Innovative energy recovery in existing sulfuric acid plants

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With a history of safety risks in sulfuric acid energy recovery, most plants worldwide have opted for acid cooling by wasting energy through evaporation in water cooling towers. Addressing this issue, Clark Solutions has developed SAFEHX, a three-fluid heat exchanger that physically separates acid and water, even in the event of a leak, enabling safe energy recovery. Due to plant configurations designed to disregard acid energy recovery, the standard heat recovery solution involves significant changes to the existing layout. While this approach offers substantial returns, it requires a considerable initial investment and shutdown time. In response, Clark Solutions introduces one of the many possible SAFEHX installation configurations that requires reduced investment and minimal layout changes while delivering significant results by recirculating acid from the main pump tank to heat make-up water for deaerators.

Advancing Circularity and Energy Optimisation in Sulfuric Acid Plants

Industry development seeks configurations emphasising circularity and energy optimisation, with sulfuric acid plants having immense potential. Modern sulfuric acid plants can easily integrate with other facilities, while enabling low-emission production, virtually no effluents, and high energy recovery—key aspects in a contemporary world grappling with climate change while demanding technological and sustainable progress.

Despite this goal, many sulfuric acid plants around the world disregard the energy potential of sulfur trioxide absorption. The reason for this is noble: prioritising safety. Energy recovery systems operate with higher pressures on the water side than on the acid side, promoting dilution, heating and autocatalytic corrosion in the event of a heat exchanger leak, which carries the risk of explosion due to the formation and entrapment of hydrogen. However, advanced technologies like SAFEHX enable energy recovery without compromising safety.

Although the significant economic and sustainable returns make it advantageous, adapting a plant without energy recovery to harness heat from sulfur trioxide absorption in the typical configuration can be challenging. This process often requires considerable layout changes, modifications to existing equipment, addition of new equipment, operational condition changes, and extended shutdown periods. For some specific plants, these changes may be financially or strategically prohibitive even though the payback is attractive.

The following text presents one of many possible alternative configurations to simplify the implementation of energy recovery in sulfuric acid plants, while still delivering substantial results.

Standard acid heat recovery setup

Sulfuric acid plants have various configuration possibilities for their acid circuit, often without considering energy recovery from sulfur trioxide absorption, as previously mentioned.

Figure 1 illustrates a common double absorption plant configuration with a single pump tank and independent acid coolers. Essentially, the circuit includes an acid tank from which acid is pumped by a single vertical pump that feeds all acid coolers. These coolers use cooling water to adjust the flow temperature before feeding the towers. After the mass transfer occurred within each column, the streams return by gravity to the circulation tank.

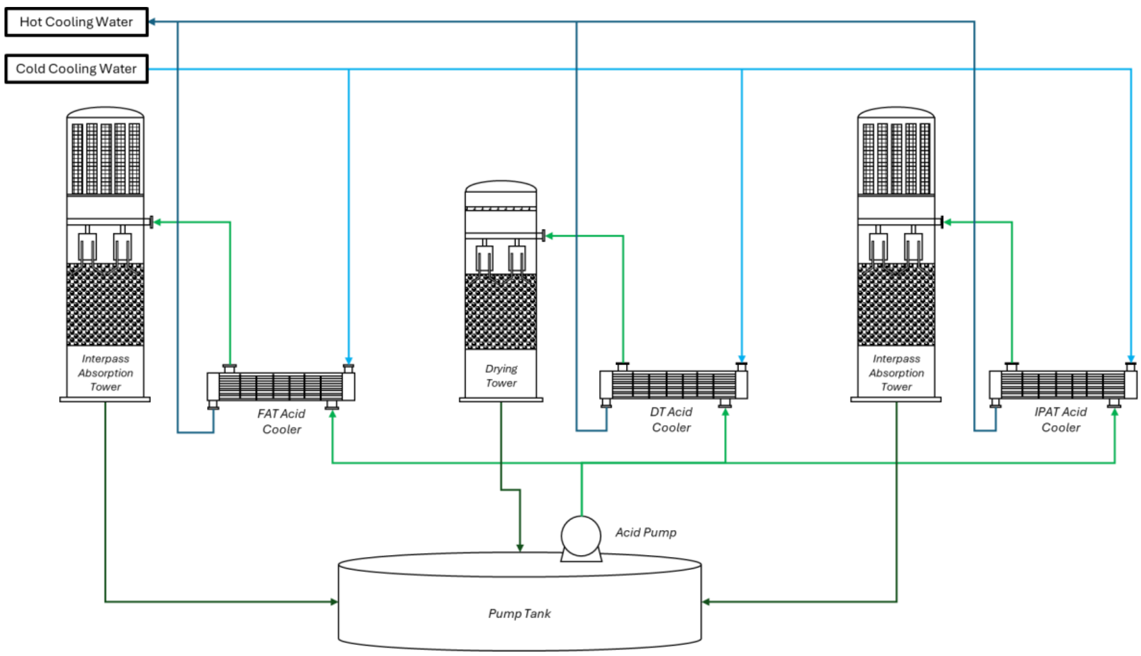

Figure 1. Simplified typical acid circuit configuration without acid heat recovery.

When energy recovery systems are applied, they typically occur in absorption towers. For new plants, energy recovery can be integrated during the conceptual phase. However, existing plants require several modifications to adapt the interpass absorption tower for energy recovery. Figure 2 illustrates a possible configuration of a double absorption plant with a main single pump tank and energy recovery system, generating low-pressure steam.

In this configuration, sulfur trioxide is absorbed by hot acid in the lower deck of the absorption tower, which is oriented to the boot pump tank, from which a dedicated pump sends the flow to the SAFEHX, where the temperature is adjusted for proper feed at the top of the column lower deck. Cooling the hot acid partially evaporates the water stream fed into the SAFEHX, generating low-pressure steam, which is separated in the knockout drum. A fraction of the dedicated pump discharge sends acid to a crossflow heat exchanger, which cools heat recovery acid stream destined for the main pump tank while heating the acid stream from the main pump tank, optimising energy recovery and allowing acid concentration adjustment.

The absorption tower has an upper deck responsible for cooling the gas stream from the lower deck and absorbing any residual sulfur trioxide content. This process uses the acid exiting the drying tower, which passes through the upper deck of the absorption tower and returns by gravity to the main pump tank. Also note that part of the cooling water circuit is not necessary anymore, reducing cooling water consumption.

This configuration is one of many possible, depending on the final objective. However, the necessary modifications to convert a plant into an energy-recovering system can be observed by comparing Figure 1 and Figure 2. The main changes include: (a) replacing the absorption tower with a double-deck tower or adapting the existing one, if applicable; (b) adding a boot pump tank attached to the absorption tower; (c) adding the SAFEHX circuit with the exchanger and knockout drum; (d) adding a crossflow heat exchanger to minimise heat losses by crossflow acid streams;

(e) adjusting the drying tower's outlet stream to feed the top of the absorption tower's upper deck, if applicable; (f) removing the cooling water circuit for the inter-pass absorption tower acid cooler; (g) adding a circulation pump for the hot acid circuit of the lower deck; (h) modifying applicable piping for system operation; (i) adapting or adding instruments and valves for proper system operation; and (j) evaluating layout and interferences.

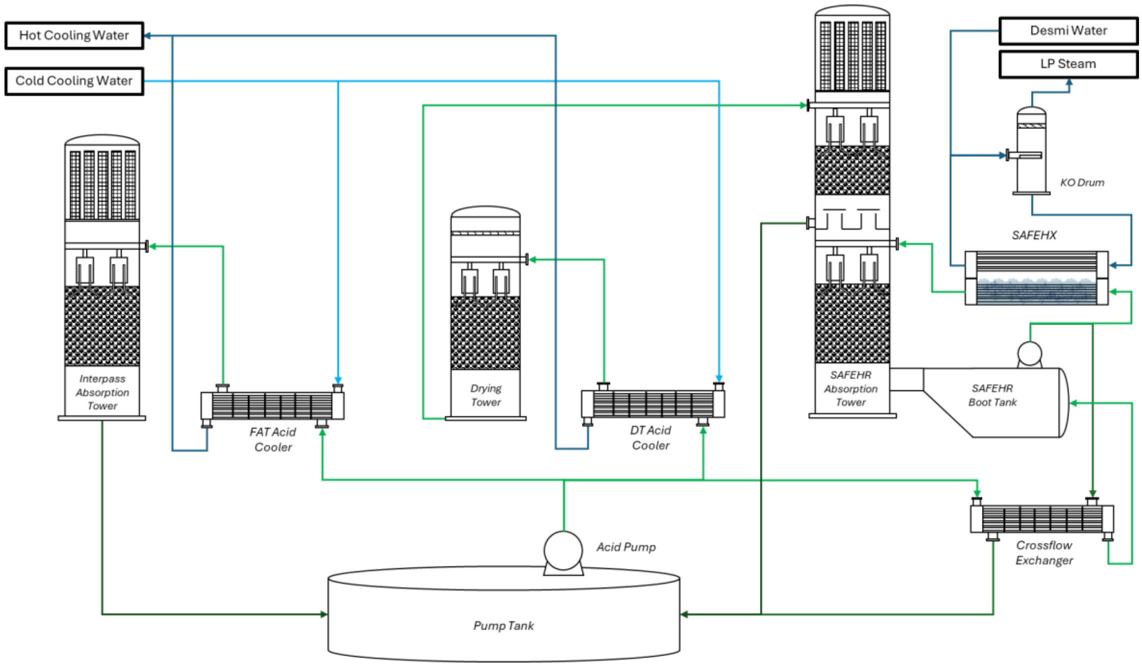

Figure 2. Simplified typical acid circuit configuration with acid heat recovery.

The economic and sustainable returns from adding an energy recovery circuit to an existing plant have both measurable and intangible aspects, making the configuration attractive. The primary benefits include steam generation or preheating higher-pressure water circuits, as well as reduced cooling water consumption. However, there are situations where plants cannot accommodate such significant modifications, whether due to financial, spatial, or temporal constraints. In these cases, simpler configurations are preferable.

Alternative heat recovery setup

The configuration presented in Figure 2 is essential when the goal is the direct generation of low-pressure steam, as hot acid circulation is necessary to reach boiling temperatures in water streams under pressures up to 10 bar. However, an enhanced balance of low-pressure steam does not necessarily have to come from direct steam generation but can also result from saving existing steam used in other applications.

The example presented below is the heating of demineralised water make-up streams to the plant's deaerators. Deaerators are responsible for removing dissolved air from the demineralised water that supplies the plant's steam circuits, including economisers, boilers, and superheaters. This process uses low-pressure steam at a sufficient flow rate to ensure the deaerators' output stream has an appropriate residual dissolved air content with a temperature typically around 105°C. Depending on the plant's steam circuit configuration and the amount of make-up water added to the equipment, the steam consumption for sensible heat exchange can be significant.

A way to reduce steam consumption in the deaerator is by preheating the demineralised make-up water stream using heat from the acid circulation tank, as illustrated in Figure 3. In this case, it is not necessary for the acid to be at high temperatures, as all the water heating occurs through sensitive heat exchange. This makes the energy recovery circuit significantly simpler and an independent adjunct to the plant, allowing installation while the plant is operational, requiring only a simple shutdown for tie-in alignment. These changes are significantly simpler, cheaper and quicker.

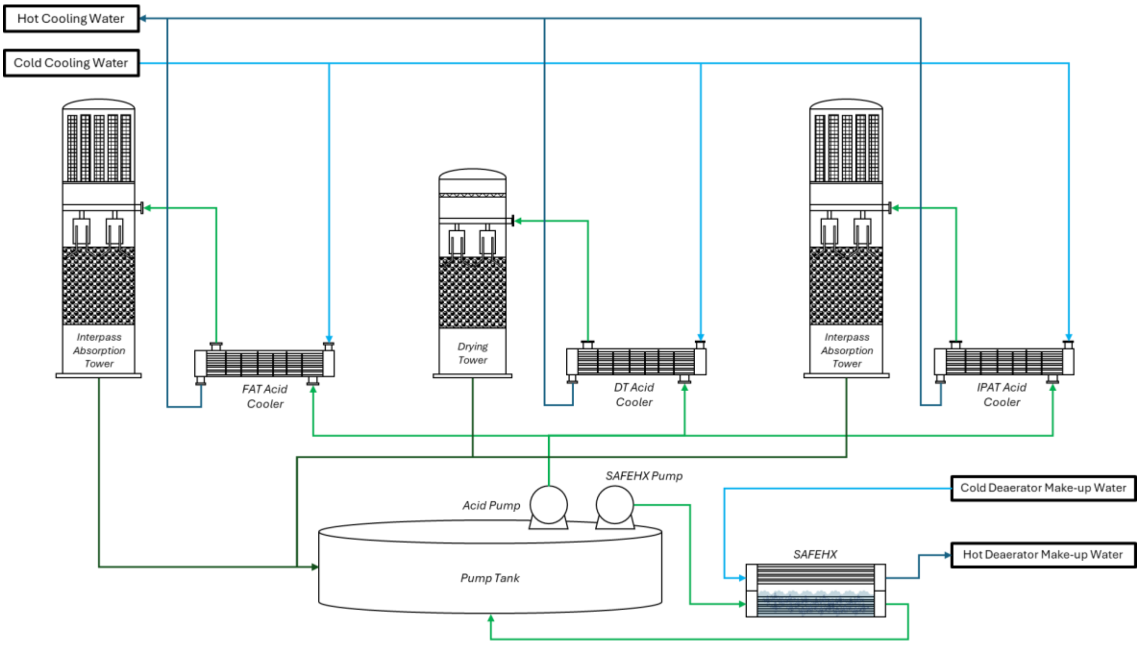

Figure 3. Alternative heat recovery configuration.

In the proposed configuration, if the existing pump cannot accommodate the required flow, a dedicated pump circulates the acid stream from the pump tank to the SAFEHX and back to the tank. This new pump requires a very low head since there is no need for elevation gains. Additionally, it cools the pump tank acid temperature, reducing heat duty on towers' acid coolers, thereby lowering cooling water consumption.

For the water circuit, demineralised water is heated as much as possible before being fed into the deaerator. Due to a more favourable log mean temperature difference, thanks to the water temperature conditions, the SAFEHX requires less heat exchange area than the configuration in Figure 2 for the same recovered heat duty. The demineralised make-up water heating translates into low-pressure steam savings in the deaerator.

This circuit is independent of the plant and can be turned on or off depending on the client's needs and strategy. It also allows for installation while the plant is operational and can be installed in any suitable location.

To illustrate the recovery, a simulation was conducted for a plant with a capacity of 2450 MTPD using the arrangement shown in Figure 3. A demineralised water flow of 100 m^3/h is heated from 27°C to 70°C using heat from the pump tank. The recovered heat in the exchanger is approximately 5 MW, translating into savings of more than 8000 kg/h of low-pressure steam that would otherwise be used in the deaerators.

Without the recovery system, the tank would have an equilibrium temperature of 112°C, whereas with the SAFEHX recirculation circuit, this temperature is reduced to 109.5°C, requiring less cooling water in each tower's heat exchangers. For the same simulation, considering conservative evaporative losses of 1% in the cooling tower, nearly 35,000 m^3/year of process water make-up is saved.

The economic return depends on the steam cost on plant's geographical region and the energy source for the saved steam generation, as well as the cost of water treatment for the cooling tower.

What makes SAFEHX different?

Energy recovery from sulfur trioxide absorption proves to be a highly attractive option both financially and sustainably, offering various possible application configurations depending on the client's objectives. However, safety in this operation cannot be overlooked.

The historical record of this application is not favourable regarding safety risks, which is why Clark Solutions developed and patented the SAFEHX. This innovation allows the previously overlooked possibility of acid energy recovery to become viable again, as the safety concerns have been effectively addressed.

The heat exchanger consists of three zones (Figure 4): (a) the lower tube bundle containing the hot fluid, (b) the upper tube bundle containing the cold fluid, and (c) a closed shell containing the buffer fluid. The operating conditions in the shell are maintained promoting the buffer fluid boiling with the hot bundle temperatures and condensation with the cold bundle temperatures. In this way, energy from the hot side is transferred to the cold side indirectly, through the buffer fluid latent heat in a cyclical approach.

This configuration offers two key benefits: (i) in the event of a leak, the hot and cold fluids will not come into direct contact, as the selected buffer fluid is inert and immiscible to both and also has an intermediate density, and (ii) the latent heat exchange of the buffer fluid allows for a highly uniform tube wall temperature.

These benefits can be leveraged for applications where fluids bring hazards when in contact (e.g., water and sulfuric acid), as well as for applications requiring tight temperature control to avoid thermal degradation (e.g., amine-based processes).

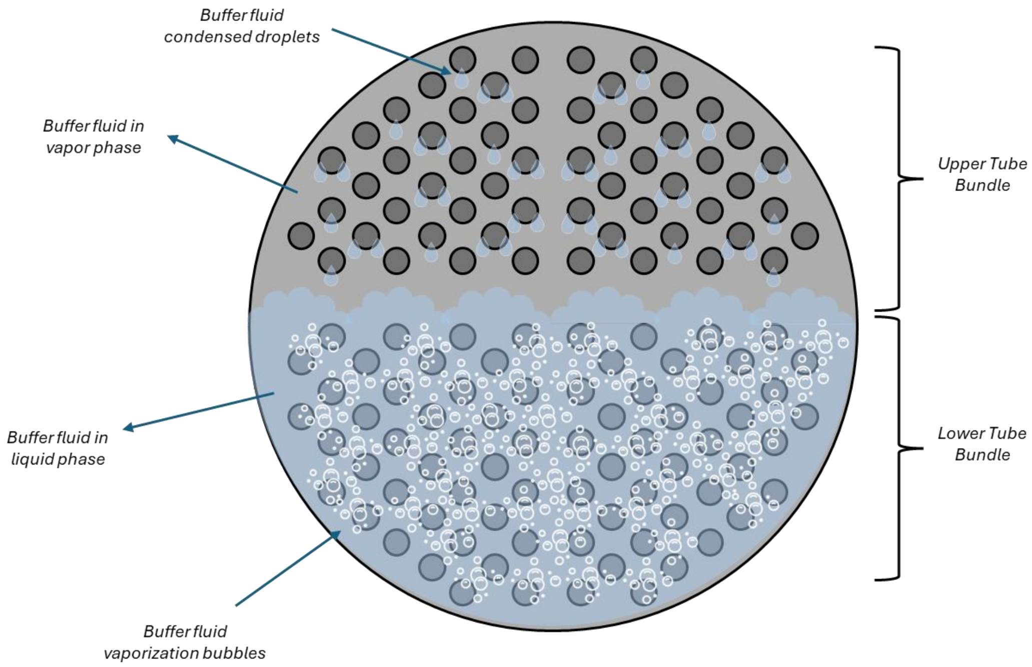

Figure 4. SAFEHX sketch cross-sectional view.

The SAFEHX concept and phenomena had already been demonstrated and validated in a pilot-scale unit at Clark Solutions research and development facility, with results discussed in previous publications.

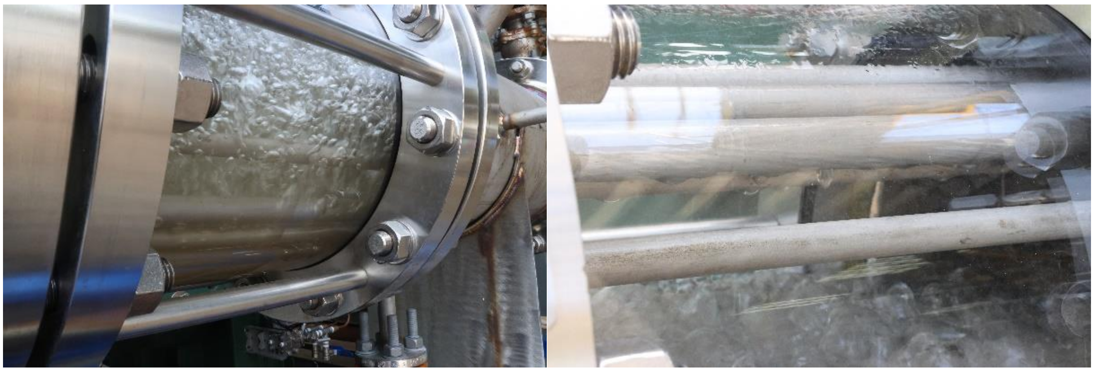

Figure 5. Simultaneous boiling and condensation happening at each tube bundle.

Conclusion

The SAFEHX technology proves to be a crucial tool for enabling optimal energy efficiency and water consumption reduction in sulfuric acid plants. Its versatility allows for installation across a myriad configurations, depending on the energy recovery objectives, specific application requirements, and client constraints, striving to balance sustainability, financial return, and safety.