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IN THIS ISSUE > > > >

SAFEHX™: Safe Heat Exchanger

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In 2016 Clark Solutions introduced the SAFEHR® heat recovery technology to the sulfuric acid industry. As in other commercial technologies, SAFEHR® uses hot sulfuric acid heat of absorption (180-220 °C) to generate steam instead of releasing this heat to the environment. The major advantage of SAFEHR® in comparison to conventional technologies is that the process eliminates any risk of hydrogen generation and/or severe corrosion in the acid cooling equipment, that will happen in standard technologies, by physically separating the hot acid from the water by means of an inert fluid. This not only dramatically increases the safety of the system but also allows the energy recovered to be shifted to high pressure steam.

Strong acid heat exchanger and boiler failures are extremely dangerous occurrences commonly experienced in sulfuric acid manufacturing. Leaks between concentrated acid and cooling water lead to acid dilution with highly corrosive diluted spots, whose corrosiveness is exacerbated by acid heat of dilution, creating a hazardous chain reaction. SAFEHR®'s use of inert fluid brings proven benefits. The first plant is up and running with all the guarantees met, but also adds some extra equipment to the system—two exchangers instead of one and an intermediate piping and pumping system. In order to improve the design and reduce the overall cost without giving up the safety and performance advantages offered by SAFEHR®, Clark Solutions developed and patented a new, breakthrough heat exchanger technology: SAFEHX™ (**SAFE H**eat e**X**changer). The technology not only fits standard heat recovery systems but also any kind of "risky" cooling where the contact between fluids may be harmful or dangerous.

SAFEHX™ is a patented multi-fluid heat exchanger technology developed to be a safe, compact and reliable part of the SAFEHR® operation.

The SAFEHX™ design reduces the intermediate inert fluid circuit into one single, multi-fluid heat exchanger. Water flows in one tube bundle while sulfuric acid flows in another tube bundle. The chosen inert fluid is encapsulated inside the heat exchanger shell, working as a temperature buffer, which constantly boils at the hot bottom bundle and condenses at the top cold bundle. This creates a chemically inert heat exchanging barrier that prevents the dangers of acid dilution in leakage scenarios while reducing the fluid volume and amount of pipes and control valves required in the intermediate circuit, thus leading to a simpler and safer design.

Since SAFEHX™ heat exchangers work via a boil–condensation cycle, most of the heat exchanged is due to phase change, so a temperature buffer forms that stays reasonably constant depending on the fluid mixture chemistry. In the event of an acid or water leak, the leaking fluid (acid/water) will not come in contact with the other fluid (water/acid) eliminating the risk of accelerated corrosion, hydrogen release, and plant upset.

Since the corrosive acid is contained inside the lower tube bundle, SAFEHX™'s shell and top tube bundle can be built with inexpensive materials, as these are unlikely to contact hot acid. SAFEHX™ brings to Clark Solutions SAFEHR® and to the sulfuric acid industry a new, intrinsically safe and reliable way to cool and recover energy from hot acid.

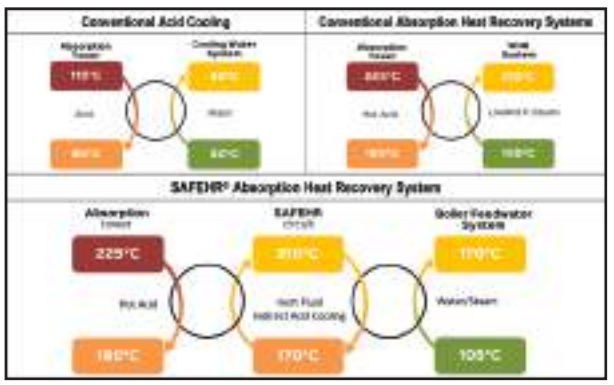
> **"SAFEHX™ is a patented multi-fluid heat exchanger technology developed to be a safe, compact and reliable part of the SAFEHR® operation."**

SAFEHR® Heat Recovery

In a conventional sulfuric acid plant arrangement, there is no heat recovery from the SO_3 absorption step. Strong acid is admitted at the top of absorption towers at temperatures around 80°C and the bottom acid temperatures are controlled to not exceed 115°C. Cooling water used to refrigerate this circulating acid is employed at outlet temperatures usually no higher than 45°C, which do not allow any quality heat recovery. The energy is returned to the environment in the site's cooling tower in the form of water vapor.

Hot water obtained from cooling the acid may be used in projects such as city district heating or for electrolyte heating, but the temperature does not allow the energy to be recovered as a useful form of steam.

Increasing absorption temperatures allows energy to be recovered at a higher grade, such as low or medium pressure steam. Acid at 200-225°C bottom temperatures can easily boil pressurized water at 8-10 bar or pre-heat high pressure boiler feedwater while reducing cooling water consumption and related treatment costs.



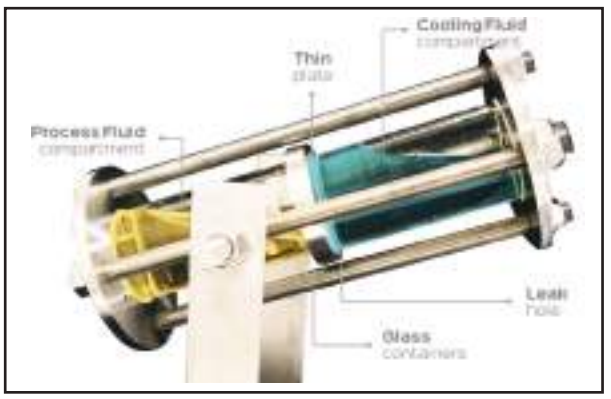
However, these benefits come associated with a definitively non-negligible risk: since heat recovery takes place on an acid/water boiler, a failure or leak in the system can, and a few times did, prove disastrous.

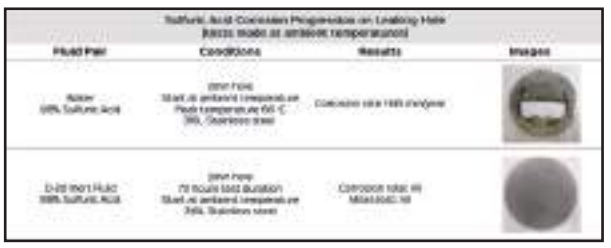
To completely eliminate this dangerous scenario, which some argue to be one important disincentive to the widespread implementation of heat recovery in the absorption step, Clark Solutions introduced SAFEHR® technology. This technology circulates an intermediary cooling fluid that is non-toxic, non-flammable, immiscible with water and sulfuric acid, and arranged in a circuit that completely separates both fluids even in a simultaneous leakage event.

Conventional cooling temperature considerations: Acid is introduced at the top of the absorption tower at a temperature of about 80°C and reaches up to 115°C at the bottom. This hot acid is cooled back to 80°C by 30° C water that is heated to about 40°C in doing so. The water is cooled back to 30°C by evaporation in a cooling tower.

Conventional absorption heat recovery temperature considerations: Acid is introduced at the top of the absorption tower at a temperature of about 180°C and reaches up to 225°C at the bottom. This hot acid is cooled back to 180°C, which is enough temperature to generate steam with the transferred heat. In doing so, 105° C water from the deaerator system is heated generating steam of about 170°C.

SAFEHR® absorption heat recovery temperature considerations: Acid absorption temperatures are equivalent as with the conventional heat recovery system. But to cool hot acid back to 180°C, an inert circulating fluid is used, heating up from 170°C to 210°C. This heated fluid is then used to generate the steam, heating water from 105°C to 170°C.





Studies of corrosion progression developed by Clark Solutions, utilizing the apparatus shown below, demonstrate that the corrosion rate of a 316L plate with 1 mm hole in an acid-water system at ambient temperature and pressure can be as high as 145 mm per year in these mild lab conditions.

When in a heat recovery system, a water leak

Continued on page 28

Continued from page 26

into the acid can dilute the strong acid in the system. The corrosion effects will occur inside the acid plant equipment and will release hydrogen, that accumulates in high spots. The leaking spot is a hot weak acid location that auto-catalyzes the corrosive process. This may further increase operations risk. Several hydrogen incidents have been reported by the industry in the recent past.

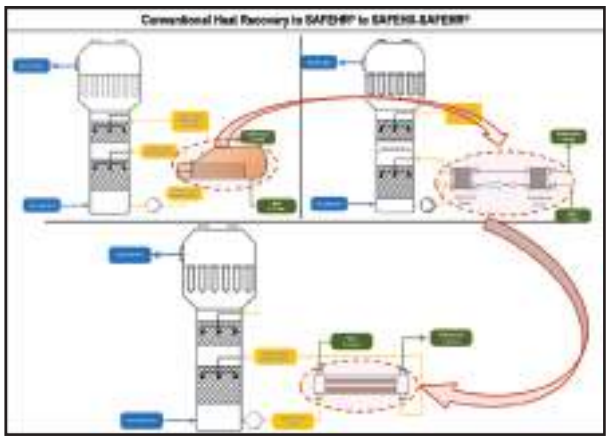
In the SAFEHR® system, regardless of the exposure time, the leakage situation using inert fluid does not speed corrosion as it does not dilute the acid. The interfacial tension and density differences between the fluids make a liquid-liquid coalescer an excellent storage tank for the system itself. Acid will settle at the bottom of the coalescer and water will stay at its top, so, even in the improbable case of both leaking, there would still be no contact between them. The coalescer/settling tank is designed to easily segregate the fluids. Conductivity and level control guarantee that a leak is quickly identified.

The immiscibility of the process fluids, having the inert fluid sitting in a middle density layer between acid and water, is portrayed in the next image:

SAFEHR® system in operation

Instead of just an interesting idea, SAFEHR® is now a proven reliable technology, which is fully operational at a Clark Solutions technology designed plant with the following key features:

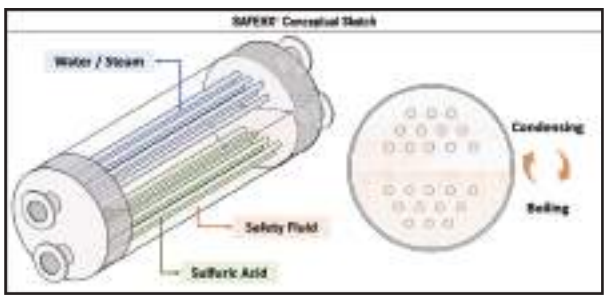
- Clark Solutions Technology and Design
- 150 MTPD production
- Sulphur Burning
- Single Absorption
- Hydrogen Peroxide Tail Gas Scrubber
- CSX®(UNS S32615) Highly Resistant Alloy Acid Piping
- Horitontal SO_2 converter
- SAFEHR® Heat Recovery Technology



SAFEHX™: SAFE Heat EXchanger

SAFEHX™ heat exchanger technology represents a further step in SAFEHR® process operation. It is a buffer-fluid heat exchanger designed to maximize the process heat exchanging capabilities while minimizing the intermediary circuit.

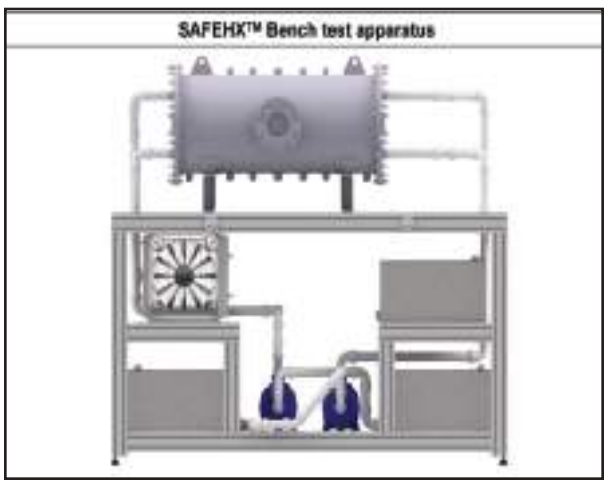
The buffered heat exchanger concept has the advantage of using an inert fluid that has a boiling temperature in between the process fluid temperatures. In other words, when exchanging heat with the hot side, the buffer fluid will boil, vapors will ascend, condense, and descend in the cold side.



The buffer fluid selection addresses the exchanged process temperatures to give the optimal thermodynamic and chemical properties in the heat exchange working range.

The internal convection promoted by the density gradients gives motion to the inert fluid sitting in between the hot and the cold heat exchanging sides. This gives the process a strong advantage by continuously exchanging fluid latent heat, which is substantially more efficient than exchanging only sensible heat, and performing the heat recovery without an extra circuit, thus reducing the required system size.

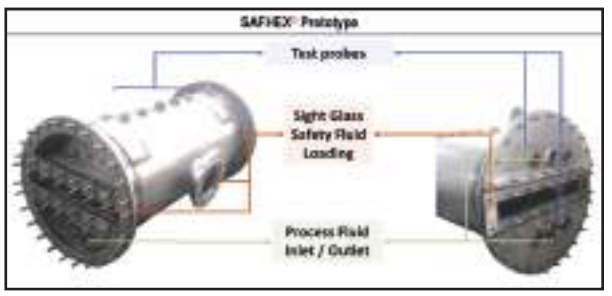
The pressure inside the exchanger shell is controlled by the flow of the cold fluid; the higher the flow, the more condensation and consequently the lower the internal pressure of the vessel. Safety fluid partly fills the volume of the shell, covering the hot side tubes, similar to a steam generating boiler. The top is out of contact with the liquid level and works as a condenser.



In addition to the safety features delivered by the SAFEHR® solution, the SAFEHX™ concept and design also brings economic advantages through higher global heat exchange coefficients, lower volume of safety fluid required, and a reduced system with fewer circulation pipes, control valves, flanges, and heat exchangers, all combined into one single piece of equipment.

In order to validate the proposed heat exchanger, an experimental bench was designed to obtain operational data to evaluate the mathematical model's accuracy, establish operation procedures, validate equipment to its application, and evaluate inert fluid thermal properties. The bench operates with two circuits of water and the heat exchanger half-filled with the inert fluid. One circuit of water is heated to 85°C by a resistor and the other water circuit is kept cooled at 25°C by an air radiator. In order to have the equipment working properly, the safety fluid is selected so its boiling temperature is 55°C—between 85°C and 25°C.

The bench design is simple because this new technology is complex only in terms of the equipment, not the process itself. The bench is made of two pumps, one heater (resistor), one cooler (air radiator) and three tanks (two for the water circuits and one to drain the liquid from the heat exchanger interior, if necessary). Furthermore, the heat exchanger was made to allow flow patterns inside the shell to be viewed through glass windows and with several ports for thermoresistors and pressure transmitters.



Conclusion

The SAFEHX™ heat exchanger adds a further safety feature to heat recovery technologies and one that is not restricted to the sulfuric acid industry. The technology improves process temperature control because the boiling safety fluid temperatures stay reasonably constant due to the heat transfer being focused on the fluid latent heat.

The SAFEHR® system's smaller size, achieved by transforming the closed loop of safety fluid into a single component, brings multiple advantages, including reduced maintenance costs, fewer control valves, less instrumentation, lower fluid volume requirements, and smaller footprint.

For more information, please visit www.clarksolutions.com. ❑

SAFEHR

HEAT RECOVERY **TECHNOLOGY**

Recover more energy

Clark Solutions SAFEHR® is a patented sulfuric acid heat recover technology which can increase high pressure steam generation in an acid plant by almost 20% and total energy recovery by as much as 35%, while addressing issues such as safety and corrosion in an absolutely innovative way.

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