Air pre-heater improves energy efficiency

A corrosion resistant air pre-heater enables valuable heat recovery from corrosive and fouling refinery flue gas streams

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In the search for energy efficiency in the refining industry, waste heat recovery from flue gas is one of the most interesting sources of hidden energy to look at. There are three reasons why a stack should be one of the first locations to look at in the search for energy savings. The first reason is that at a 'stack location' significant amounts of primary energy are converted into heat at one single location. The second reason is that flue gas is discharged into the atmosphere at relatively high temperatures between 150°C and 250°C. And finally, the outlet for the recovered waste heat is nearby as combustion air with a sufficient low temperature to absorb the excess heat. Energy efficiency improvements by up to 5% can be realised at all kinds of industrial steam boilers, furnaces and fired heaters, even in the case when air pre-heating is already applied to some extent.

The current metal air pre-heaters are designed for a minimum flue gas exit temperature of approximately 160°C in order to prevent corrosion and subsequent high maintenance cost. Flue gas originating from sulphur containing fuel (for instance, refinery gas, fuel) has an acid dew point at around 130°C. For this reason, many existing air pre-heater systems incorporate a steam heater in order to pre-heat ambient combustion air to a minimum temperature that prevents corrosion in the air pre-heater.

The Dutch company HeatMatrix Group recently developed a new generation air pre-heater that enables heat recovery from corrosive and/or fouling flue gas streams. This exchanger contains polymer tube bundles that are resistant to corrosion by concentrated sulphuric acid at elevated temperature. The characteristics of this exchanger and its case study based performance are outlined in this article.

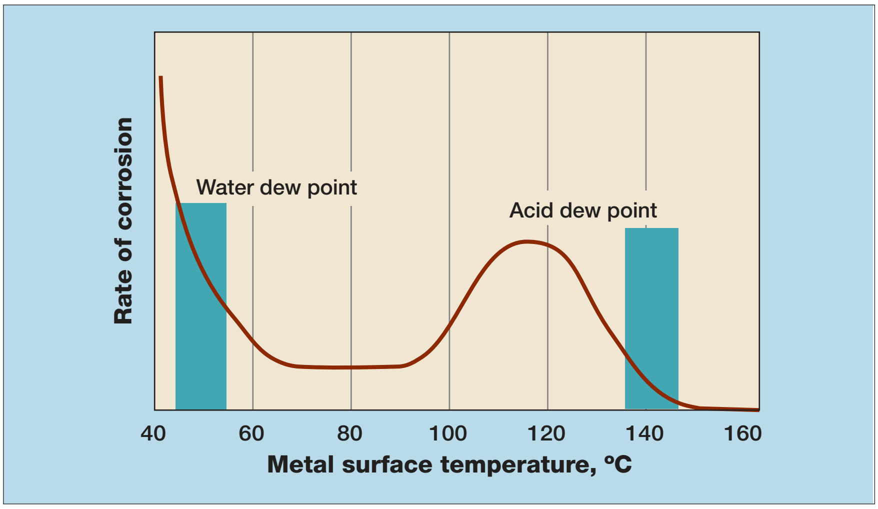

Figure 1 Relative corrosiveness of sulphuric acid along the boiling curve

Acid dew point related corrosion

During combustion, the sulphur component of sulphur contaminated fuel is converted into sulphur dioxide and trioxide. The sulphur trioxide condenses in the presence of water vapour at a dew point temperature, which is a function of the partial pressure of sulphur trioxide and water ('acid dew point'). At this dew point, a first small amount of highly concentrated sulphuric acid precipitates, for example on the air pre-heater surface. In an air pre-heater, the skin temperature of the heat exchanging surface at the flue gas side ('wall temperature') is leading in this process. The bulk temperature of the flue gas can still be significantly higher. Detailed information on acid dew point temperature calculations can be found elsewhere.[1]

When the temperature of the flue gas is further reduced beyond the acid dew point the concentration of sulphuric acid is also reduced, as well as the corrosiveness. Below 90°C, the corrosiveness of the flue gas is significantly lower compared to the corrosiveness just below the acid dew point temperature (see **Figure 1**). From a variety of exotic metals, only tantalum can withstand acid dew point corrosion at acid dew points higher than 150°C (see **Figure 2**).[2] The polymer that is applied for the HeatMatrix polymer tubes is resistant to acid dew point concentrations up to 150°C and has a design temperature of 200°C.

High temperature acidic flue gas crosses the acid dew point close to the tip of the stack as result of cooling by ambient air. This lost energy can be recovered when the right

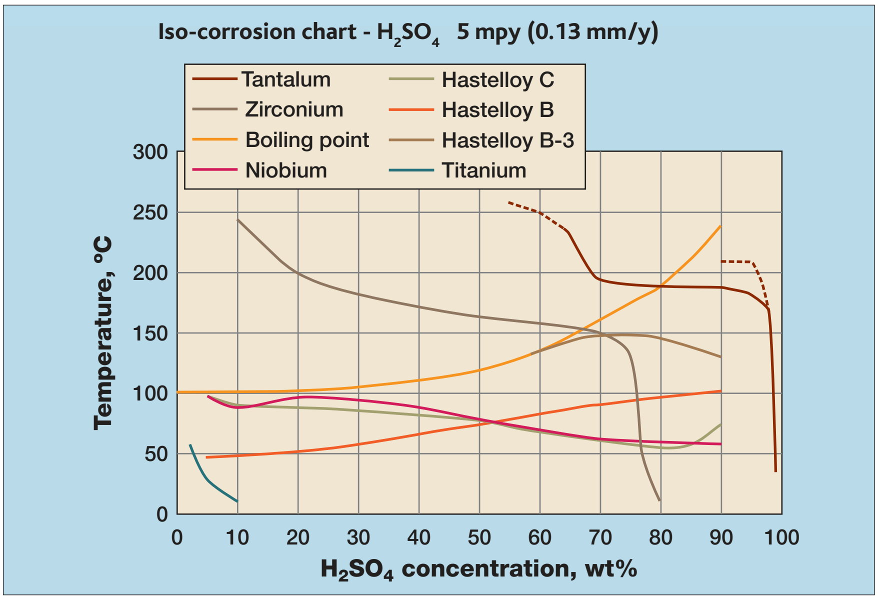

Figure 2 Corrosion resistance of several high alloy metals[2]

heat exchanger materials are applied leading to an improved energy efficiency.

Polymer heat exchanging tube bundles

The HeatMatrix air pre-heater consists of multiple corrosion resistant tube bundles contained in a single metal shell or housing, which is made corrosion resistant through a coating or polymer liner. The proprietary polymer bundle design consists of multiple tubes that are connected to each other over almost the full length of the tube. This structure creates a strong rigid matrix grid that is able to resist high gas velocities and thermo-shocks. As opposed to polymer hose or glass tube designs, the connected polymer tube bundles are not sensitive to breakage or rupture. The connector between the individual tubes creates simultaneously a counter-current flow configuration between the two fluids. This configuration improves the heat transfer by up to 20% compared to cross flow type exchangers (see **Figure 3**).

Flue gas flows from top to bottom through the tubes (red arrow) and combustion air flows in the opposite direction around the tubes (blue arrow). The top end of the polymer tube bundles is fixed to the upper tube sheet and the lower end is allowed to expand in a sealing system connected to the lower tube sheet. The extra tube sheet in the middle of the exchanger prevents bypassing and directs combustion air into the polymer tube bundles.

The inlets and outlets of the exchanger are located at the side of the heat exchanger in order to allow easy access to the polymer tube bundles. These lightweight bundles are retractable from the top and can be cleaned or replaced without demounting the complete exchanger. In the case of fouling flue gas, each bundle can be equipped with a spraying nozzle, which thoroughly cleans each bundle in an alternating cleaning sequence (see **Figure 4**).

The capacity of the air pre-heater is fully scalable by placing several polymer bundles in parallel in a shell. The smaller size exchangers have a cylindrical shape, as **Figure 3** shows, and the larger size air pre-heaters have a container shape to accommodate flue gas flows up to 500 000 kg/hr.

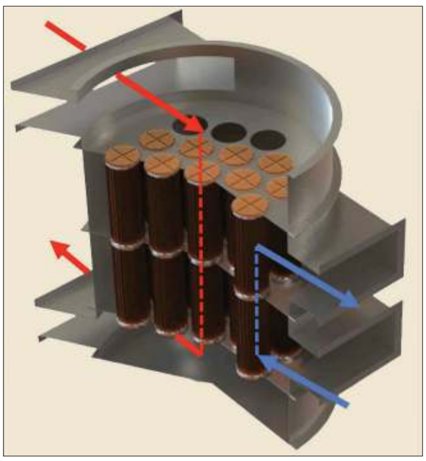

Figure 3 Cross section of a HeatMatrix air pre-heater

Installation options

For grass roots installations with a flue gas temperature below 200°C, integration of the polymer air pre-heater is straightforward. For installations with a flue gas temperature above 200°C, a combination between a metal air pre-heater and polymer air pre-heater in series is required. This hybrid design has the following advantages:

- Increased heat recovery over a wide temperature range
- The polymer air pre-heater protects the metal air pre-heater against low air temperatures that lead to cold spot corrosion problems
- The metal air pre-heater protects the polymer air pre-heater against high temperatures

A steam air pre-heater for raising the temperature of the combustion air is no longer necessary with this hybrid air pre-heater design.

Addition of a polymer air pre-heater to existing installations will be a profitable investment as well. Existing civil and steel structures frequently have sufficient over-design to accommodate an additional lightweight exchanger. Also, for boilers with a large distance between stack and combustion air induced draft fan solutions can be provided. For this case, a twin coil system comprising a polymer flue gas exchanger and a simple finned tube exchanger is recommended.

Case study

The following typical case is based on the performance of multiple projects that have been realised over the past years. A flue gas flow from a large steam boiler of 100 000 kg/hr at a temperature of 170°C enters the polymer air pre-heater and is cooled to 85°C by 95 000 kg/hr combustion air at 15°C. The recovered energy is 2.6 MW, which is approximately 5% of the steam boiler duty.

Conclusion

Energy efficiency and carbon abatement are currently hot topics and energy efficiency is seen as a most important contributor in every governmental strategy to reduce fossil fuel consumption. In that light, flue gases should be seen as an important source of hidden energy because flue gas still contains 5 to 10% of the primary energy used to drive the combustion process. New technologies like this polymer air pre-heater can contribute to improve energy efficiency throughout the refining industry.

Figure 4 HeatMatrix air pre-heater equipped with an *in situ* cleaning system

References

1 Hijbrechts W W M, Leferink R, Latest advances in the understanding of acid dew point corrosion: Corrosion and stress corrosion cracking in combustion gas condensates, *Anti-Corrosion Methods And Materials*, 2004, Vol 5, issue 3,173-188.

2 Gambale D, Heat exchangers for hot acids: material selection, *Chemical Engineering*, July 2011.

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