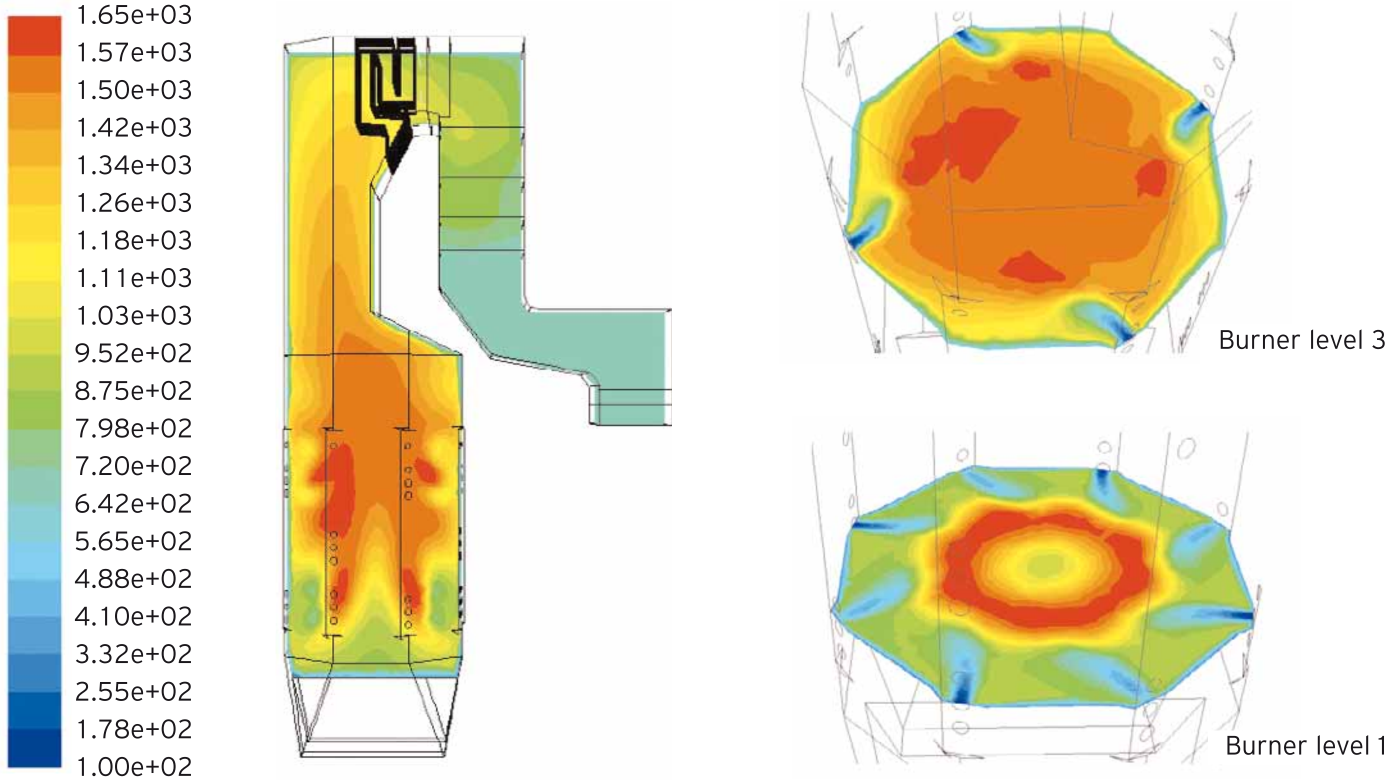

Temperature distribution from a simulation of Vattenfall's tangentially-fired coal powder boiler in Wedel, Hamburg.

Flow dynamics – a cornerstone of combustion technology

Almost all forms of human activity are associated with liquids and gases in motion. The valves in our hearts and the bronchial tubes in our lungs are good examples of excellent flow dynamics design. Knowledge and an understanding of flow dynamics in processes will make it possible to improve the functioning and efficiency of these processes in most cases.

The principle underlying all combustion is to bring together fuel and air in the right proportions and at sufficiently high temperatures to enable a chemical reaction to take place between the fuel and the oxygen in the air. Consequently, work on flow dynamics in the field of combustion technology largely focuses on finding ways to mix the fuel with the air so that combustion takes place as efficiently and effectively as possible.

Some solid fuels, for example biofuels, contain a high proportion of volatile substances. These substances are given off as combustible gases when the solid fuel is exposed to high temperatures. Combustion is thus further complicated by the fact that both solid and gaseous fuels have to combusted at the same time in one and the same plant. This poses a challenge in terms of flow dynamics as the air must be mixed with both the solid and gaseous fuels.

Vattenfall has long and sound experience in the field of flow dynamics and has established two methods for the modelling of combustion plants: physical (experimental) and mathematical (computational) modelling. The methods are general and practicable for almost all combustion techniques and fuels.

Physical modelling

Physical modelling entails building a small-scale model of the boiler in a transparent material. In the model, water is used to simulate flows. In order for the model to function correctly in terms of flow dynamics it cannot be a direct, scaled-down copy of the original. Certain adjustments must be made to compensate for thermal effects and flow resistance, for example.

In order to demonstrate flows in the model, two different methods are used:

1. The first method involves adding dye at various points in the boiler model in order to get an overall view of the flow pattern. This reveals, for example, where there are vortices or stagnant zones (bands) in the boiler and how the air fed into the boiler spreads.

2. The second method entails demonstrating the mixture of fuel and combustible gases in the boiler's combustion chamber. The fuel is simulated using a slightly basic substance, while the air is simulated using a slightly acidic substance. One or several indicators are also added to the model. The model is adjusted so that the indicators change colour when exactly the right mixture of air and fuel is achieved. The indicators can also be used to reveal where there are zones with a high or low oxygen content in the boiler and where there are neutral zones.

The information provided by the two methods can be used to analyse the performance of the boiler.

The advantages of physical modelling are that it provides very clear results and that changes can be made easily and very quickly. Simplified two-dimensional models, so-called flow tables, can be used prior to carrying out three-dimensional modelling.

Mathematical modelling

In this method, which is also referred to as CFD (Computational Fluid Dynamics), the geometry of the boiler is set up in a computer-based calculation model that calculates flow patterns and gas composition. With the help of Vattenfall's powerful calculating computers and long experience of flow calculations, detailed information on flow patterns and the functioning of the boiler can be calculated with a high degree of accuracy.

The advantage of mathematical modelling is that it provides detailed information not only on flow and mixture patterns but also on temperatures, heat flows to boiler walls, emission levels and so on. A good mathematical model requires accurate background data on fuel flows, fuel composition and air flows in the boiler concerned.

It is often a good idea to conduct simple physical modelling (using flow tables) before carrying out mathematical modelling in order to identify operating cases that may be of interest for mathematical modelling.

Improvement measures

The results obtained from physical and mathematical modelling are used as a basis for measures to improve the performance of the boilers. Such measures have been implemented at Vattenfall's own plants and at those of our customers. Examples of the results are presented below.

At the Idbäcken CHP Plant (105 MWth, BFB boiler) the secondary air levels were converted following mathematical modelling. Together with improvements in fuel supply, this provided a better temperature distribution in the furnace and cleaner furnace walls. Savings as a result of improved availability, a higher maximum load for solid fuel and a reduction in flue gas losses amount to approximately SEK 10-15 million per year.

At the saw mill boiler in Myresjö (grates, 10 MWth), new portals for recirculated flue gas were introduced following mathematical modelling. These enabled quicker drying of the fuel and lower temperatures after the furnace. The savings resulting from an increase in the maximum load, increased efficiency and a reduction in NOx emissions amount to SEK 1.5-2 million per year.

The physical modelling of Gruvön's bark boiler (175 MWth) formed the basis for the installation of new air portals. This resulted in an average reduction of NOx emissions of 40 per cent, which is equivalent to a saving of SEK 4.5 million per year. In addition, oil consumption decreased and efficiency increased.

Vattenfall's coal powder plant in Wedel, Hamburg (2x350 MWth) is being analysed with regard to the residual carbon content of the fly ash. A combination of mathematical modelling, furnace measurements and advanced carbon characterisation is being used. It is estimated that the potential savings resulting from the increased use of "off design" coal will amount to SEK 3 million per year.

Mathematical modelling is also used in Vattenfall's "The CO2-free Power Plant" project when evaluating new burner and boiler designs for so-called oxyfuel combustion.

- **Research and development is an integral part of the effort that Vattenfall is making to achieve its vision of becoming a leading European energy company.**
- **We ensure that the systems we use today for the generation, production and distribution of electricity and heat are as efficient and safe as possible.**
- **We participate in the development of the energy solutions of the future and ensure that they comply with demands relating to the environment, acceptance and economic viability.**

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