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Sulfidation Corrosion in a Claus Waste Heat Boiler

Sulfidation corrosion in Claus Waste Heat Boilers (WHB) is one of the leading causes of unexpected failures that result in unscheduled shutdowns of Sulphur Recovery Units (SRUs). Sulfidation corrosion is caused by two main factors: high temperatures, typically exceeding 650°F or 343°C, and hydrogen sulphide (H_2S). Both factors are prevalent in an SRU, especially in the front-end where the Reaction Furnace and WHB operate. Refractory lining is used as protection wherever metal surfaces may see high temperatures and H_2S. Other special protection measures are put in place in the front end of the WHB in the form of ceramic ferrules to protect the tube-to-tubesheet transition joint as well as the first several inches of tubing. It's in this region of the WHB where most of the failures occur.

Although metal temperature and H_2S concentration are the two basic factors that go into determining the rate of sulfidation corrosion, tube metal temperature is influenced by several parameters. In a WHB, one of the factors is heat flux. Heat flux is the rate at which heat is exchanged from the hot process gas through the tube wall to the cool utility water/steam. The faster that heat is transferred through the tube walls, the hotter the tube walls become, which makes it a vital consideration when designing a WHB or managing changes in operating an SRU. Oxygen enrichment can have a profound effect on heat flux.

A North American refinery was considering adding oxygen enrichment to their Claus unit in an effort to increase its capacity. Adding oxygen enrichment to an SRU can be a simple and inexpensive way to squeeze more hydraulic capacity through the plant without huge capital expenditure. This is achieved by increasing the oxygen content of the air, replacing the diluent nitrogen that otherwise simply takes up volume.

Figure 1 shows the facility as a typical three conversion stage SRU with a front side split design on the reaction furnace (the plant processes Sour Water Acid Gas with high ammonia), and a two-pass WHB.

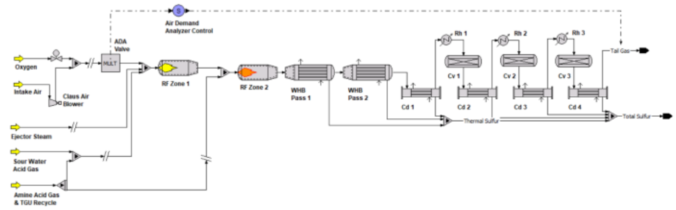

Figure 1. SRU Configuration

As designed, the SRU operates on air only but the facility was considering upgrading to low-level oxygen enrichment (up to 28% oxygen). The WHB steam generation pressure is slightly elevated at just over 650 psig (45 barg). A normal WHB design is somewhere between 300 – 600 psig (20 – 40 barg). This will be important later in the discussion.

To get a better understanding of how this change will affect the SRU and to reveal any possible pitfalls, the unit's current operating conditions were used in a simulation model of the facility using SulphurPro®. The corrosion calculations are based on Carbon Steel tubes using research data from ASRL (Alberta Sulphur Research Limited). This gave a good picture of the heat transfer characteristics along with an estimate of the current corrosion rate in the WHB. Figure 2 shows the heat flux and tube wall temperature through the first pass of the WHB under the current air-only base conditions.

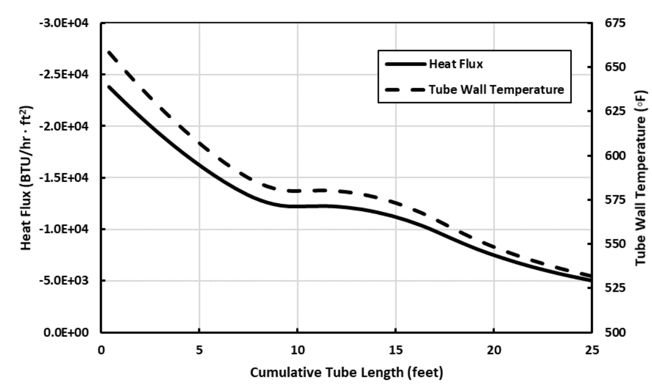

Figure 2: Heat Flux and Tube Wall Temperature in WHB Pass 1 – Base Case Air Only

As shown in Figure 2, the front of the WHB (Pass 1) is where the heat flux and tube wall temperatures are highest. The tube wall temperature is slightly elevated at just over the 650°F threshold. Figure 3 shows the predicted sulfidation corrosion rate in the first pass of the WHB. In this air-only base case, the peak corrosion rate is just over 21 mils per year (mpy). It is a bit alarming that on air-only operations, the corrosion rate is already twice the recommended limit of 10 mpy. Returning to the steam generation pressure of just over 650 psig, the higher the steam generation pressure, the higher the heat flux needs to be to meet that demand. A higher heat flux will be accompanied by a higher tube wall temperature, thus causing the corrosion rate to increase.

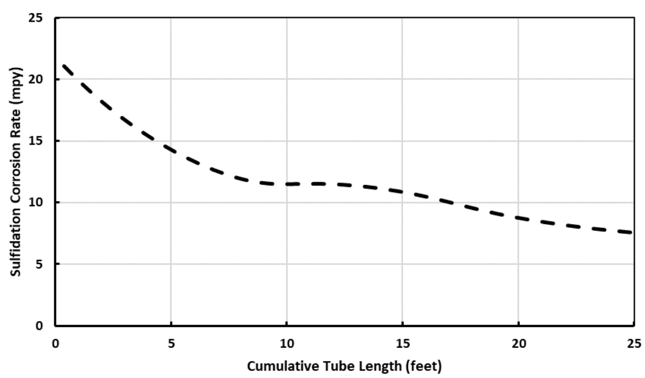

Figure 3: Sulfidation Corrosion in WHB Pass 1 – Base Case Air Only

With the base case understood, oxygen enrichment was added to the simulation and the acid gas rates adjusted to keep the same overall hydraulic throughput in the unit. Figure 4 shows a similar plot to Figure 2, but now with oxygen enrichment. For reference, the oxygen-enriched results (red) have been overlaid on the original air-only results (black).

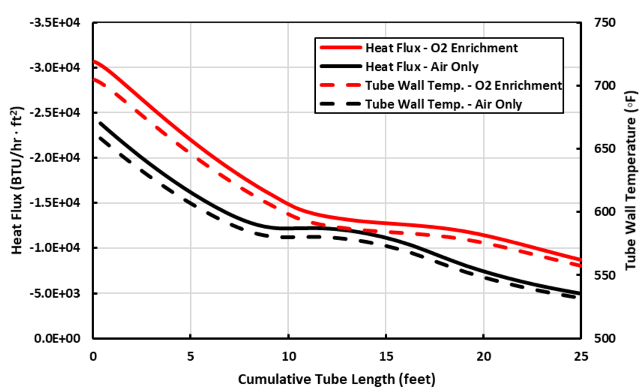

Figure 4: Heat Flux and Tube Wall Temperature in WHB Pass 1 – 28% Oxygen Enrichment (red) & Air Only (black)

The tube wall temperature has increased to over 700°F and the heat flux has increases by approximately 20% over the air-based operation. As shown in Figure 5, this results in a sulfidation corrosion rate of just over 29 mils per year (mpy). Although that may not sound like a big increase, it is 50% higher than the base-case air-only operation, a factor of three higher than advisable!

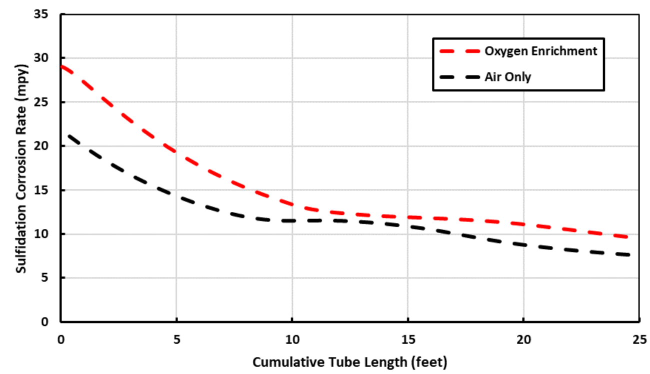

Figure 5: Sulfidation Corrosion in WHB Pass 1 – 28% Oxygen Enrichment (red) & Air Only (black)

The higher than normal WHB steam generation pressure for this plant led to the tube wall temperatures operating in the "caution" region at just over 650°F on air only, resulting in a much higher-than-advisable corrosion rate of 21 mpy. Low-level oxygen enrichment would compound the problems that were already present, and reduce the life expectancy of the WHB tubes even more. The corrosion prediction feature in SulphurPro® uses state of the art research results and allows areas of the plant that cannot be monitored easily with instrumentation to be better understood. In this particular plant, the limitation may have been the original WHB design and choice of steam generation pressure. With the rigorous WHB rating feature in SulphurPro®, a what-if analysis can be conducted to help engineer out a previously hidden problem.

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