WHITE PAPER

Optimizing boiler response times in waste heat recovery solutions

March 2023

Introduction

Investing in waste heat recovery (WHR) boilers for internal combustion engines and gas turbines presents a unique opportunity that benefits operating economy as much as it does the environment. By recapturing energy and putting it to use, they reduce both fuel consumption and emissions, which lowers operating expenses.

However, in combined cycle power plants that experience frequent start and stops of the primary power source, slow response times of the secondary cycle can negatively affect the efficiency of the power generation system. Typical cycle start-up times of conventional WHR boiler systems range from 45-90 minutes. This hampers their ability to recover heat from thermal power plants serving as on-demand, grid backup or for peak load power production – ultimately making the investment in the WHR system less profitable.

This paper focuses on the heat recovery boiler system, and how to identify start-up bottlenecks and related factors.

Thermal inertia in combined cycle power plants

The primary cycle of a combined cycle power plant (CCP), especially with ICEs, is often quick to respond to load changes and the start-up times are short. The secondary cycle, however, takes longer to respond due to factors related to its thermal inertia and the start-up sequence meant to ensure safety and reliability. Thermal inertia is associated with the thermal capacity of the boiler's heat surfaces and the water/steam it contains. The start-up sequence is a series of interlocks that mitigate excessive thermal shocks to the boiler, turbine and piping as well as prevent water hammering and guarantee stable drum level behaviour. If the sequence is executed incorrectly, it may cause damage or even an accident.

Issue one: circulation

At initial start, the exhaust gasses admitted to the boiler are restricted in a controlled manner. The boiler heat output is thereby modulated and protected from rapid thermal effects during start-up. When the boiler is not up to pressure, the evaporator behaviour is compromised as lower pressures mean larger specific volumes, which in turn hinder natural circulation. When the steam/water mixture doesn't circulate properly inside the evaporator, it can cause rapid oscillation of the drum water level, which can result in an emergency shut down of the steam boiler or even damage.

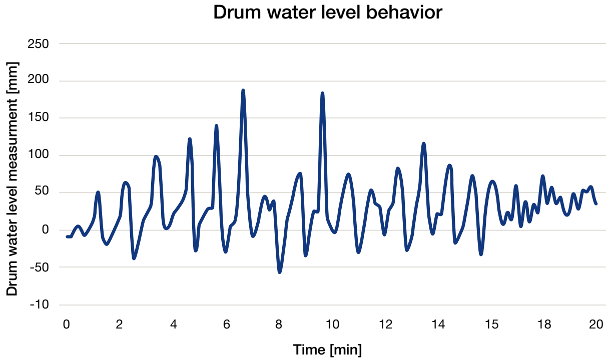

Figure 1: Steam drum water level fluctuation

Issue two: condensation

The other concern is condensation of steam inside the boiler super heater and piping. As the superheater is always below the steam drum, condensed water will naturally flow down and form pockets. This can cause an effect known as "water hammering", which can damage the piping. Hence, the boiler heat input needs to be controlled to reduce the likelihood and severity of this effect.

Blow out sequence

When the exhaust damper is fully opened, and the primary cycle is at full load, the boiler pressure increase rate is dependent on its thermal inertia. The water and steam inside the boiler, as well as the material in the heat surfaces, piping etc, must be heated to operational temperature. See Figure 2 for how much the pressure gain rate reduces after the blowout valve is opened in the 6 to 8-minute interval. An optimum blowout procedure ensures safe, reliable and fast start-up.

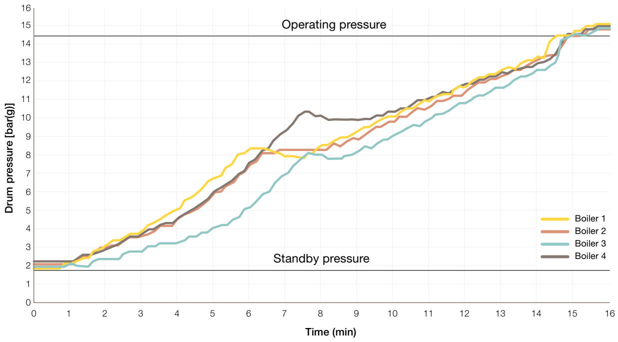

Figure 2: Drum pressure gain rate

Conclusion

The waste heat recovery boiler system start-up process is mainly a question of ensuring that the boiler is in a state that enables fast loading and correct operation of the start-up sequence. Here, the design of the boiler system and the steam piping plays a big role, since it is critical to ensure that the piping and the boiler super heater are condensate free and that the control system secures correct start-up operation. Response-optimized control software and case-specific boiler system design, enable safety, reliability and performance.

In closing, one overlooked issue with conventional WHR systems is the remote operations capability. The option for one operator to be able to remotely control the secondary cycle (including starting and stopping) from a common control system not only decreases the risk of operational mistakes and thereby increases safety – it also adds a lot to the efficiency of the entire system by allowing for more convenient (and thereby faster) start-ups.

Source: This whitepaper is based on a summary of the Master's thesis "Optimizing response times in power generation in combined cycle application", Tommi Toikka, 2021

This is Alfa Laval

Alfa Laval is active in the areas of Energy, Marine, and Food & Water, offering its expertise, products, and service to a wide range of industries in some 100 countries. The company is committed to optimizing processes, creating responsible growth, and driving progress – always going the extra mile to support customers in achieving their business goals and sustainability targets.

Alfa Laval's innovative technologies are dedicated to purifying, refining, and reusing materials, promoting more responsible use of natural resources. They contribute to improved energy efficiency and heat recovery, better water treatment, and reduced emissions. Thereby, Alfa Laval is not only accelerating success for its customers, but also for people and the planet. Making the world better, every day. It's all about *Advancing better*™.

How to contact Alfa Laval

Contact details for all countries are continually updated on our web site. Please visit www.alfalaval.com to access the information.

How to contact Alfa Laval

Up-to-date Alfa Laval contact details for all countries are always available on our website at www.alfalaval.com

100009946-2-EN 2303