations

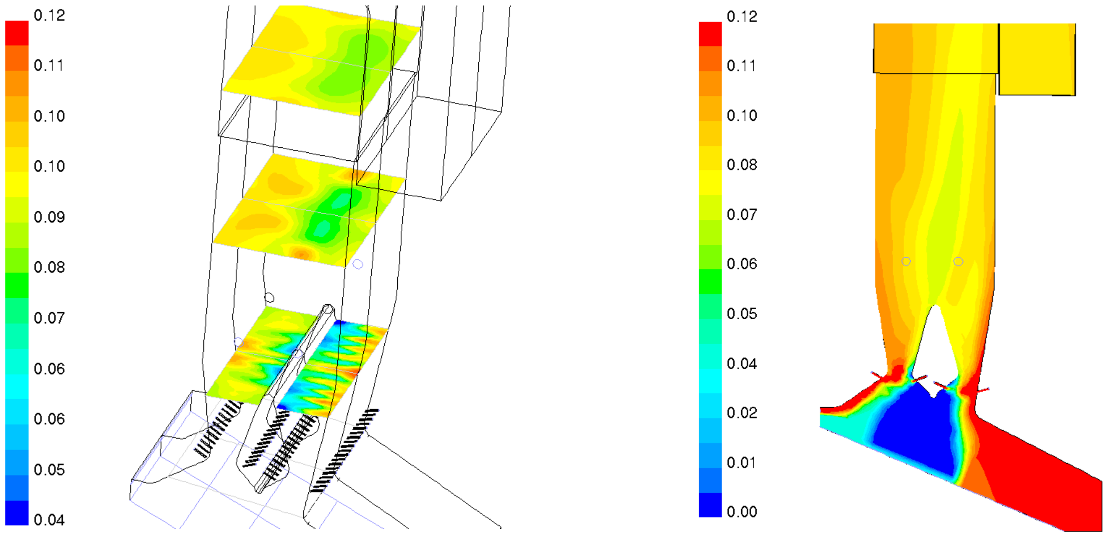


Figure 4: Oxygen concentrations

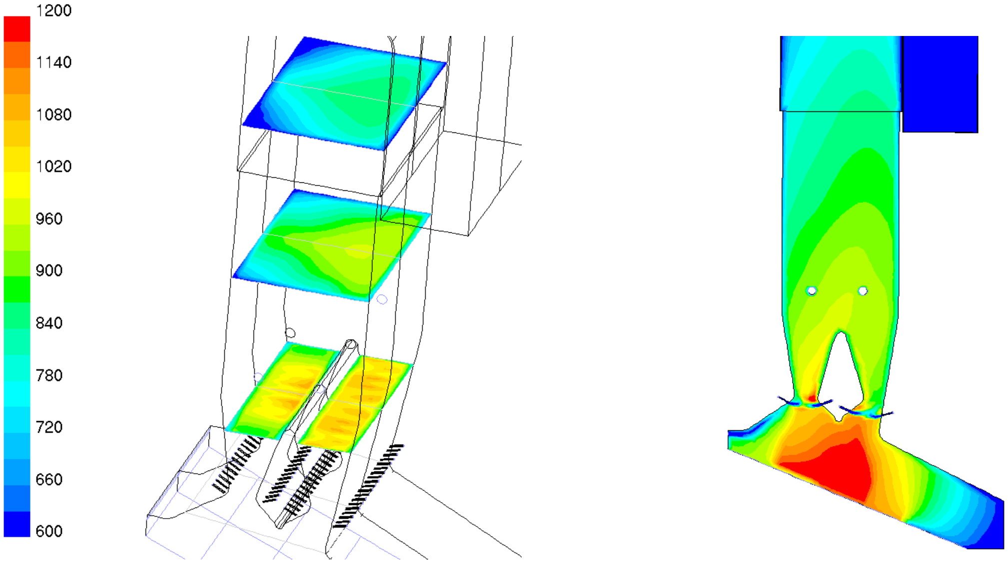


Figure 5: Contours of static temperature (°C)

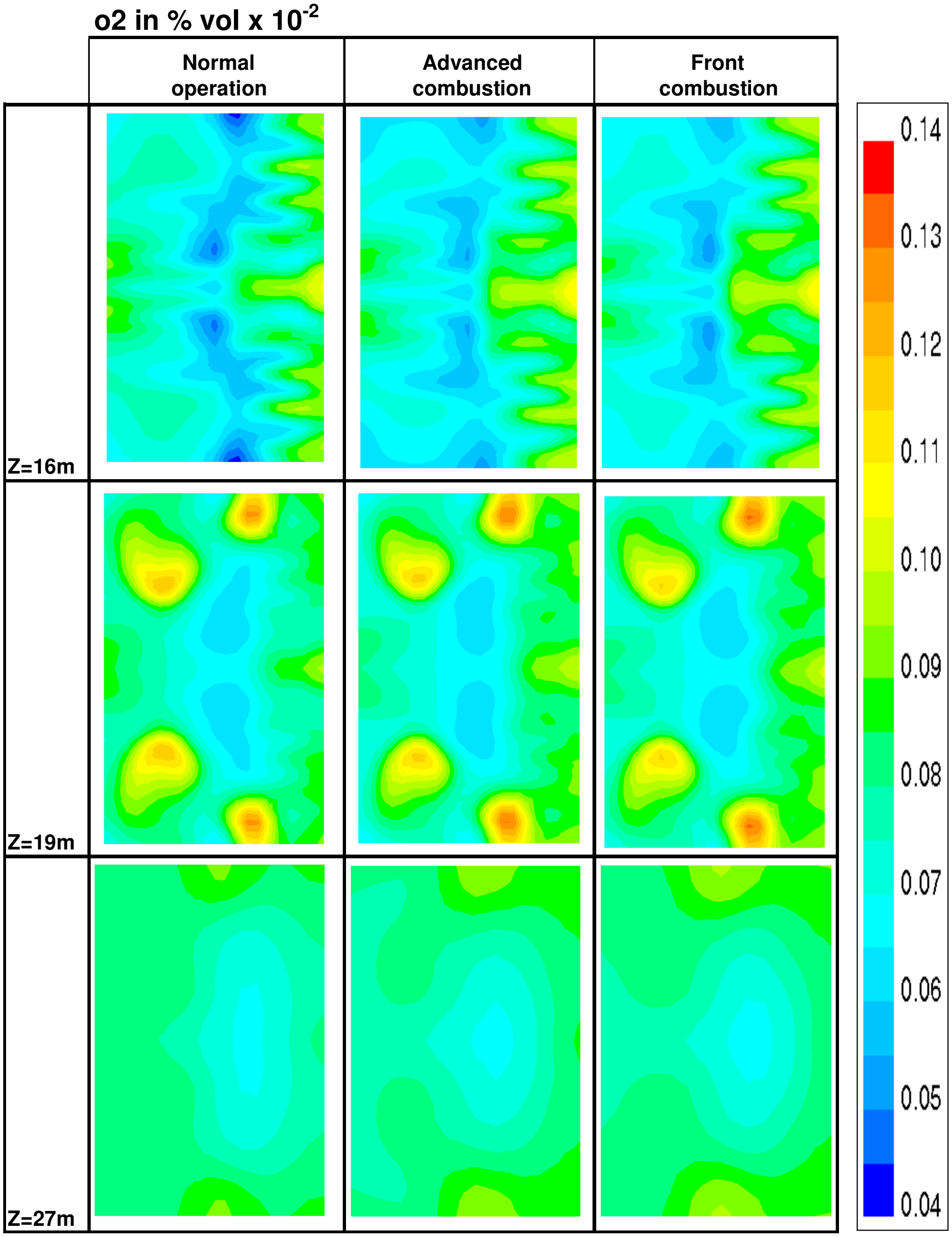


Figure 6: Comparison of Oxygen concentration at different levels

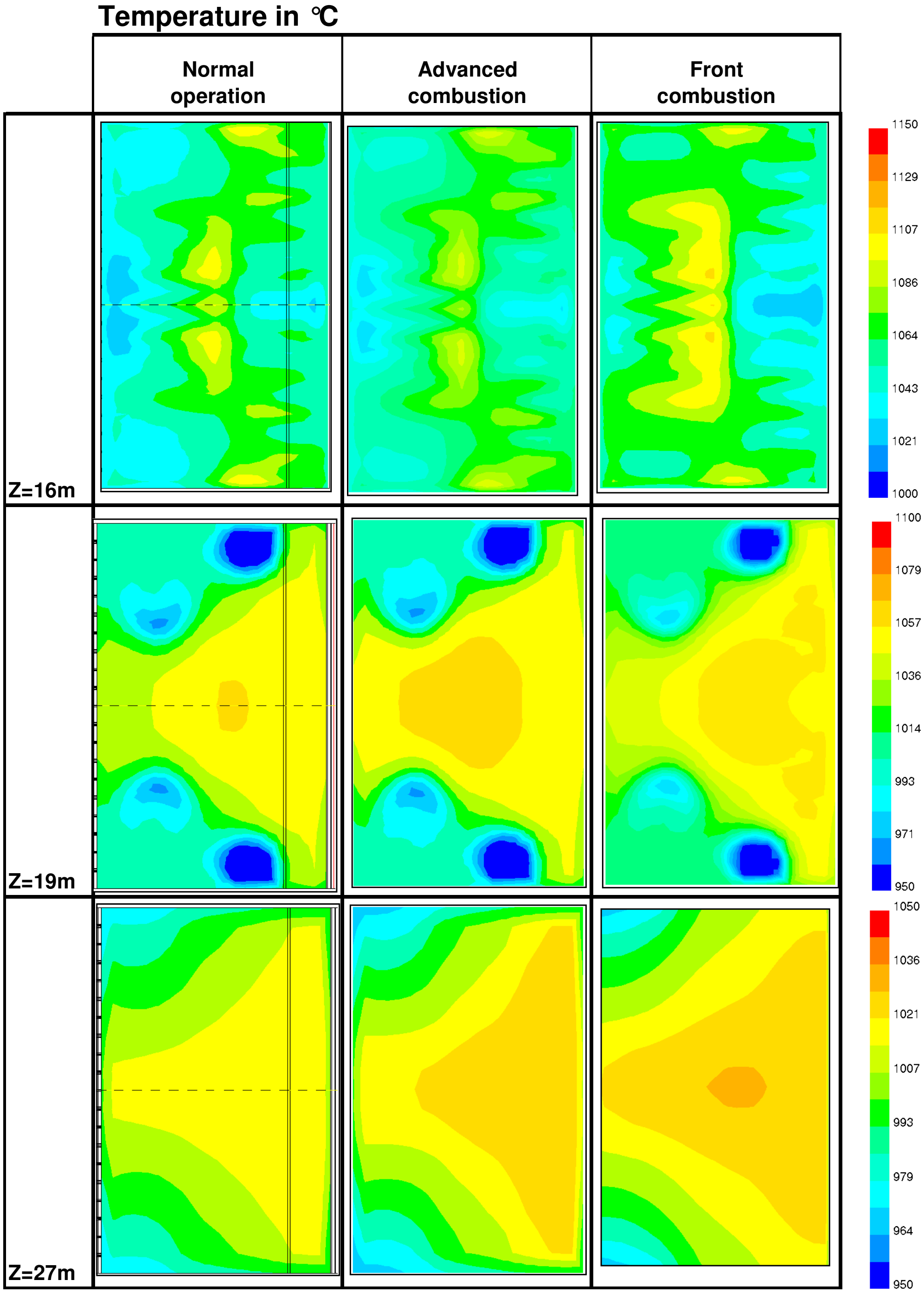


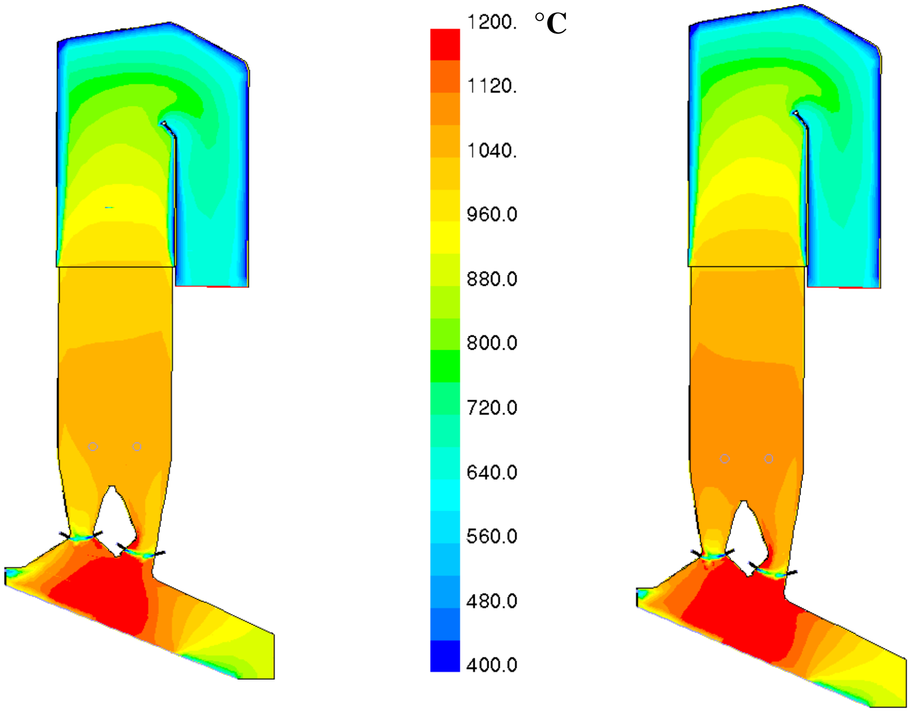
Figure 7: Comparison of static temperature at different levels

• Latest modifications on the geometry

This final geometry is checked again as well with boundary conditions for a normal heat release profile on the grate as with boundary conditions for an increased front combustion.

Aim for this optimisation is to assure that S.A. injection system can, regardless the boundary conditions related to the heat release profile on the grate, reduce the influence to the values at the proper boiler entrance.

As we can see there are no big differences in between the temperature profiles (fig.8)

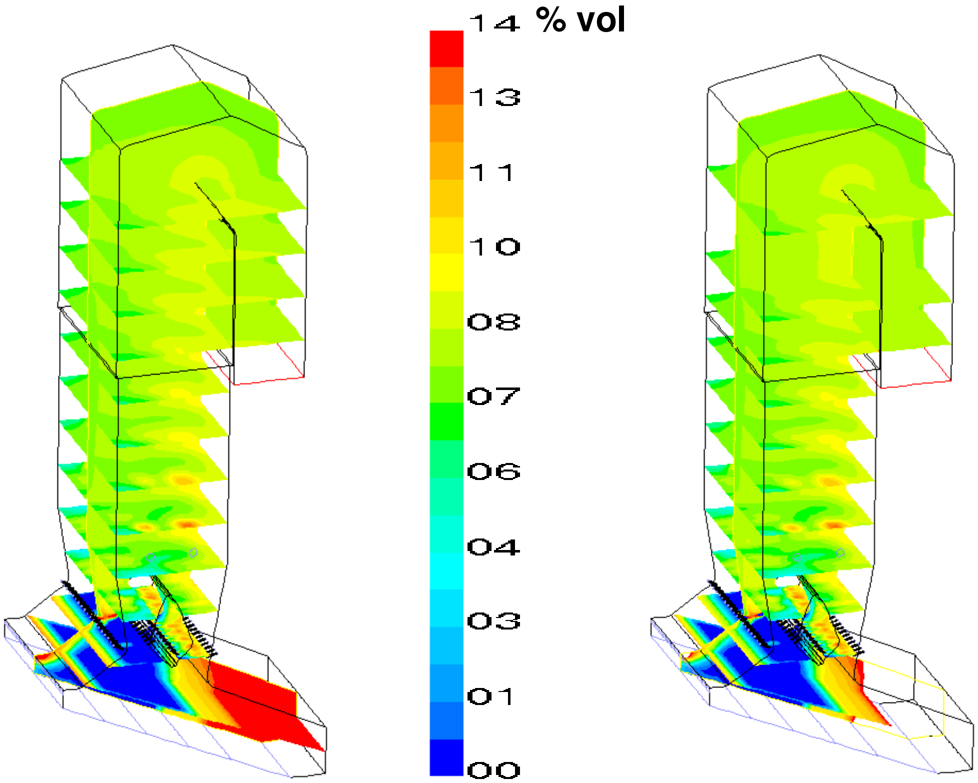


Normal operation

Advanced combustion

Figure 1: Temperature profile final geometry

Also the differences in the oxygen concentrations are negligible as we can see on fig.2



Normal operation Advanced combustion

Figure 2: Oxygen concentration final geometry

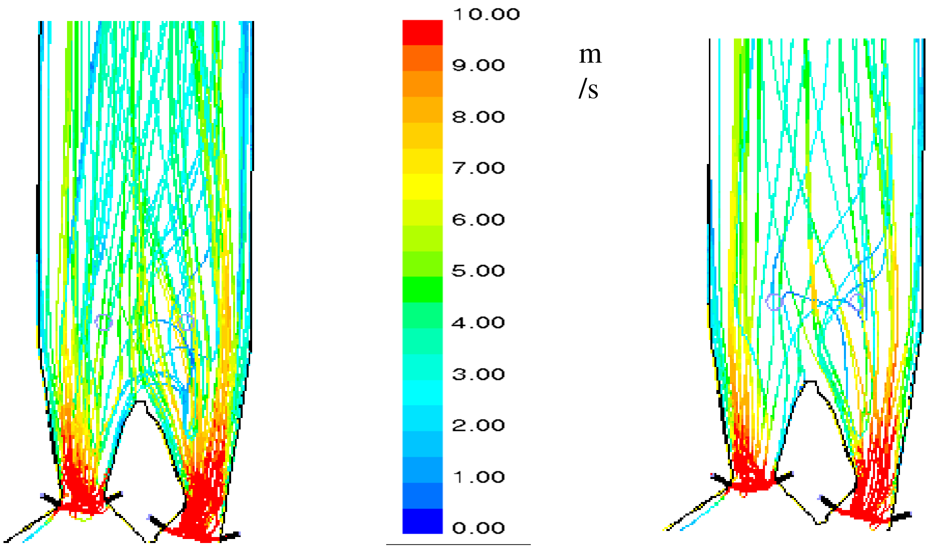


Figure 3: Velocity Path lines final geometry

CFD Simulation without Prism (with secondary air nozzles)

To check the fulfilment of the 2s-850℃ rule, 12 flowlines evelly distributed over the half-section of the boiler (starting at a level approximately 1m above the last secondary air injection) are plotted together with iso-surfaces of temperature. This shows that after 2 seconds (when flowlines turn black), the temperature is still above 850° for all flowlines (Figure 1).

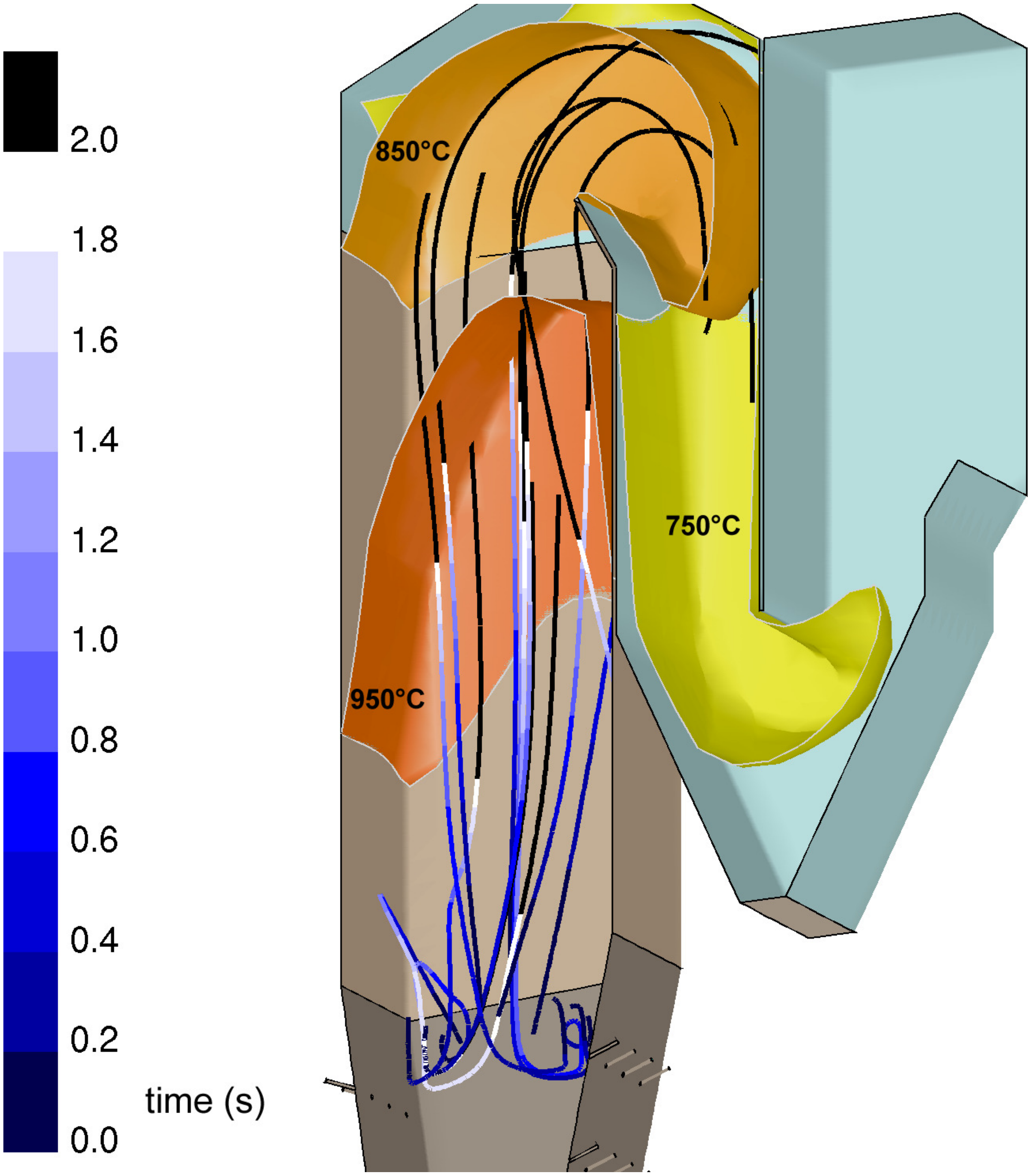


Figure 1: Flowlines and isotherms (view on half section of the boiler)

The temperature, velocity and oxygen profiles are presented on the symmetry plane of the boiler/furnace:

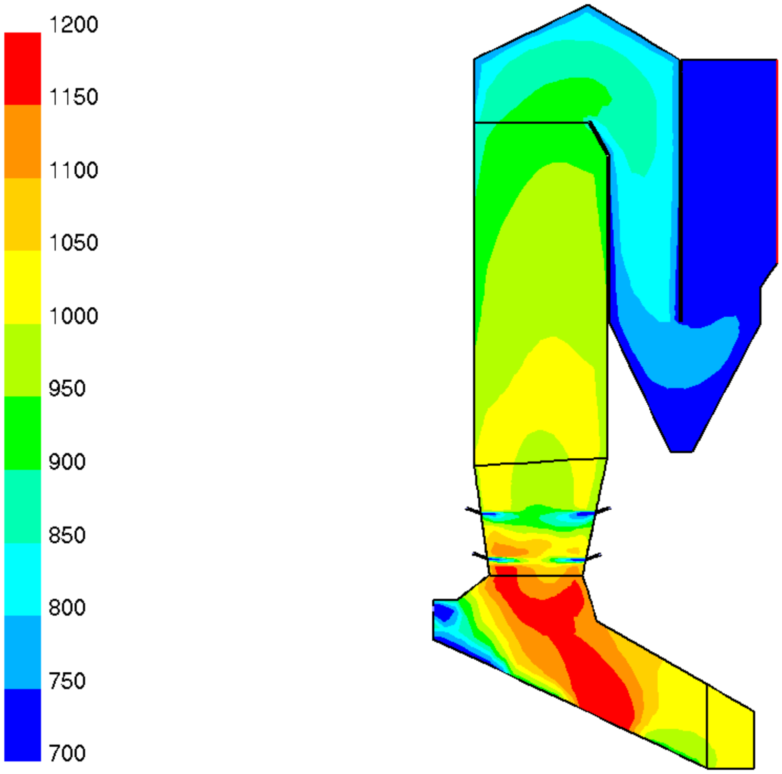


Figure 2: Temperature (℃) profile on symmetry plane

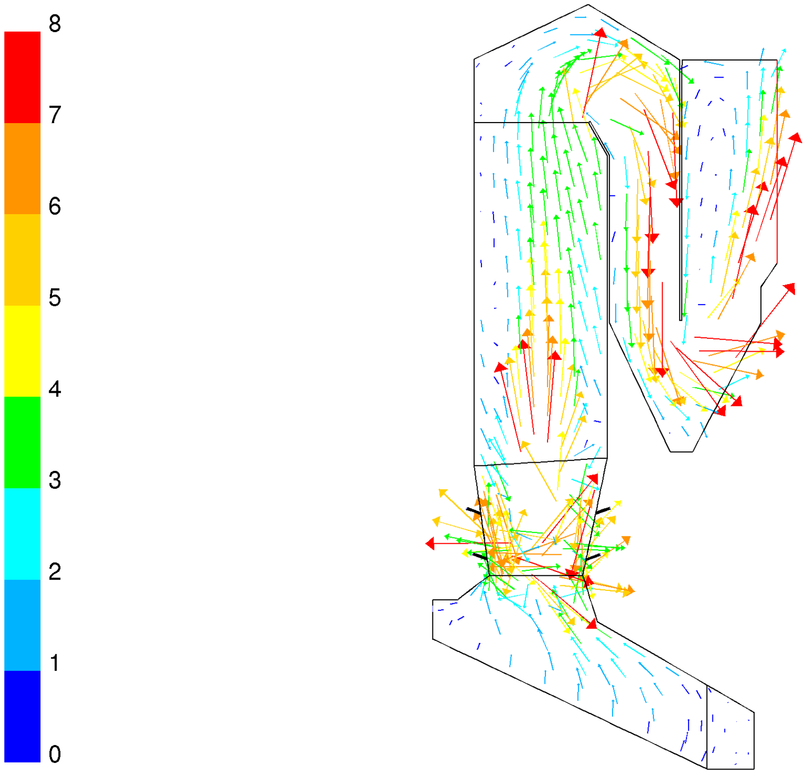


Figure 3: Velocity (m/s) profile on symmetry plane

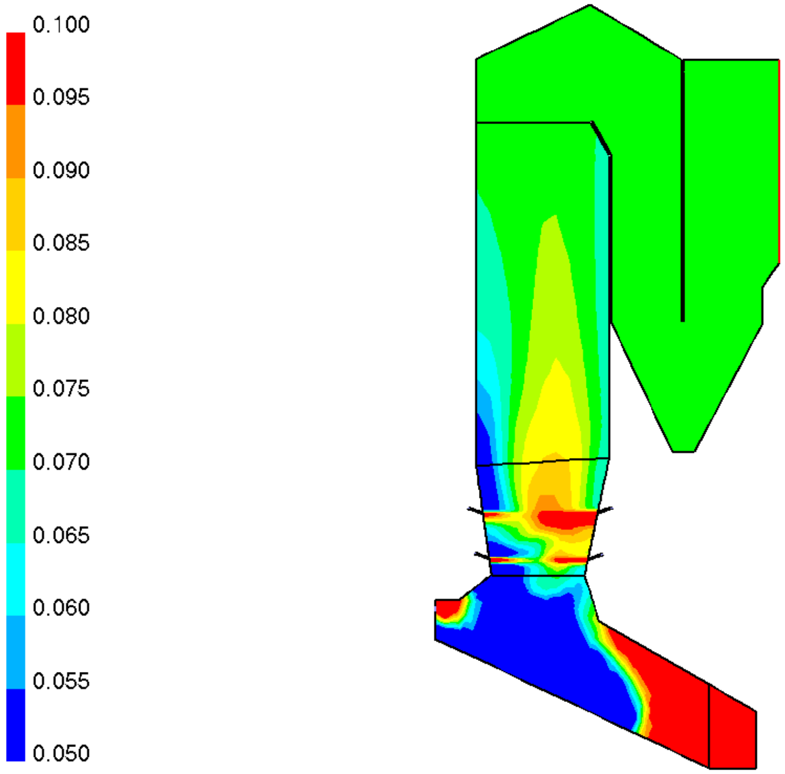


Figure 4: Oxygen concentration (vol%) on symmetry plane

From the velocity and oxygen profiles it can be seen that the secondary air injection is not yet completely optimized. Especially the homogeneity of the vertical velocity in the first pass of the boiler is still subject to improvement. This further optimization will be performed during the detailed engineering phase.