Heat recovery from corrosive flue gas

For improvements to energy efficiency in the petrochemical industry, waste heat recovery from corrosive flue gas is the most cost effective source to exploit

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During the conversion of primary energy, approximately 5-10% of the energy used is lost via hot flue gas. There is no need to emphasise that significant savings are within reach when 60-70% of refining operational costs consist of energy costs. Nowadays, many petrochemical companies are focusing their efforts on improving energy efficiency in order to remain competitive. Waste heat recovery from flue gas is the most cost effective way to contribute to this target. This article introduces an air preheater technology for reliable waste heat recovery from corrosive flue gas.

Figure 1 Tube bundles consisting of multiple connected tubes

Corrosive flue gas

The corrosiveness of flue gas is the main reason why the energy efficiency of furnaces, fired heaters and steam boilers remains poor. Flue gas originating from sulphur containing fuel becomes corrosive below a temperature of approximately 150°C (acid dew point corrosion). Local cold spots in metal air preheaters will lead to rapid corrosion and breakdown of plates and tubes. Breakdown goes unnoticed for a while, but the shortcut between combustion air and flue gas leads to energy loss (reduced flue gas temperature at flue gas inlet), more power to the combustion air fan and limited throughput because of a maxed-out combustion air fan. These cold spots already occur when the flue gas bulk temperature is as high as 250°C because of cold ambient air at the other side of the heat exchanging surface, which results in a flue gas side surface temperature below the acid dew point.

Existing technologies

In order to lower flue gas outlet temperatures and improve energy efficiency, several techniques have been applied with mixed success. When cooling down flue gas to approximately 170°C, recycling of heated combustion air to the inlet of the forced draft fan will lift the air temperature and subsequent local cold spot temperature. Frequently, an air preheater driven by steam is also applied for additional heating during the winter. These measures cost energy and limit recovery to approximately 20°C above the acid dew point.

Local cold spots in metal air preheaters will lead to rapid corrosion and breakdown of plates and tubes

For the highest energy efficiency, flue gas has to be cooled below the acid dew point; for this, metal exchangers are not suitable any more, or they become very expensive. Alternatives, such as glass tube and polymer tube, have been applied but they are sensitive to flow induced vibrations and temperature shocks, which leads to tube breakage or rupture. The subsequent short cut between combustion air and flue gas leads

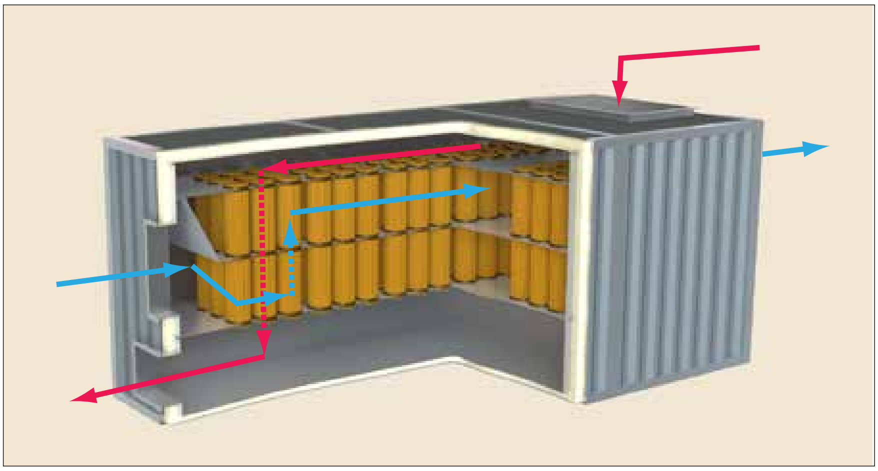

Figure 2 Cross section of a HeatMatrix air preheater

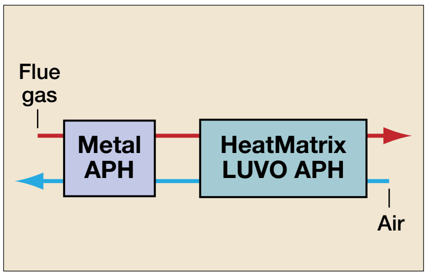

Figure 3 Metal and polymer air preheater in series

to the consequences described above.

Polymer heat exchanging tube bundles

The HeatMatrix LUVO air preheater consists of multiple corrosion resistant tube bundles contained in a single metal shell or housing, which is made corrosion resistant by applying a coating or polymer liner (see **Figure 1**). 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. The connector between the individual tubes creates simultaneously a counter current flow configuration between the two gas streams. This configuration improves the heat transfer by up to 20% compared to cross flow type exchangers (see **Figure 2**). 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.

Cooling flue gas beyond the acid dew point is unconventional but significant savings can be realised in a reliable way

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 an in-line spray nozzle, which thoroughly cleans each bundle in an alternating cleaning sequence during operation.

Hybrid air preheater design

For applications with a flue gas temperature below 200°C (such as steam boilers), integration of the polymer air preheater is straightforward. For applications with a flue gas temperature above 200°C a combination of a metal air preheater and polymer air preheater in series is required (see **Figure 3**). The polymer part protects the metal part against low air temperatures that lead to cold spot corrosion problems and the metal part protects the polymer part against high temperatures. This combination is available as an integrated exchanger with only one single shell or as a compact assembly containing a separate metal air preheater and a separate polymer air preheater. The latter can be equipped with an extra induced draft fan between the metal and polymer air preheater for independent control of flue gas towards the air preheater assembly and to overcome the extra pressure drop of the exchangers (see **Figure 4**).

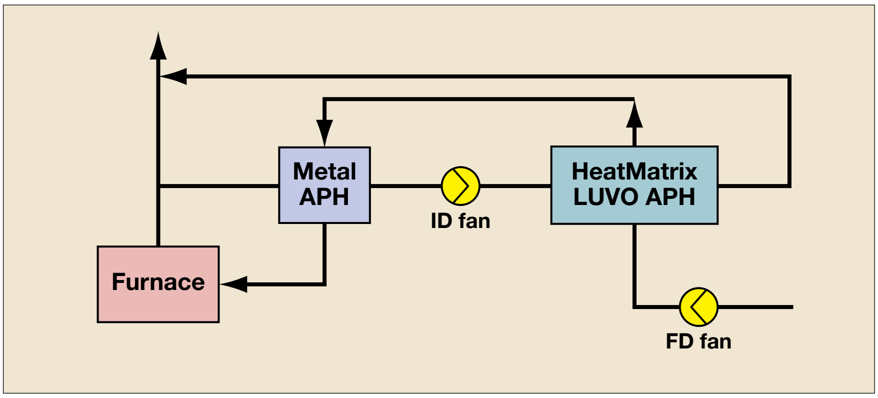

Figure 4 Process diagram of a metal and polymer air preheater assembly

Waste heat to liquid

Not all combustion processes can benefit from preheated combustion air as the outlet for waste heat from

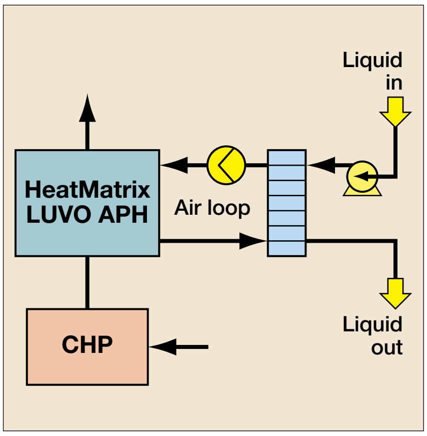

Figure 5 Process diagram of a waste heat to liquid recovery system

corrosive flue gas. For example, the electrical efficiency of gas turbines will reduce dramatically when combustion air is preheated. Furthermore, some installations have limited space for large ducting and/or air preheater assemblies. For these applications a liquid outlet for waste heat can be utilised if available (for instance, preheating condensate, a city heating grid, or other process streams). Such a recovery system consists of a polymer gas-gas exchanger and a standard finned tube gas-liquid exchanger separated by a circulating air loop in order to separate corrosive flue gas from higher pressure liquid. This fail-safe and robust design prevents any upsets in either of the independent connected systems (see **Figure 5**).

Case study air preheating

The following example involves a typical furnace at a refinery. A flue gas flow of 95 000 kg/hr at 290°C was used to preheat combustion air in a hybrid configuration of a metal and polymer air preheater. The realised efficiency improvement is 9.6%, which corresponds to 5.8 MW in this specific case. Flue gas is cooled to 180°C in the metal exchanger and subsequently to 91°C in the polymer exchanger. The combustion air is first preheated to 122°C before it enters the metal exchanger and is further heated to a final temperature of 247°C.

Conclusion

In order to improve energy efficiency in the petrochemical industry, waste heat recovery from corrosive flue gas is the most cost effective source to look at. Cooling flue gas beyond the acid dew point is unconventional but, with a robust exchanger for the corrosive duty, significant savings can be realised in a reliable way. Additionally, this extra efficiency step contributes to a low carbon emission strategy.

Bart van den Berg is a co-founder of HeatMatrix Group and has spent 20 years in various positions throughout the petrochemical industry. He holds a master's degree in chemical engineering from Twente University, The Netherlands.