SRU Thermal Stage Revamps

By Karen Hanlon-Kinsberg, Dimitri Travlos and Attila Racz

Comprimo, part of Worley
The Hague (The Netherlands), London (UK)

Best practices for SRU Thermal Stage Revamp design

Revamping or replacing the thermal stage of a sulphur recovery unit (SRU) is a common challenge faced by most facility operators, which requires a site-specific design analysis. Replacement could be considered as the thermal stage is a critical equipment cluster with a limited lifespan of typically 15 to 20 years, depending on the operating conditions to which they are exposed.

The stage encompasses the Main Burner, Thermal Reactor, Waste Heat Boiler (WHB), and the first condenser. See Figure 1 for a typical thermal stage block flow diagram. As facilities age, operators can see a corresponding increase in the frequency of chronic issues around the thermal stage. WHB tube leaks, ferrule damage and refractory lining deterioration, leading to patches on the shell are common challenges.

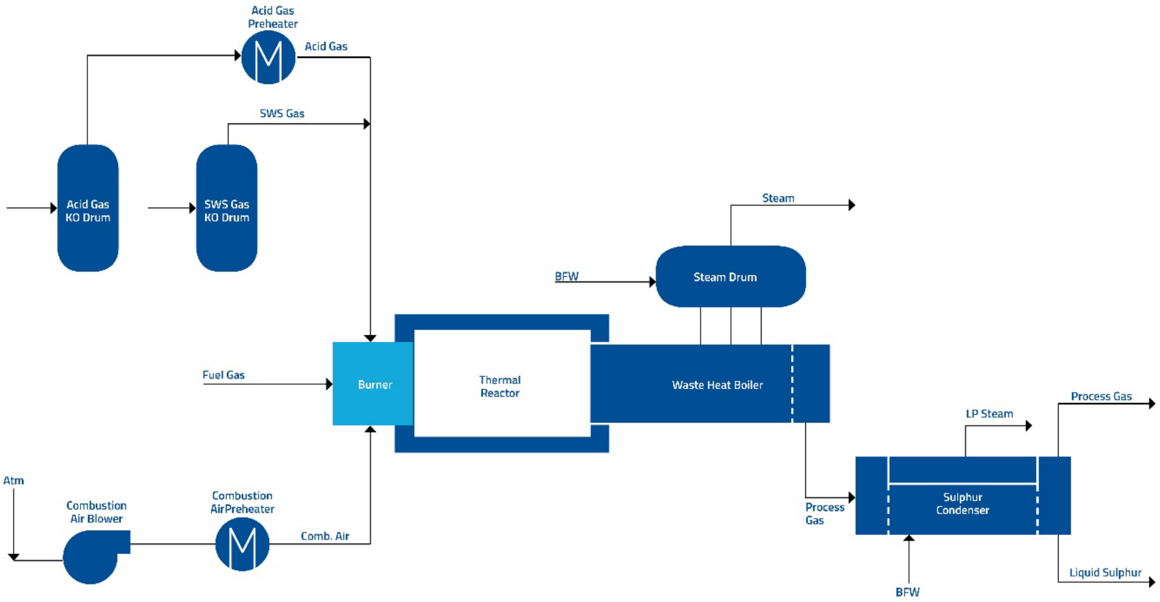

Figure 1. SRU Thermal Stage

Separate from mechanical issues, there could be debottlenecking requirements within a plant which warrant reviewing the thermal stage capacity. From a multitude of initiating events, facility operators are motivated to conduct a thorough review of the thermal stage performance.

As each thermal stage has unique configuration details and operating requirements, every evaluation should be handled on a case by case basis, with no one-size fits all solution. However, there are some common themes to be reviewed and considered to apply best practices in a thermal stage revamp design.

The main areas of evaluation correspond to the key equipment items:

- the main burner
- the thermal reactor with associated refractory lining
- the waste heat boiler

The Main Burner

As burner technology has advanced in recent decades, one of the first issues to consider is upgrading a low intensity burner to a high intensity model. Benefits of this change include improved mixing performance which lowers the required residence time, better destruction efficiency for contaminants such as ammonia and aromatic compounds (benzene, toluene and xylene), and opportunity for debottlenecking the SRU capacity with the addition of oxygen enrichment.

Moving to higher levels of oxygen enrichment requires a new burner design with a dedicated oxygen port. These process improvements do come with mechanical layout impacts. High intensity burners are normally longer and may have a larger diameter than low intensity designs, requiring a change to the thermal reactor sizing and configuration. The plot space impact of a longer burner can be offset somewhat by reducing the length of the thermal reactor due to the lower residence time requirement afforded by the better mixing performance of high intensity designs.

As well, if the current burner is a tangential design, moving to an axial burner arrangement (standard for high intensity) requires a different physical footprint for the overall thermal stage, depending on whether more length or a larger width are necessitated by the new equipment configuration.

The demands placed on the burner have increased over the years as well, as the typical operating window has widened for most SRUs. Facilities can often require a whole spectrum of conditions: Fuel gas firing during start-up and shut down, 0 to 100% oxygen enrichment, 0 to 100% amine acid gas feed, a range of Sour Water Acid Gas (SWAG) flows as well.

To illustrate the increasing complexity: for 100% oxygen enrichment, the design could require splitting some of the Acid Gas feed to the Combustion Air nozzle on the burner. This then results in a more involved control and Safeguarding system and requires extra switching valves.

These conditions go far beyond the demands of simple “air-only” operation and typically warrant a customized burner design to meet this challenging range of scenarios. Computational Fluid Dynamics modeling (CFD) is typically provided by the burner vendor to predict the performance of these customized designs. Therefore, it is vital to have solid collaboration with the burner vendor over the course of the engineering development to align between the project requirements and equipment capabilities.

The Thermal Reactor

When evaluating the Thermal Reactor, key elements to consider are:

1. Capacity and configuration
2. Engineered refractory design
3. Instrumentation for temperature measurement

Thermal reactor capacity in terms of residence time is important when reviewing the NH_3 and BTX destruction efficiency. Both flame length and diameter must be accounted for in the configuration, especially in case a low intensity (jet style) burner is part of the revamp design, which have longer flame lengths.

A robust engineered refractory design is critical, particularly when oxygen enrichment is part of the thermal stage design. Many units have experienced chronic refractory failures after switching to oxygen enrichment without upgrading the refractory. The higher process temperatures drive the need for higher refractory design temperatures. Current industry practice is a two-layer brick system for the thermal reactor lining. It is highly recommended to engage experienced refractory specialists to provide an engineered refractory design including a thorough thermal analysis of the thermal stage. This is a multi-component system, where all the elements from the reactor lining, the weather shield and the WHB tubesheet protection (ferrules) must work together comprehensively for the best long-term reliability.

The design of the refractory and weather shield system should ensure the following:

- Refractory lining to withstand the whole operating temperature range including start-up and shutdown conditions,
- Control the thermal reactor shell metal temperature within a defined range to prevent high temperature sulphide corrosion or wet H_2S/SO_2 corrosion, and
- Control the WHB tube and tubesheet temperature within a range to prevent the same corrosion conditions as above.

In conjunction with the refractory design considerations is the importance of proper procedures for start-up (warming up rate) and shutdown (adequate purging). Without proper purging, sulphur compounds can remain behind the refractory lining and/or ferrules causing corrosion following a unit cool down.

The temperature measurement in the thermal reactor takes specialized instrumentation as well as design considerations. Without oxygen enrichment temperature measurement is merely informative with a straight through configuration, except at start-up. But with split flow (or fuel gas co-firing) it is an actual (manual) control tool. With oxygen enrichment temperature measurement is required for both control and safeguarding. Pyrometers should be installed free draining looking at the opposing wall (but if they give the option to measure gas temperature that is valuable secondary info as it detects changes sooner). As Pyrometers tend to drift, they require regular re-calibration to continue providing reliable data. Thermocouples with ceramic sleeves, are now available which last longer if installed correctly (i.e., in the spot with least refractory movement and the hole drilled exactly right). With an inert purge they don't corrode, but they still can break. So, depending on the situation the temperature measurement requirements and possibilities need to be determined.

During revamps, we can sometimes overlook what is working well within a unit. Specifically, if the plant is seeing stable and reliable temperature measurement, it is important to minimize impacts on that existing instrumentation and configuration. This is an operational aspect worth preserving for the post-revamp. A balance must be struck between the requirements for replacing aging equipment with improved technology and maintaining the existing dependable elements.

The Waste Heat Boiler

The Waste Heat Boiler (WHB) is a very specialized heat exchanger and the design warrants careful evaluation. The constraints of the existing plot plan and equipment layout also require consideration when proposing changes in the WHB configuration.

The progress towards higher levels of steam generation has also impacted the criticality of a robust design. In general, at higher operating pressures and temperatures the margin for error in the mechanical reliability is much smaller.

Kettle type exchangers have been applied widely in the industry. Thermosyphon type exchangers with separate elevated steam drum can achieve higher water side circulation rates, and all other things being equal are therefore capable of handling higher heat fluxes. In revamp situations this becomes an important factor as higher operating capacities and higher operating temperatures associated with oxygen enrichment result in higher heat fluxes.

Traditionally waste heat boilers are designed with a thin (< 30 mm) flexible tubesheet to limit the temperature gradient over the tubesheet. This ensures the hot face temperature remains below the design limits for carbon steel with respect to high temperature H_2S corrosion. Generating steam at higher pressure levels requires more thickness for strength and this limits the diameter for a kettle type exchanger, which by design has a large unstayed area above the tube bundle.

Traditionally waste heat boilers have been designed using limitations with respect to overall heat flux and/or mass velocity. These criterions do not account for configuration details of the bundle and refractory nor for steam or process gas operating conditions. Hence relying on generic criterions alone has the risk to either replace a waste heat boiler unnecessarily or worse to overwhelm the boiler resulting in a failure. CFD analysis of both water and process side have been utilized to better predict boiler capabilities, which is time consuming and needs highly specialized knowledge to specify the input data. We at Comprimo have developed a tool, based on finite element analysis, which can help to determine if the design is nearing its limits and if further evaluation is required.

In case the boiler needs to be replaced and more surface area needs to be installed, typically this is achieved by increasing the tube count. This increases the overall diameter of the tube bundle and may exceed existing space constraints. Using smaller tubes both in terms of tube diameter and pitch can be considered as this will give you more surface area in a fixed tube bundle volume. However, this comes at the cost of the additional process side pressure drop. Moreover, bundle configuration does affect the max allowable (critical) heat flux of the exchanger, above which vapour locking may occur, particularly at the front end of the tube bundle.

For facilities with a congested layout or in case of modular unit layouts, space for growth could be limited. For facilities with more spacious layouts, such as often the case in North America, height restrictions aren't normally a concern. There switching to a thermosyphon design with separate steam drum would allow location of bigger bundles.

The range of expected process gas outlet temperatures from the WHB is another issue. If the temperature is hot enough (higher than 320°C), the carbon steel outlet piping will require refractory lining to the 1st condenser inlet nozzle. This could impact the unit hydraulics and the total scope of the revamp project. Alternatively, the outlet piping could be stainless steel to avoid the need for refractory lining

Project Example

The above principles can be illustrated by an example where 75% capacity increase was targeted, which was possible by incorporating oxygen enrichment up to 40%. The ratio of amine gas to SWS off gas could vary considerably, for some cases resulting in low temperatures during air-based operation and high temperatures during oxygen enriched operation.

The thermal stage was completely blocked in by structural steel and other equipment, except on top. The burner vendor performed extensive CFD modelling to ensure good mixing, prevent hot gas impingement and determine which ports to combine to limit length. The increased duty required replacing the original kettle type boiler by a thermosyphon type, with smaller tube diameter and longer length.

Those length increases were compensated by shortening the combustion chamber and marginally increasing its diameter. In cooperation with refractory engineers the thinnest possible refractory was installed to satisfy the residence time requirements as well as to limit the weight increase of the new design.

Double Combustion Option

In situations where higher oxygen enrichment could be necessary, double combustion can be considered to manage the high temperatures associated with high oxygen enrichment levels. In double combustion, the oxygen is introduced in two stages, essentially distributing the temperature over these two stages.

The design can be done either by installing two thermal stages in series (see Figure 2a) with the second stage not having a burner or as a single thermal stage (see Figure 2b), employing a two-pass waste heat boiler where a portion of the oxygen demand is injected in the channel between the first and second pass of the WHB, essentially creating a second combustion zone. The second option is preferred for grassroots and certain retrofits where plot space may be limiting.

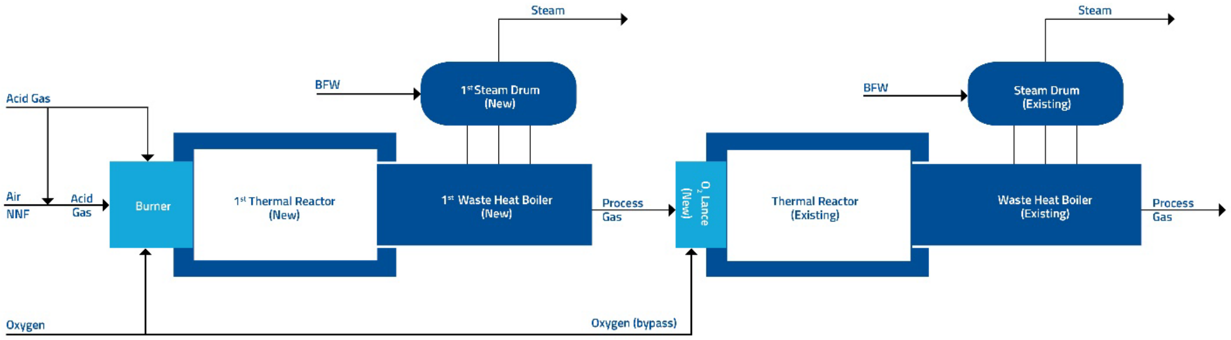

Figure 2a. Two-Stage Double Combustion

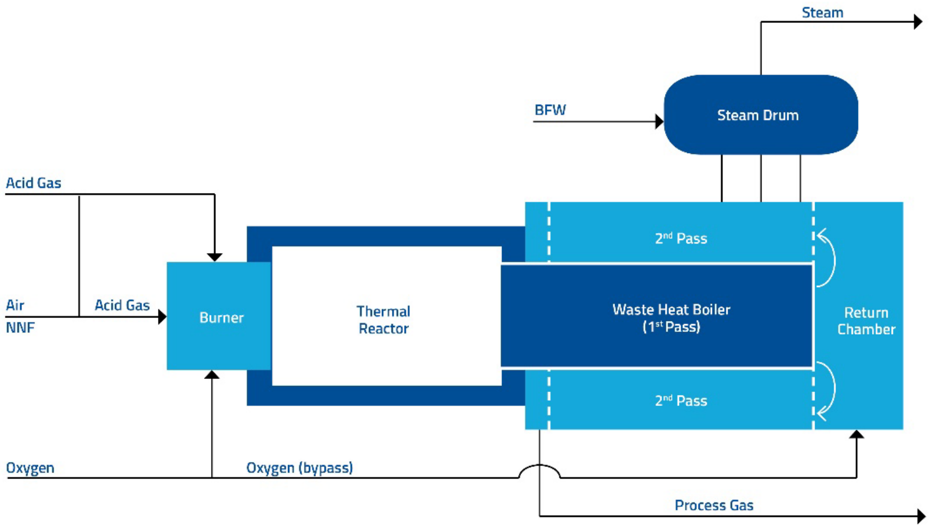

Figure 2b. Two-Pass Waste Heat Boiler

Comprehensive Thermal Stage Supply

Once the extent of the revamp scope has been studied and determined, Worley Comprimo can offer the Thermal Stage as a complete Engineering/Procurement/Fabrication supply contract in partnership with our Worley Chemetics colleagues. This contracting model can streamline the engineering and fabrication phases for our clients under a single supplier umbrella and with the prime advantage of a single mechanical warranty for all the equipment in the full thermal stage.

Conclusion

Overall, there are many factors which require special attention when evaluating an SRU Thermal Stage revamp. Careful consideration is necessary to overcome the existing configuration limitations while also working to minimize the physical impacts of new equipment. When all the elements of the design are integrated cohesively the unit has the best chance for long term reliability and ensuring a successful retrofit project.

Interested or have any questions? We're ready to help.

comprimo@worley.com

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