



Improving performance and reducing emissions at ZETES 2 unit 3, Turkey

Poor combustion and less than optimum boiler efficiency were among the problems being encountered at an Eren Enerji 615 MW supercritical power plant at Zonguldak on the Black Sea. Following extensive analysis and CFD modelling, the solution saw extensive modification of the entire burner and combustion system, while retaining as many “non-performance critical” components as possible, to reduce costs

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Turkey is committed to achieving net zero greenhouse gas emissions by 2053 and has already made significant progress in its ongoing energy transition, placing a strong emphasis on renewable energy and energy efficiency.

As part of this transition, coal-fired power plant owner/operators in Turkey are adopting the latest technologies to increase efficiency and significantly reduce their emissions of CO₂.

One such owner/operator is Eren Enerji, which is committed to improving its environmental record. Eren Enerji is a major supplier of electricity in Turkey, with 2790 MW of coal fired units, supplying almost 7% of the country's

total electricity demand. Eren Enerji is part of Eren Holding, a Turkish conglomerate with investments in paper, packaging, retail, textiles and cement.

Eren Enerji tasked RJM to undertake a major review of its ZETES 2 unit 3* plant to identify how performance could be improved and emissions significantly reduced.

ZETES 2 unit 3, located at Zonguldak on the Black Sea, is a 615 MWe supercritical power plant. It is equipped with opposed-firing boilers and combustion technology featuring NR3 style burners supplied by Dongfang of China under licence from Mitsubishi Hitachi Power Systems.

ZETES 2 unit 3 came online in 2010 and fires local and imported bituminous coals.

Project objectives

Although ZETES 2 unit 3 is a modern, supercritical power plant equipped with Dongfang low NO_x burners, it was experiencing unsatisfactory performance across a number of parameters.

These included poor combustion and less than optimum boiler efficiency. In addition, the plant operators were seeking to protect the future life of the plant by avoiding tube leaks.

With a proven track record in solving complex combustion and emissions challenges, the

* Eren Enerji's ZETES (Zonguldak Eren Termik Santrali) consists of 2790 MW of coal-fired power plants built in three phases: ZETES 1, 160 MW; ZETES 2, 2 x 615 MW; ZETES 3, 2 x 700 MW. Unit 3 is one of the pair of 615 MW units that comprise ZETES 2.

management team at Eren Enerji called in RJM to assess the plant and propose a solution that would address all the key issues.

Poor combustion identified

RJM spent a considerable amount of time analysing the problems at ZETES 2 unit 3 and the combustion audit (site survey), combined with associated CFD analysis, confirmed that the dynamics of the Dongfang burners were actually very poor.

Each burner was set up individually, with different swirler settings, resulting in 24 different sets of competing burner dynamics. This resulted in long flames and uncontrolled combustion and high levels of excess air.

The incomplete combustion was such that the over-fire air system was unable to complete combustion of the unburned fuel as it could not penetrate to the centre of the combustion chamber.

In addition, the burners were being thermally damaged, due to the presence of flames within the burners themselves.

Poor combustion was also responsible for the high levels of CO.

Taken together, these findings confirmed that the entire burner and combustion system needed to be modified. There then followed a sequence of CFD studies to help identify the optimal solution.

Developing a solution

RJM focused on its well-proven staged approach, with detailed engineering tailored to the precise requirements of the plant and a common-sense philosophy that provided new RJM burner components but retained as many “non-performance critical” components as possible. By adopting this pragmatic approach, the old equipment removal / new component installation phase of the project was completed very quickly – within a ten week outage.

At the heart of RJM's solution were 24 bespoke sets of ultra-low-NO_x burner modifications, tailored to the precise requirements of the Dongfang boiler and with interfaces engineered to fit.

Installation of the new RJM equipment, along with ancillary components, took place during the planned outage of spring/summer 2024.

Performance improvements

As well as delivering the performance objectives in terms of addressing combustion instability, poor efficiency, burner damage, high CO and control of NO_x prior to the SCR, the performance results, summarised below, confirm that, in addition, the plant is now able to generate the same amount of power using less fuel and less reagent, with one fewer mill in service.

Less fuel translates to lower CO₂ emissions – an important objective for Eren Enerji – and the upgrade has reduced emissions of CO₂ by over 80 000 tonnes per annum on a like-for-like basis.

In addition, the RJM upgrade, by reducing flue gas flow, delivers significant operational cost



savings in terms of fuel, reagent for the SCR and fan power consumption. It also achieves further cost savings by extending the life of the SCR catalyst and avoiding future costs associated with tube leaks.

After the commissioning phase, overall performance of the plant post upgrade fulfilled the contractual performance guarantees and met and exceeded all Eren Enerji's objectives and expectations.

Key performance improvement data for the ZETES 2 unit 3 project is summarised in the table below.

Parameter	Improvement
NO _x (mg/Nm ³)	47% less
CO (mg/Nm ³)	49% less
Carbon in ash	50% less
Boiler efficiency	2% more
Mills in service	One less
Mill motors and fans	14% less power consumed
Mill mechanical power	9% less power consumed
Reagent for SCR (kg/day)	70% less required
CO ₂ emissions reduction	80 000t per annum

The RJM approach

As power generators all over the world are embarking on their own transition programmes to net zero, identifying where efficiency savings can be made and reductions in emissions achieved – cost-effectively – and without threatening the reliability and integrity of the plant, is of the utmost importance.

By focusing on engineering assessment, coupled with advanced equipment design, RJM aims to deliver the optimum combustion and emissions control solution.

While the technology is applicable to all boilers, its attention to engineering detail is particularly important for older boilers, where the retrofit of new technology can easily exacerbate existing operational problems or create new ones.

RJM's philosophy is therefore that combustion solutions must be customised for each site to ensure project objectives are met without compromising current operations.

The key elements of RJM's strategy are the combustion audit (site survey) and baseline testing which help identify pre-existing operational problems. A detailed engineering assessment of these pre-existing plant issues is then undertaken and state-of-the-art CFD modelling is applied to assess the impact of the proposed upgrade on operational parameters, to deliver the optimum solution.

The project road map adopted for ZETES 2 unit 3 (and for other similar projects) was as follows:

Preliminary project work

- combustion audit;
- airflow distribution – CFD isothermal;
- baseline test;
- CFD single burner model (existing burner);
- CFD full furnace model.

Main project work

- physical modelling;
- detailed burner design;
- burner manufacture;
- HAZOP study;
- commissioning;
- optimisation & performance tests;
- guarantees.

Ultra low NO_x burner

The RJM ultra low NO_x burner is manufactured to the highest standards and out-performs OEM equipment. It features:

- high alloy castings;
- state-of-the-art components;
- ease of installation;
- long life;
- excellent performance;
- full spares back-up.

In the ZETES 2 unit 3 case, having configured the new ultra low NO_x burners to fit the existing plant interfaces, installation was problem-free.

This was followed by the commissioning phase, which focused on fine-tuning the burner airflow balance. The unit was then returned to service with oil burner commissioning optimised as a first stage, followed by PF coal firing with solid and stable flames confirmed. Commissioning was successfully completed within two weeks of the end of the outage.

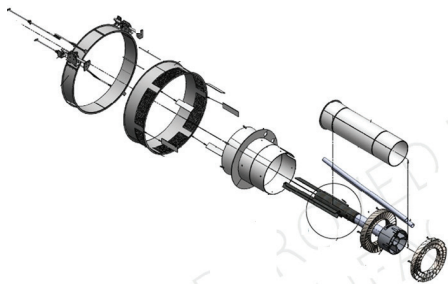
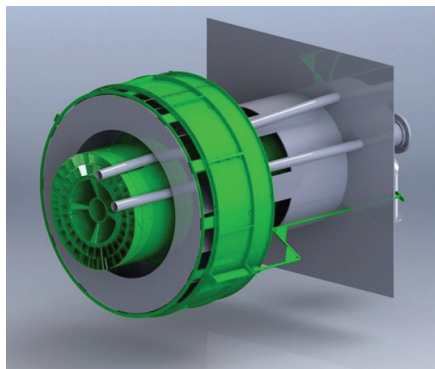
The importance of CFD

RJM harnesses its experience and expertise, alongside the power of CFD modelling, physical modelling and discrete element method modelling to help determine the optimal solution to resolve any combustion, emissions and performance challenges.

For the ZETES 2 unit 3 project, a series of CFD studies was undertaken to help build up an accurate picture of combustion behaviour at the plant (see opposite page).

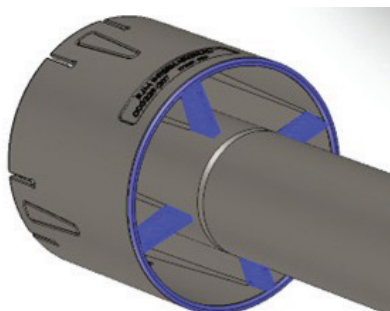
Designing and building the new hardware

For the ZETES 2 unit 3 project, RJM did not need to fully replace the existing burners and burner assemblies but instead came up with an innovative and cost-effective upgrade solution that enabled some elements to be retained. In the image below, the new components designed and supplied by RJM are shown in green, while the grey components were retained. Also shown is the associated engineering drawing, exploded view.



Fuel nozzle construction

To ensure robustness and reliable performance in aggressive high temperature environments, the RJM fuel nozzle is an advanced high alloy steel cast assembly, manufactured to the highest



Measuring air flow distribution as part of the preliminary project work

standards. Additional wear resistance is assured through Stellite 6 hardfacing to high wear areas (shown in blue, below left) such as on the outer rim of the coal nozzles.

Installation

The entire upgrade project was completed during the 2024 spring/summer outage. The RJM team worked closely with the in-house team at ZETES and was supported by specialist external contractors.

Future prospects

Eren Group, as one of Turkey's leading conglomerates, is committed to taking cutting-edge measures to improve the environmental record of each of its business lines and meet international standards. RJM is now working with Eren Enerji to develop upgrade solutions at other power stations within its generation fleet.

Below: **The commissioning team (Eren and RJM), following a successfully completed project**



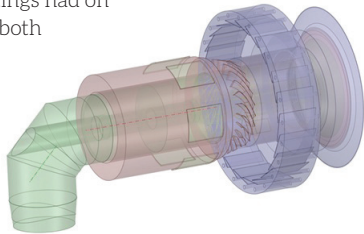
Above: **Checking measurements**



CFD studies for ZETES 2 unit 3 project

CFD study 1: Single burner geometry isothermal CFD model

The single burner model looked at what effects different TA (tertiary air) damper settings had on air mass flow and swirl, both of which affected flame shape and stability. The RJM upgrade removed the need to adjust these TA damper settings once properly set up during commissioning.



The single burner CFD modelling confirmed different airflow behaviour at different TA damper settings (below) ●

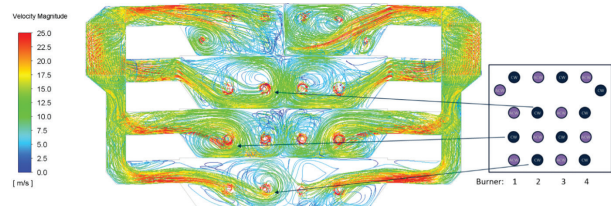
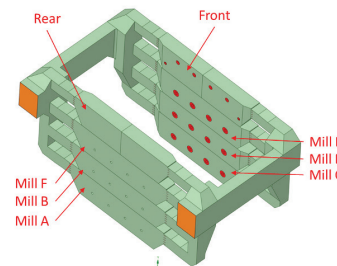


CFD study 2: Windbox isothermal CFD model

This model evaluated how the air was distributed to each windbox as well as the burner and OFA port within each one.

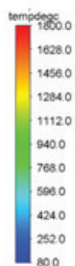
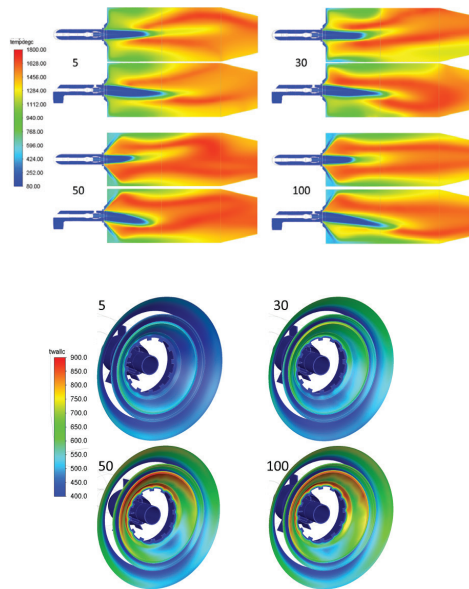
The modelling also showed that some burners were receiving air in the opposite swirl direction to the burner swirl configuration.

Reconfiguring the windbox dampers to operate in an opposed blade configuration resolved this problem. ●



CFD study 3: Single burner combustion

The CFD models confirmed that different tertiary air damper settings produced different flame profiles (numbers = % open) and that at certain settings (eg. 50% and 100% open) the burners were subject to damage due to excessive heat. To resolve all of these issues, RJM applied its tried and tested burner, which is designed as a multiple layer, air & fuel staged low NO_x burner.



The benefits of the multiple layer staged burner (below, left) are extremely low NO_x and controlled carbon in ash. Also, the strong internal recirculation zone (IRZ) ensures the flame is controlled by the burner and will remain stable across the load range for all coal types. The right hand image shows CFD modelling of burner prior to modification. ●



CFD study 4: Full furnace CFD model

Having established the desired combustion characteristics in the single burner model, RJM then applied these parameters to the full furnace model.

This 10 000 ppm CO isosurface model indicates flame extent. The baseline study (below left) shows damaging flame extent into the top of the boiler, whereas following the RJM upgrade, the flames are fully retained within the furnace (below right). ●

