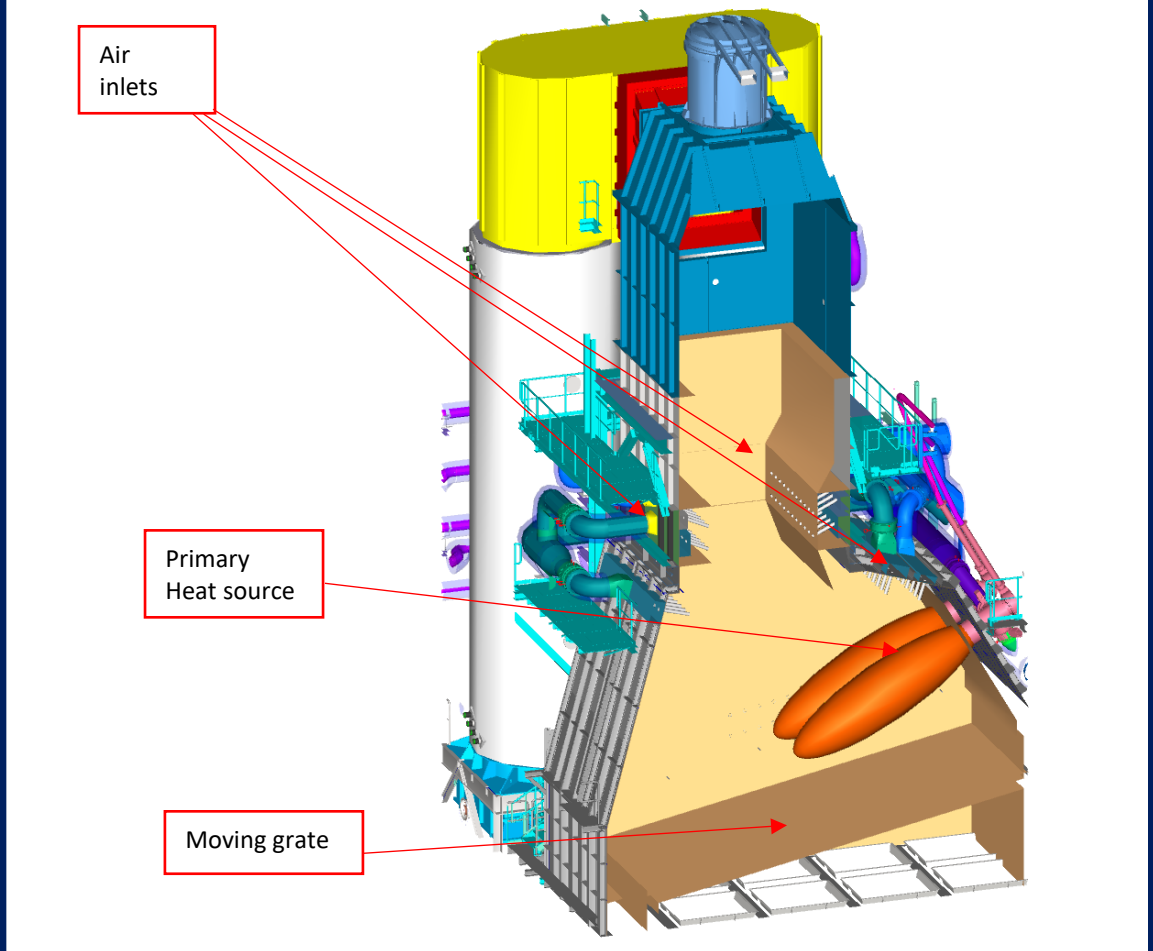
PHOENICS Case Study: Combustion - CFD Analysis of Biomass Combustor, by Shakil Ahmed, CHAM, October 2019 / PH - 2019

CHAM conducted a CFD analysis of a biomass combustor with the objective of confirming that the design of its combustion chamber and furnace flue met the residence-time and temperature requirements set forth within the environmental permit issued by the regulator for the region. In essence, the CFD analysis was required to help establish whether the combustor's performance met the indicative BAT design stage requirements given in the Incineration of Waste Sector Guidance Note EPR 5.01.

The moving grate combustor modelled - shown below - is designed to burn untreated wood and waste wood. The BAT stage design requirements necessitate a minimum air temperature of 850^{o}C within a specified qualifying zone and a minimum residence time of two seconds.



3D CAD drawing cut-out of the combustor

The entire volume of the combustor is embodied in the CFD model, including each individual recirculation inlet. The upper section of the combustor is also modelled, corresponding approximately to the section shown in yellow (above.)

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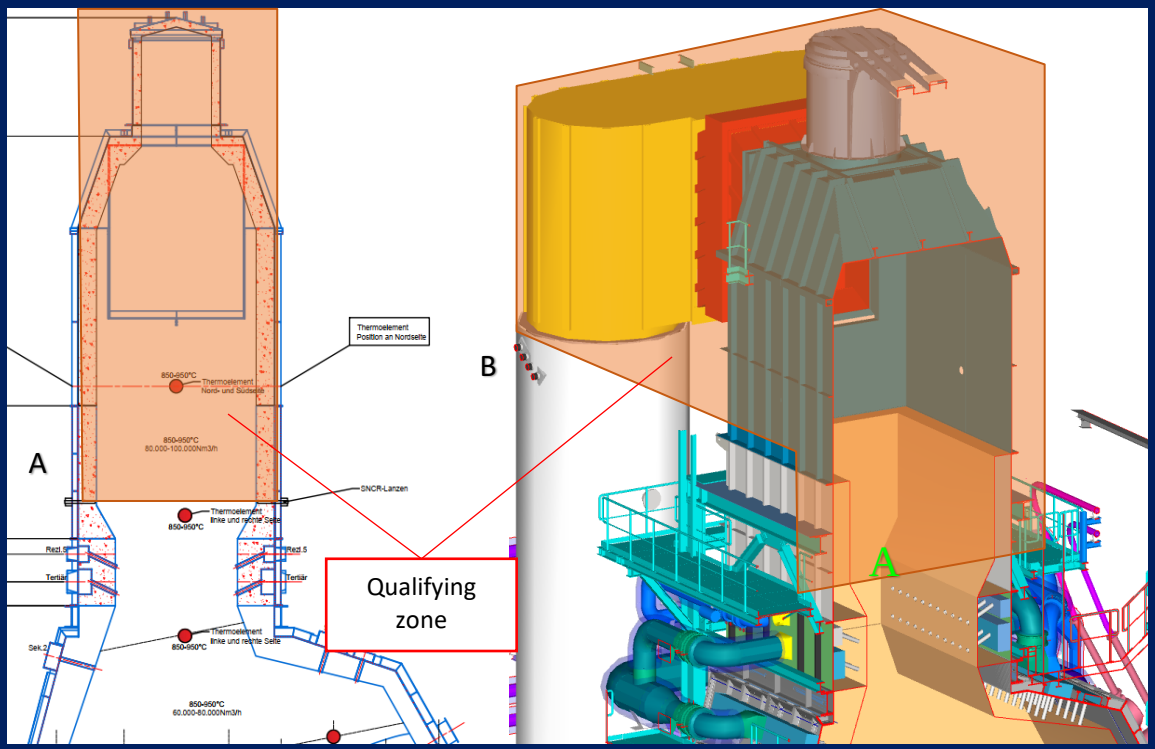
For this particular requirement, it is not necessary to model the combustion process explicitly; instead, the heat of combustion of the main fuel is distributed uniformly over a specified volume approximating to the region of principal combustion. A mass inflow rate corresponding to the source of gaseous combustion products has also been introduced.

Additional heat is produced by the flash burning of fine particulates injected into the combustor when the temperature inside it rises above a pre-defined temperature. The amount of heat produced by burning these particulates is in fact similar to the primary combustor. Again, this has been modelled by distributing this extra heat source over an appropriate region representing the location of the principal particulate combustion. Secondary and tertiary air inlets are added into the combustion chamber at multiple locations across the combustor walls and at varying flow rates and temperatures, to ensure complete combustion.

Residence time within the system has been simulated by means of a mean-age-of-air calculation. To assess the residence time within the "qualifying zone," this has been calculated to represent the age since the air entered the "qualifying zone". This is referred to as the "qualifying age."

The qualifying zone within which residence time is accumulated is taken to start after the last recirculation air is injected and mixed. At this point, all heat has been added into the model and hence the average temperature is typically well above 850^{o}C at the start of the qualifying zone.

The qualifying zone starts high above the grate, from points A to B (see shaded area below.)

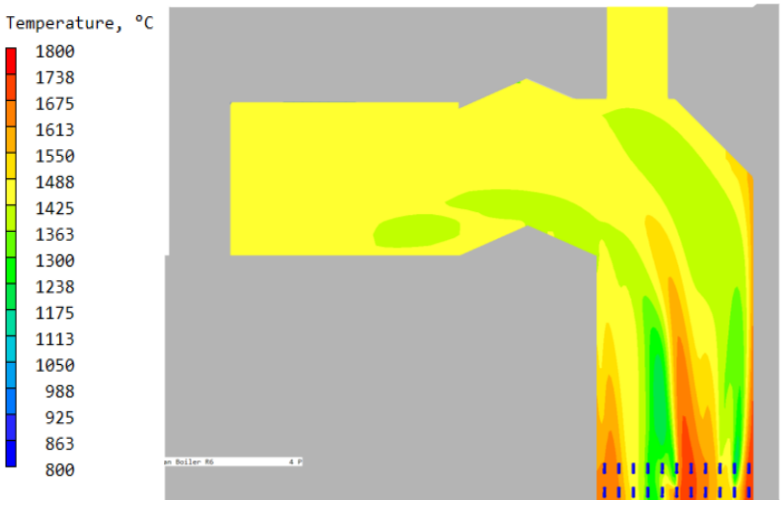


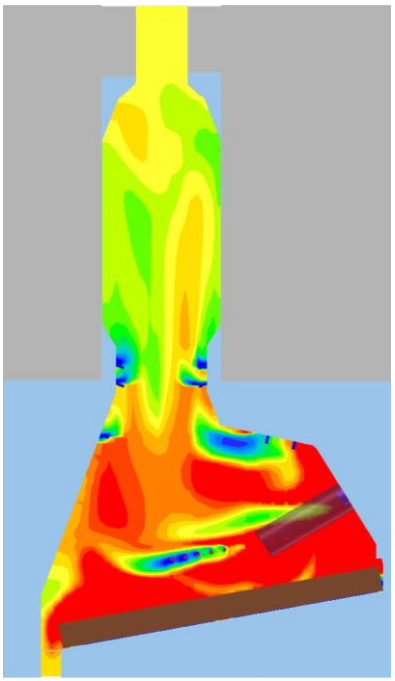
Location of the qualifying zone

Air inlets under the grates supply primary and recirculation air into the combustor. The air and granulates for the granulate burners are injected into the combustor and are designed to mix immediately upon entry.

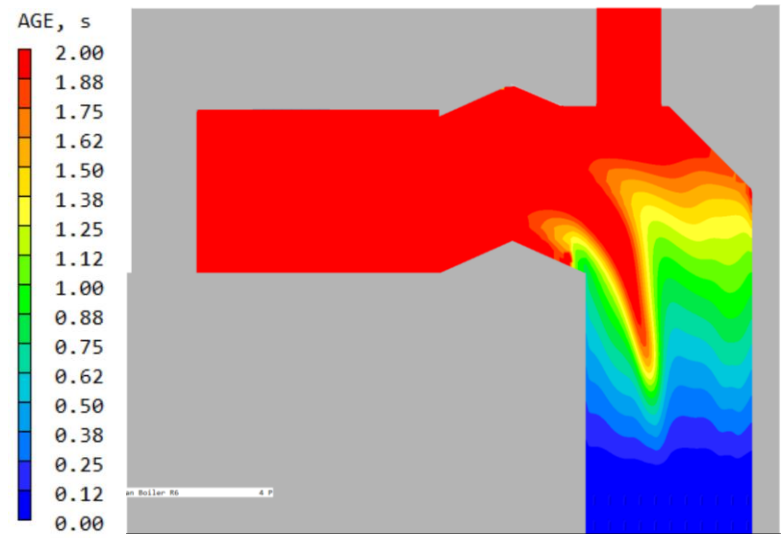
Typical results are shown below.

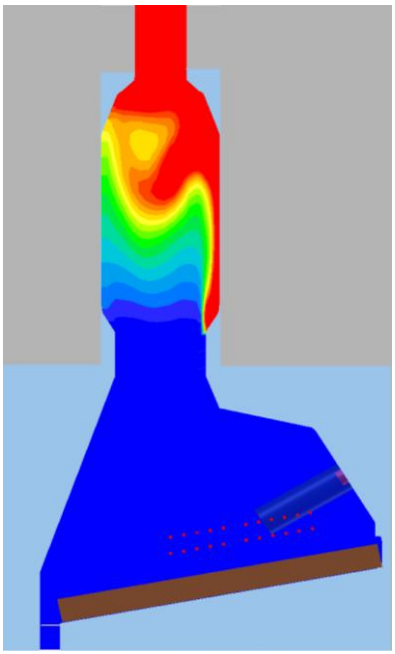
Temperature along the flue (X & Y planes)





Residence Time – Qualifying Age along the flue (X & Y planes)





The CFD results indicated that the minimum gas temperature throughout the qualifying zone met or exceeded the target values. Similarly, the results confirmed that operational testing of the proposed design of the combustion chamber was likely to meet or exceed the residence time and temperature targets recommended in the Incineration of Waste Sector Guidance Note EPR 5.01.