

A DECADE OF SMALL-SCALE SRU OPERATION AT CONIFER'S RED WATER FACILITY

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ABSTRACT

Over the years there has been a significant amount of sour gas production in Alberta, either directly or as associated gas as a result of oil production/refining. For many years the H₂S in this sour production was disposed of by converting it to elemental sulfur with a Sulfur Recovery Unit (SRU). Though there are exceptions, typically these SRUs have a capacity to handle over 25 tonnes of Sulfur per day with alternative methods often being used to dispose of H₂S below this rate. Of these alternative methods, Acid Gas Compression and Injection (AGI) has become the most common H₂S disposal method not only for smaller rates of sulfur but also for larger sulfur rates since the 2000s.

With this in mind, a potential production change provided an opportunity for reflection on the ability to handle produced gas at the Conifer's Red Water Processing Plant. The facility, constructed in 2015, disposes of H₂S using a Claus SRU. This SRU has the footprint of an AGI system, is skid-mounted, has a design capacity of less than 5 tonnes of sulfur per day, and has been operating effectively since its installation. This paper will discuss the factors leading to the selection of this small scale SRU and highlight key design characteristics that allow it to process these small sulfur flow rates. In addition, a summary of the key learnings from operating this SRU over the last 10 years will be presented.

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Introduction

This paper provides an overview of the Conifer Redwater small scale sulfur recovery unit, which has been running for approximately 10 years. The unique design features of this plant will be highlighted along with the performance history and key learnings from the operation of the unit during this time.

The Conifer Redwater Gas plant processes associated gas from oil production from the Redwater Field located in Alberta Canada. The Redwater field has been in production since the 1940's and in the mid 2010's it was determined that the existing gas plant, which included an amine sweetening unit and sulfur plant, were at the end of their usable life and needed to be replaced. The initial design of the new gas plant included an amine sweetening unit and an acid gas injection compressor skid to dispose of the approximately 2.8 tonne/day of sulfur. The new gas plant used a skid mounted modular construction approach and considered only the space available on the existing plant site while still allowing space for the decommissioning of the previous plant equipment. During the design phase of the facility, it was found that the necessary permits for a well to inject the acid gas from this plant were not granted. As a result, an alternative approach to dispose of the H₂S was required - one which was constrained by the skid footprint that was allocated to the acid gas compression skid. Of the potential alternative options (Ref 2,3), the team decided that a Claus SRU was the best option to meet the project goals also accounting for their past experience and familiarity with operating an SRU.

Design Basis and Project Drivers

The following were the key process design basis parameters and project drivers that were considered.

- Design Basis

| Fluid | Acid Gas |
|---------------------------|--|
| Pressure (kPag) [PSIG] | 35 to 70 [5.0 to 10.2] |
| Temperature (°C) [°F] | 35 to 45 [95 to 113] |
| Composition (mole %) | 35 (H ₂ S); 65 (CO ₂) |
| Sulfur Tonnage (Tonnes/d) | 2.8 |
| Recovery Requirements (%) | 70 (quarterly average) |

- The required sulfur recovery specification for a total sulfur flowrate under 5 tonne/day in Alberta, based on the AER Interim Directive ID 2001-3 (Ref 1), is 70% which can be achieved with a single stage Claus, however a two stage Claus unit was installed to provide operational flexibility.

- The SRU had to be contained in the space allocated originally for the acid gas injection compressor skid.
- The SRU had to be able to be operated with limited operations staff (not manned 24 hours).

Process Overview

With these considerations in mind, a 2-stage co-fired Claus SRU with air, fuel and acid gas pre-heat was selected. Figure 1 illustrates a process schematic of the SRU.

The acid gas from the amine unit is fed to an acid gas scrubber to remove liquids. Acid gas, pressurized air (from blowers) and fuel gas are pre-heated in individual heating coils in the waste heat exchanger (WHE) prior to being fed to the main reaction furnace burner. The burner effluent passes into a reaction furnace which provides additional residence time for combustion. The gasses from the reaction furnace pass through a coil in the waste heat exchanger that partially cools the stream with the heat medium before passing into the first sulfur condenser. Tail gas and condensed sulfur are separated in a vessel attached to the outlet of the condenser. Sulfur is directed to the on-skid sulfur storage tank and the vapor from the separator is heated to reaction temperature via an electric reheater prior to the first Claus bed. Sulfur formed in the first bed is condensed in the second condenser. Similar to the first condenser, tail gas and condensed sulfur are separated with the tail gas stream flowing to an identical electric reheater, Claus converter and condenser/separator. The tail gas from the third condenser separator is sampled by an air demand analyzer (ADA) before flowing into an incinerator which operates at a sufficient temperature to combust any remaining sulfur components.

The sulfur collected from the sulfur condensers is directed into a storage vessel located on the bottom level of the skid. This vessel contains heat medium coils to keep the sulfur in a liquid state. The coils are sufficient to melt the sulfur in the event of an extended unplanned shutdown. Any vapors from the vessel along with the nitrogen purge are combined with the tail gas and sent to the incinerator.

The unit has a self-contained heating/cooling system based around a common WHE vessel which holds the hot oil heat medium and contains the previously mentioned coils that are used to either heat streams (acid gas, air, fuel gas) or cool them as is the case with the reaction furnace effluent. In addition, there is a firetube style fuel gas burner that is used for start-up and also to provide supplemental heat to the heat medium fluid as required. Hot oil from the WHE is circulated to supply heat to the sulfur storage vessel and the various heat tracing circuits throughout the unit. Finally, hot oil from the hot return circuit is cooled with air coolers and routed to the sulfur condensers where it cools the process gas entering the condensers before being returned to the WHE.

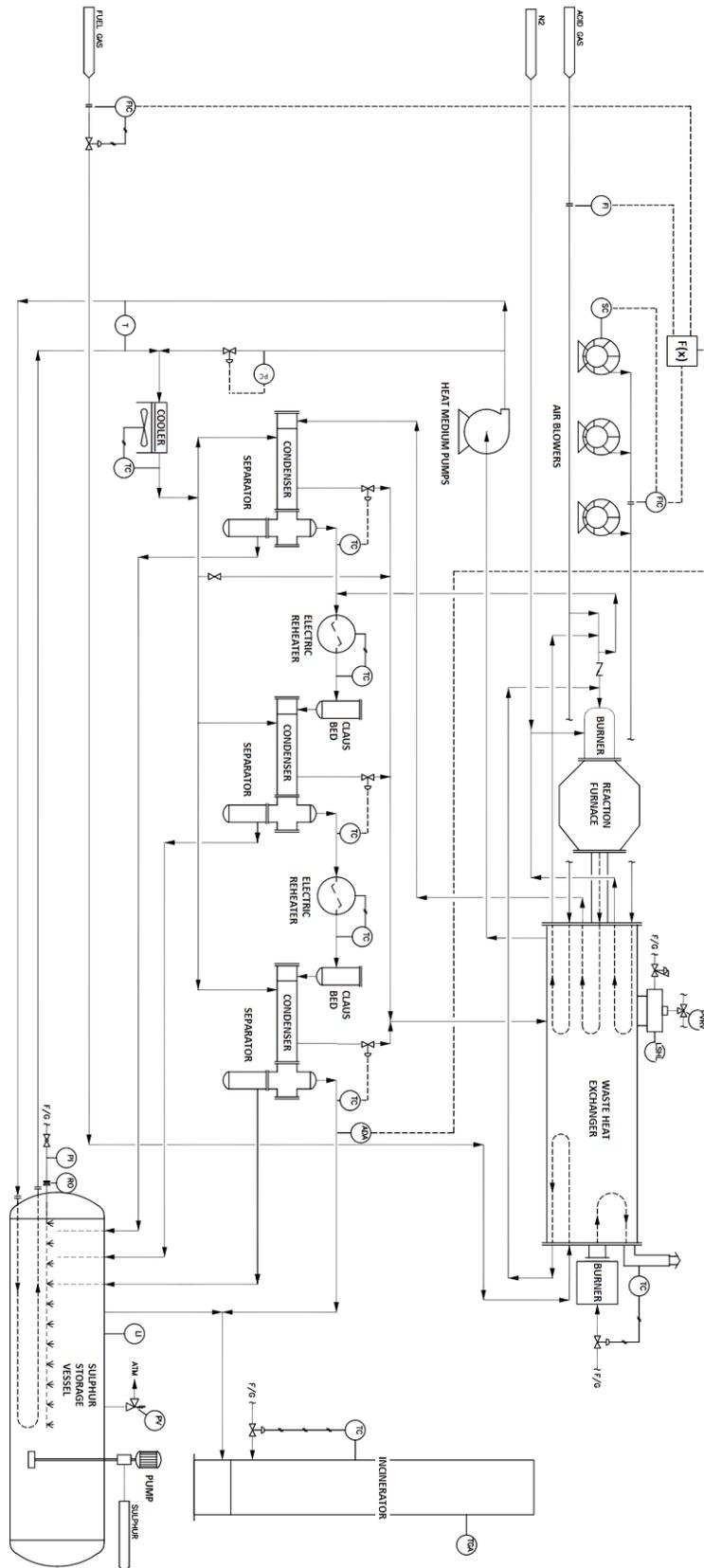


Figure 1 – SRU Process Schematic

Figure 2 shows a photo of the SRU skid installed and in operation. The Incinerator is in the background, and the truck loading arm is in the foreground. Figure 3 shows a labeled model view (with some items removed for visibility) of the SRU skid with a similar angle as Figure 3a. Figure 3a shows a side view of the SRU skid under construction in the shop. The sulfur storage vessel is on the bottom of the skid, the reaction furnace can be seen on the upper right side of Figure 3a with the waste heat exchanger to the left of this, the heat medium coolers can be seen at the far left of the upper portion of the skid. Figure 4 shows a labeled model view (with some items removed for visibility) of the SRU skid with a similar angle as Figure 4a. Figure 4a shows an end view of the SRU skid under construction. One of the sulfur separators attached to the end of the condensers can be seen in the foreground of the Figure 4a, with the condensers located on the of the left hand side of the upper skid. An electric reheater and Claus converter can be seen at the far end of the upper section of the skid directly above the other end of a condenser.



Figure 2 - SRU Skid in operation

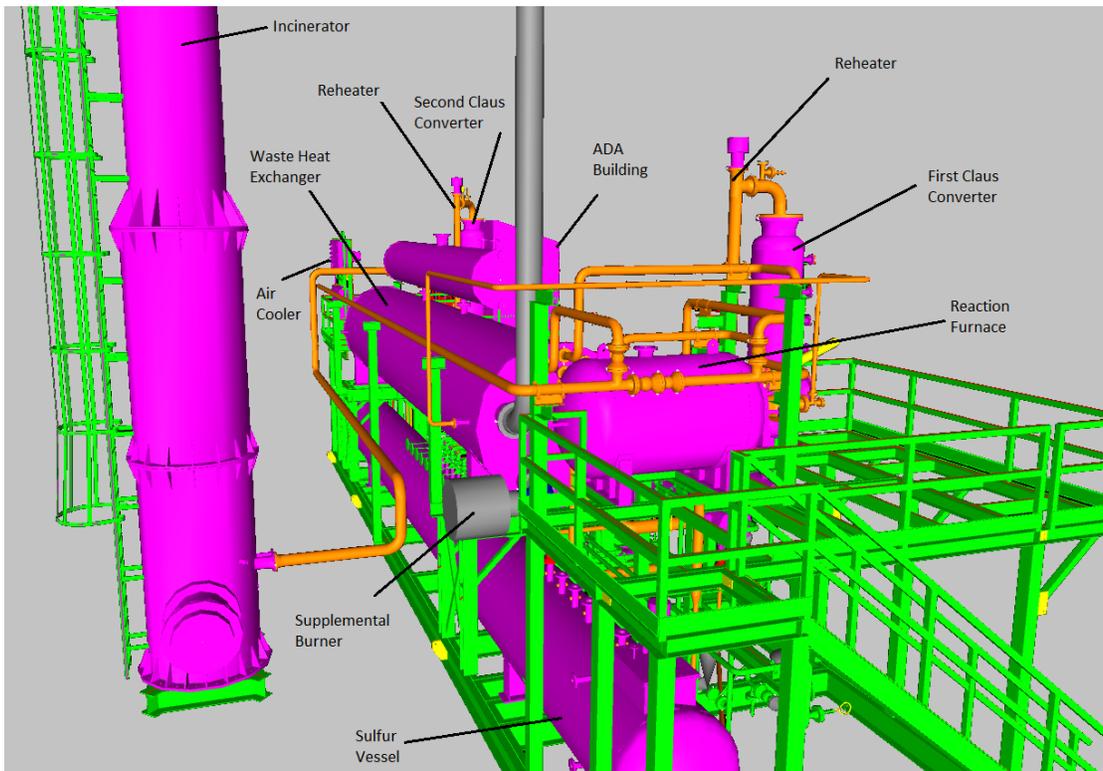


Figure 3 – Model Side view of SRU with Equipment Labels



Figure 3a - Side view of SRU skid being constructed in shop.

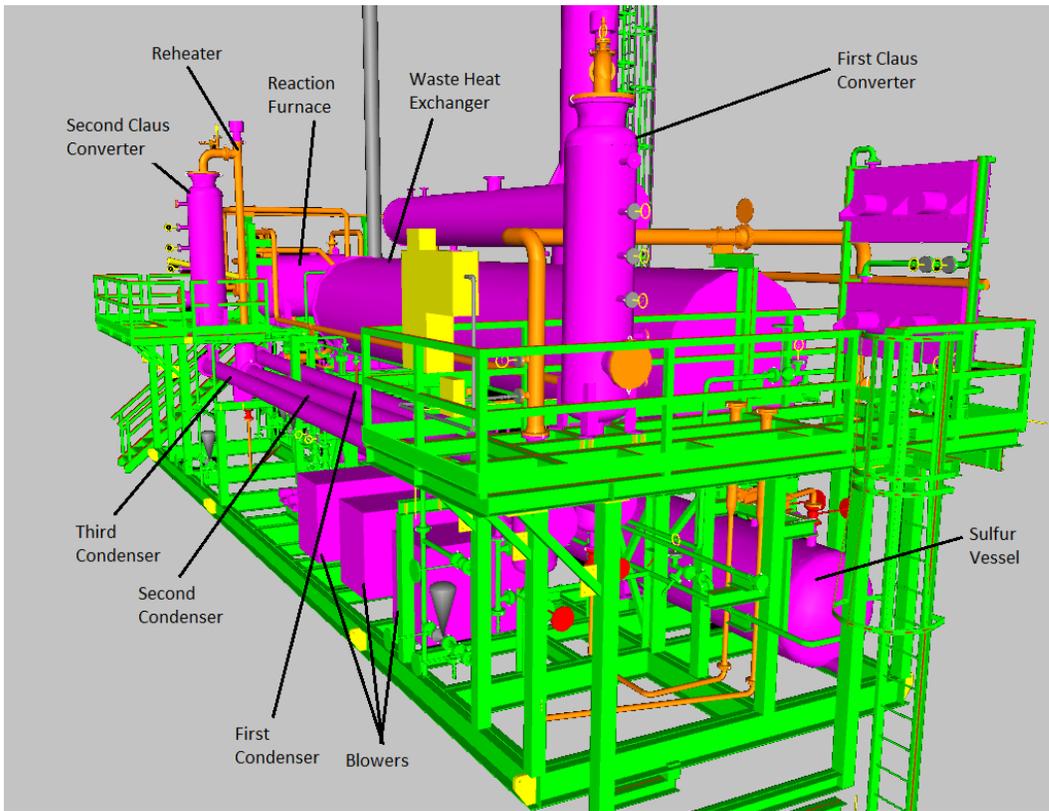


Figure 4 - Model End view of SRU with Equipment Labels .



Figure 4a - End view of SRU skid being constructed in shop.

Unique Design Features

The following section details the unique design features of this unit and will discuss the innovation rationale, benefits, and practical considerations for each.

Two-Stage Claus Configuration

A two stage Claus unit was selected despite the fact that a 70% sulfur recovery could be accomplished with a single stage. This was desired to provide a significant margin on the sulfur recovery unit in order to provide operational flexibility. The unit is capable of recovering sulfur in excess of 90%.

Claus Converters

The Claus beds both utilize a conventional Claus catalyst (no titanium oxide catalyst even though 35% H₂S acid gas requires significant natural gas co-firing in the reaction furnace burner). The temperature entering the first bed is set higher than the second in order to promote the hydrolysis of the COS and CS₂ formed in the reaction furnace with the introduction of natural gas. The converter vessels are constructed of SA-387-GR22-CLA which allows higher operating and design temperatures without the need for refractory lining. The catalyst is loaded from the top of the vessel and uses an elephant stool over the vessel outlet to support it. The converters are located directly above the inlet of their respective sulfur condensers which are directly connected to the bed outlets. There are 3 locations along the length of the catalyst bed for temperature measurement.

Main/Trim Air Control via Blower Speed

In a Claus SRU, one third of the H₂S in the feed stream must be converted to SO₂ before the Claus reaction can be utilized to produce elemental sulfur. This requires precise control of the combustion air flow to the burner in order to avoid forming either too much or too little SO₂ which would reduce the sulfur recovery in the unit.

In this SRU, the control loop for the combustion air does not make use of any control valves. Instead, the speed of the blowers is adjusted to provide the necessary combustion air to the SRU burner to maintain the proper ratio of H₂S to SO₂ for the Claus reaction. The air flow rate is controlled based on the overall air demand, the demand is mostly based on the feed forward loop that is combination of the ratio of the air to acid gas and the air to fuel gas ratio (or the main) and a smaller demand (trim) is adjusted based on the H₂S to SO₂ ratio measured by the air demand analyzer (ADA). All of these contributions are summed and the signal is sent to the blower speed controller to give the required flow. The original conceptual design, saw the each of the two demands utilizing dedicated air blowers. In practice, one of the blowers (smallest in its class at the time) was capable of exceeding both air demands and only a single blower is utilized. A manually controlled excess blow off valve is utilized to optimize the controllability of the air stream.

Waste Heat Exchanger/Hot Oil System/Heat Integration

Given the space constraints and lack of external utilities, the decision was made to design a heat integrated system centered around a waste heat exchanger which utilizes hot oil as the heat medium. The reaction furnace effluent passes through a coil in the WHE to cool this stream before entering the first sulfur condenser. This heats the hot oil and provides a significant amount of the heat duty needed for preheating the air, acid gas, and fuel streams feeding the SRU burner. Each of these streams flow through a dedicated coil in the WHE to heat them prior to entering the burner.

Hot oil is also pumped from the WHE through the heating coils in the sulfur storage vessel and through the ControTrace heating loops used throughout the facility. Finally, the hot oil from the heating coils is combined with additional hot oil from the WHE and cooled using an air cooler before being routed to the sulfur condensers. Here it is heated by the process gas entering the condensers before being returned to the WHE in a closed loop.

The WHE includes a separate fire tube and burner to provide heat for start-up and supplemental heat as necessary. It also has an expansion tank on top of the main vessel and the hot oil level is adjusted so that there is always a level in this expansion tank to ensure all of the coils and burner tubes are fully submerged.

This heat integration results in a significant space savings and helps to provide stable operation for the facility while effectively utilizing the heat generated in the SRU.

Electric Reheaters

Electric reheaters upstream of the Claus beds were selected for their controllability at low flow rates and for ease of skid integration. The first reheater ensures temperatures sufficient for COS/CS₂ hydrolysis, while the second reheater maintains adequate sulfur dew-point margin at the second reactor outlet. The reheaters are located in the vertical piping between the condenser separator and the downstream Claus converter to minimize piping, allow for drainage, and provide easy access for maintenance.

Hot Oil Cooling for Sulfur Condensers

The sulfur condensers are located in the middle section of skid and the process inlets are located directly below the process outlets of the equipment items feeding them. This was done to minimize the amount of piping between equipment items. The condensers are sloped from the inlet to the outlet and there is a small vertical separator directly connected to the process outlet of each sulfur condenser. The vapor from these separators exits the top while the liquid from these separators drains through a P trap within sulfur storage vessel which provides a liquid seal to keep the process gases from entering the storage tank. This configuration eliminates conventional underground sulfur seal pots.

The sulfur condensers use air-cooled hot oil as their cooling medium. The flow rate of this cooling medium is adjusted to achieve the desired exit gas temperatures. Using the cooled hot oil stream allowed for further heat integration with the WHE thereby reducing the overall footprint of the skid and provided enhanced thermal stability and controllability.

Incinerator

The incinerator is the only component of the SRU that is not mounted on the skid, it is however installed adjacent to it. The tail gas line connecting the SRU skid to incinerator is heat traced using ControTrace which utilizes the hot oil from the WHE. In the event that the total amount of sulfur in the acid gas falls below 1 tonne/day, the incinerator is designed to be able to handle the entire acid gas stream with the SRU shut down.

Liquid Sulfur Handling

Storage and truck-out facilities for the sulfur produced by the SRU are also included on the same skid as the process equipment. A vessel capable of storing two weeks of sulfur production was designed and located on the bottom level of the skid. The three sulfur rundown lines come into the

storage vessel from the top and extend all the way to the vessel bottom to form a seal. There are heating coils (heated with hot oil) within the vessel as well as a sparge gas system to be able to de-gas the liquid sulfur. The sparge gas is available and sent to the incinerator (if used). The vessel has a submersible sulfur pump installed in it which pumps the sulfur to a loading rack located on the second level of the skid where it can be loaded onto a sulfur truck. The non-degassed sulfur is trucked to a nearby facility.

The rundown lines are short and heated with ControTrace heating elements utilizing hot oil . There is no rod out capabilities designed into the piping layout, but the piping is small enough that it can be easily replaced or removed should there be any issues. To prevent sulfur solidification due to issues with a heating loop, all sulfur lines have low skin temperature alarms to alert operations of any issue. Viewports for each run down are simply pipe flanges on the second level of the unit that can be opened to view sulfur flow or to extract a sample for testing.

Skid-Mounted Modular Design

Given that the requirement for an SRU to dispose of H₂S came later in the overall gas plant design process, the skid-based modular approach and footprint limitations had to be adhered to in the design of the SRU. In addition, the lack of existing utilities that could be used in the SRU required the use of a unique process configuration to have an operable process and meet all of these design constraints. A two-level design layout was developed with careful attention being paid to the orientation of equipment to minimize pipe runs and also considering hydraulics to be able to take advantage of height differences where appropriate. For example, the Claus beds are located on the top level and are directly above the inlets to the sulfur condensers, a vertical separator vessel is connected directly to the outlet of the sulfur condenser with sufficient height to allow the liquid sulfur to flow into the sulfur storage vessel with the gas being able to flow upwards back to the electric reheater and second Claus bed.

Once each piece of equipment was sized and ordered from the respective vendors, it was all shipped to a skid fabrication facility located in Calgary that fabricated the structural components and assembled the skid. The skid was transported to the site and the integration of the SRU skid into the larger gas plant was largely “plug and play” with most of the construction and assembly work being done in the shop.

Lessons Learned or Challenges Overcome

1. Tail Gas Line Freezing and Sulfur Backflow

In the original design, the tail gas line and the vapor line from the sulfur storage vessel to the incinerator were heat traced with electrical tracing. This tracing failed and eventually led to a blockage of the vapor lines from the SRU to the incinerator. This caused a backup of sulfur through the Claus beds into the condensers as well as into the incinerator. This resulted in the unit being shut down for a couple months in order to add ControTrace heat tracing to this and other spots such as flanges on the sulfur separators.

2. Insufficient Supplemental Heat Duty

It was also found during the initial operating period that there was not sufficient heat coming from the process and that the original supplemental burner in the waste heat exchanger was not

sufficient to provide the required heat duty. This was due to the flow of sulfur being lower than expected along with the additional duty needed for the heat medium supplying the additional tracing. To address this, the duty provided by the supplemental burner was increased by first installing larger burner orifice. However, this still did not provide sufficient heat so eventually a blower was added to convert the burner from a natural draft air burner to a forced draft burner. It was also discovered during this time that the heat medium stream flowing to the sulfur condensers was not being cooled enough to provide the desired temperature at the outlet of the condensers. In order to address this, additional heat medium coolers were added to system.

3. Automated Excess Air Valves

The original configuration had a manual air blower bypass valve which has since been automated. This has made operation significantly easier, particularly during start up and shut down.

4. Waste Heat Exchanger Gasket and Skid Layout

The coils for the preheat and the furnace effluent enter the waste heat exchanger through a gasketed head. This gasket started to leak which required the head to be removed in order to repair it. The compact layout of the reaction furnace and waste heat exchanger meant that the reaction furnace had to be moved in order to service this gasket. If a new unit was designed, changing this configuration to allow for easier servicing of these components should be considered, including separating the unit into two separate skids if there is space available.

5. Waste Heat Exchanger Moisture Removal

It was also found that the configuration of the waste heat exchanger should be modified to allow for an improved method for letting moisture escape from the hot oil since it took a significant amount of time for it to leave the system.

Although they were problematic at the time, each of these issues provided valuable lessons for small-scale SRU design, particularly regarding thermal integration, heat-tracing reliability, and the importance of conservative design margins for auxiliary heating systems.

Operation and Performance Review (10-Year Perspective)

Since starting up, the Conifer Redwater SRU has consistently exceeded its required sulfur recovery efficiency, averaging much more than the required 70% recovery over its entire operating period with an average sulfur production rate of 1.5 tonnes per day. The unit is operated at a point optimized for reliability and uptime, balancing available operator coverage and the impact any downtime would have on field production, while still surpassing performance requirements. To date, the plant has not needed to run at its full design capacity.

Conclusions

The Conifer Redwater small-scale SRU has proven that compact sulfur recovery units can effectively replace AGI systems when regulatory or geological constraints prevent injection. Almost a decade of reliable operation shows that such units can:

- Meet or exceed sulfur recovery and emissions requirements.
- Operate reliably and continuously in harsh northern Alberta climates conditions.
- Be integrated efficiently into modular facilities.
- Maintain high availability with minimal operational oversight.

Although the Redwater installation is unique and represents the first deployment of this design, its performance provides a strong foundation for future iterations. Several improvements have been identified for next generation units:

- Improved layout: possibly split into multiple skids which would address hot oil leaks from WHE.
- Improved access to hot oil tracing manifolds
- Improved access or configuration of hot oil expansion tank vents

Collectively, these refinements would further increase maintainability, safety, uptime, and overall lifecycle performance.

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