APEX HEAT TRANSFER

V-FLEX® HEAT EXCHANGERS WITH A-CORREX® TECHNOLOGY

Acid Resistant Heat Exchanger

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The Challenges of a Greener Industry

The transition to a green industry forces companies in many sectors to develop innovative solutions to reduce the amount of energy used and to improve efficiency of the processes. There is also a growing need to recover more heat from the flue gas and to clean it before it is discharged into the atmosphere.

In case of majority of process fired heaters, the heat recovery from flue gas aims at increasing the overall efficiency of the process by preheating the combustion air. Such approach, for which heat exchangers are essential, allows reducing fuel consumption, which in turn has direct effect on reduction of harmful emissions and operational costs.

The need to avoid acid condensation

Nowadays, the exhaust flue gas temperature is usually defined by the need of avoiding acid condensation. Especially in the case of fired heaters, boilers or process furnaces, the heat exchangers in air preheat systems are usually designed to have a minimum metal temperature close to, but above the *acid dew point* (ADP) of the flue gas (e.g. 10-15 °C above ADP) to avoid condensation of H_2SO_4 and, as a result, to avoid corrosion of the heat transfer surface.

Sometimes, operation below the ADP cannot be avoided. In these cases, precautionary measures can be taken to extend the lifetime of the air preheater, for example through expensive glass or polymer coating techniques applied to its sensitive metallic parts.

However, constant operation below the ADP will cause severe corrosion issues in heat exchangers constructed from ordinary metallic materials.

Safe constant operation below the acid dew point

APEX Group developed the A-CORREX Technology to overcome this common problem, and built a range of heat exchangers handling highly corrosive fluids. Using steel alloys or metallic substrates with polymer lining or borosilicate enameling, A-CORREX Technology helps to avoid corrosion, especially in intermittent operations below acid dew point. The acid resistant technology is then implemented to the group's product lines; mainly CORPEX, CORTEX, V-FLEX products.

Moreover, current impulses to further decrease the exhaust flue gas temperature below the *acid dew point*, motivated APEX Group to expand its A-CORREX Technology and develop an innovative heat exchanger capable of working in *a constant corrosive environment in heavy duty applications.*

Formation of H_2SO_4

Flue gas consists of many components that can condense, such as H_2SO_4 HCl, HF, H_2O, CO_2, SO_2, generated during the combustion of air/fuel mixtures. In combustion technology, the sulphuric acid dew point, which has the highest temperature of all these dew points, is traditionally known as the *acid dew point* (ADP).

During the combustion process, SOx is generated (mainly as SO_2). Downstream of the flue gas, part of SO_2 is oxidized to SO_3 (conversion rate for gas/liquid fuels is 2% to 8%; conversion rate for coal is 0.05% to 1%). Then, SO_3 combines with H_2O to form H_2SO_4 in gaseous (g) form, defined by its ADP. If the metal temperature falls below the ADP, variable concentrations of liquid (l) H_2SO_4 will condense on its surface.

Condensation of sulphuric acid - Typical process

The flue gas temperature at the channel inlet is usually above the acid dew point (ADP) and all its components form a homogeneous gaseous phase. When the heat transfer surface temperature on the flue gas side drops below the ADP, sulphuric acid vapour condenses on this surface and builds a highly corrosive acidic film (liquid). Due to the condensation on the surface, the sulphuric acid vapour concentration of the flue gas decreases.

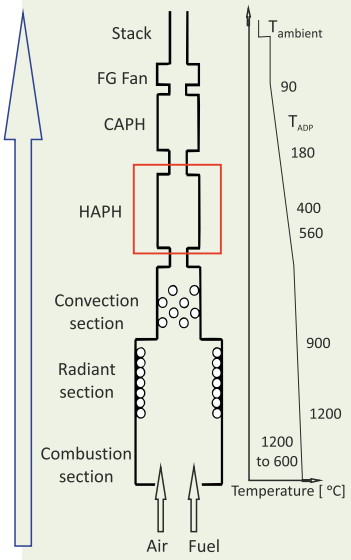
The liquid film will grow over time. The rate of growth is dependent on the flow rate of sulphuric acid vapour, the capture efficiency of the heat exchanger and the material of which the heat exchanger is constructed.

At flue gas bulk temperatures below the ADP, H_2SO_4 may condense on particles (nuclei) existing in the flue gas (heterogeneous condensation) and/or spontaneously, as homogeneous condensation, in which case the condensation rate on the surface is diminished.

At the outlet of the heat exchanger, a corresponding portion of H_2SO_4 remains in its gaseous state and is released as gaseous H_2SO_4 (g) out of the heat exchanger.

Depending on the process operating conditions, the sulphuric acid vapour content entering the heat exchanger is divided into three distinct portions at the outlet of the heat exchanger:

- H_2SO_4 (g) in the flue gas bulk stream; this is the portion which determines the ADP at the channel exit;
- H_2SO_4 (l) formed as film on the surface;
- H_2SO_4 (l) as acid mist in the bulk stream.



Below the ADP H_2SO_4 gaseous (g) starts condensating as H_2SO_4 liquid (l) on the surface and in the bulk by homogeneous and/or heterogenous condensation.

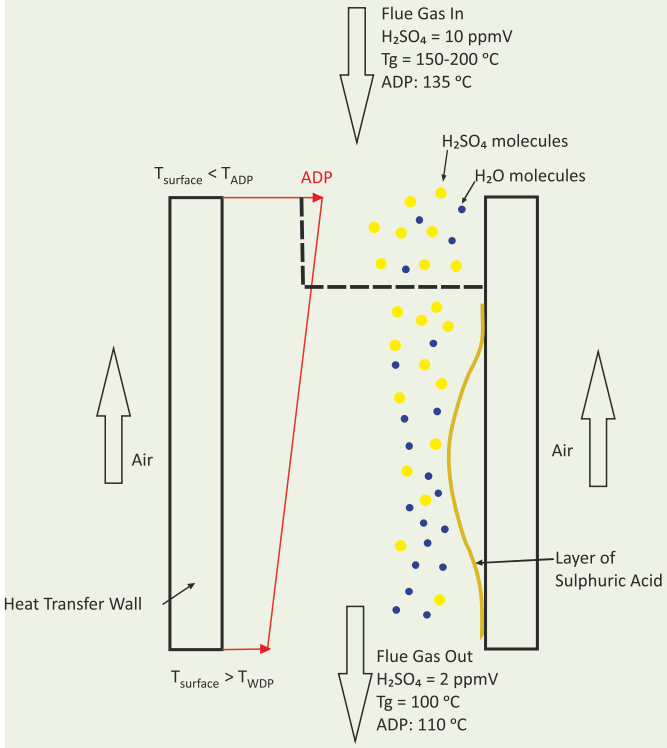
All SO_3 (g) reacts with H_2O to form H_2SO_4 (g)

Part of SO_2 (g) is reacting with molecular oxygen O_2 (g) to form SO_3 (g), between 400 °C and 180 °C.

Part of SO_2 (g) is reacting with atomic oxygen O (g) to form SO_3 (g).

All sulphur components are converted to SO_2 (g) in the combustion section due to the presence of oxygen O_2 (g).

Gaseous H_2SO_4 formation process



Typical condensation process of H_2SO_4

APEX Group's Solution: Heat Exchanger Constructed of Acid-Resistant Polymer Composite

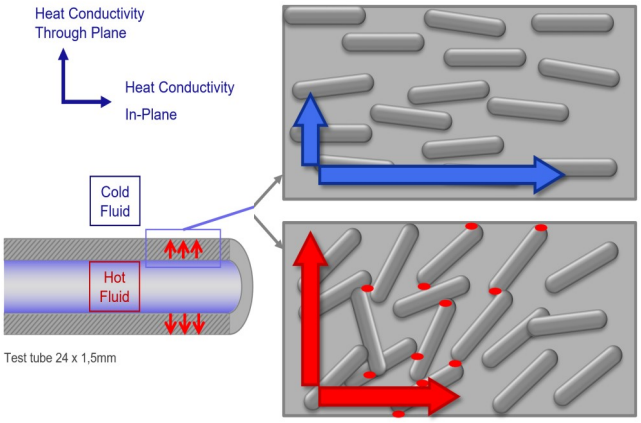
Constant operation below the acid or water dew point requires a heat exchanger constructed from acid resistant materials at an affordable cost. APEX Group has expanded it's A-CORREX Technology by developing an improved type of acid resistant heat exchanger. The new product is constructed from heat transfer elements made of *high thermal conductivity and acid-resistant polymer composite* known as *PPS-GR.*

Corroded metallic air preheater

Polymer composite PPS-GR

Polymers offer excellent resistance to chemical attacks. However, the drawback of most polymers is their low thermal conductivity, and their consequent thin walls required for an efficient heat transfer. This drawback results in a lower mechanical strength of the heat transfer elements.

A polymer composite overcoming this drawback is PPS-GR.
The PPS-GR composite consists of polyphenylene sulphide and graphite (a heat-conductive filler), and thus features *resistance to chemical attacks* and additionally *high thermal conductivity*. The heat transfer walls can be designed thicker in order to improve *mechanical strength*, overcoming the thermal resistance of the polymer.



Standard extrusion technology vs new extrusion technology, with enhanced thermal conductivity

Resistant to virtually any chemical attack

APEX Group has integrated the PPS-GR material into its tubular and plate-type heat exchangers. As all APEX Group's heat exchangers, the new acid resistant heat exchanger provides *great flexibility in design and flow arrangement* (cross, co-current or countercurrent flow).

The heat exchangers constructed of PPS-GR have been successfully tested in the field, in applications such as a water/gas heat exchanger in a waste incineration plant,
a gas/gas heat exchanger in a heat recovery system of a steel mill plant and in a water/gas heat exchanger of a heat recovery system in a biomass power plant.

PPS-GR heat transfer elements in a V-FLEX Heat Exchanger with A-CORREX Technology

Heat Exchanger with PPS-GR elements:

- resistant to virtually any chemical attack below ADP and WDP;

- higher thermal conductivity compared to pure polymer;

- good resistance to heat cycles.

V-FLEX Heat Exchangers with A-CORREX Technology: Application Examples

Fired Heaters

In industrial processes, heat exchangers are often applied as air preheaters for fired heaters, which constitute the process heart of oil refineries. For example, in hydrogen plants, steam methane reformers (SMR) incorporate such air preheating systems.

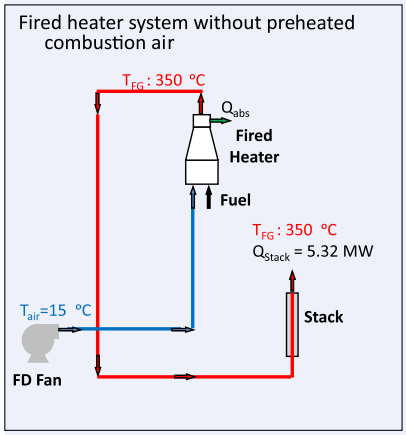
The installation of a heat exchanger as a part of a fired heater system considerably reduces the operational expenses (OPEX) and CO_2 emissions due to a lower fuel consumption.

Figures below show three fired heater systems, with a variation in the stack temperature from 350 °C to 90 °C. The heat exchangers are traditionally designed to operate with minimum heat transfer surface temperature close to, but above the ADP (in the range of 120 °C to 140 °C, resulting in a stack temperature of about 150 °C) to avoid condensation of H_2SO_4 and, as a result, corrosion of the heat transfer surface.

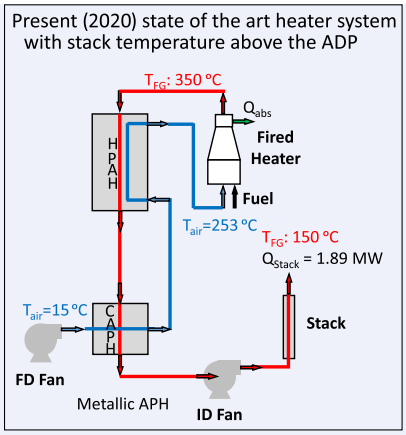
Recently, driven by stricter stack emissions regulations, the air preheating system operators tend to further decrease the flue gas stack temperatures to as low as 90 °C, to further increase the overall fired heater efficiency and to reduce the emissions. Flue gas temperature well below the ADP makes the condensation of H_2SO_4 on the heat transfer surface of the air preheater unavoidable.

The solution to this problem can be the installation of V-FLEX heat exchangers with heat transfer elements made of PPS-GR.

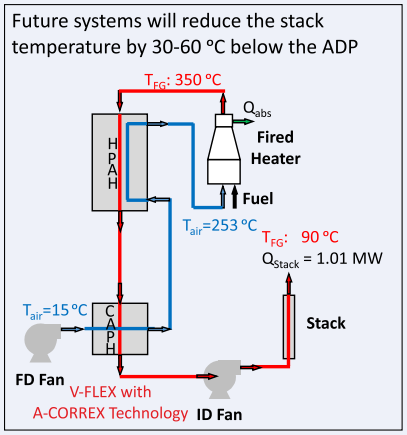
Example: Required heat from fired heater Q_{abs} = 29.45 MW



FG Flow rate: 50,194 kg/h
Fuel Flow rate: 2,500 kg/h
Heater Efficiency (LHV): 83.86 %
CO_2 emissions: 6,860 kg/h



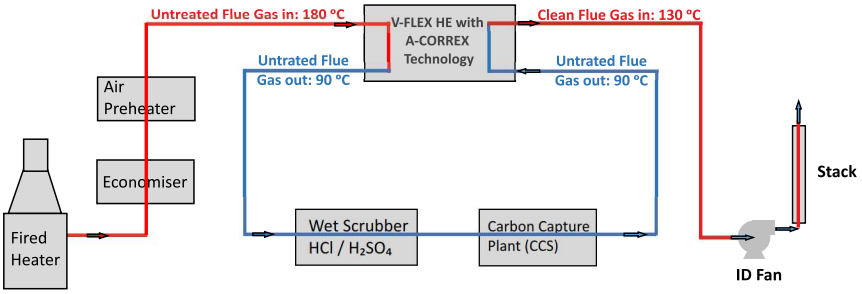
FG Flow rate: 45,199 kg/h
Fuel Flow rate: 2,251 kg/h
Heater Efficiency (LHV): 93.03 %
CO_2 emissions: 6,176 kg/h



FG Flow rate: 43,890 kg/h
Fuel Flow rate: 2,186 kg/h
Heater Efficiency (LHV): 95.73 %
CO_2 emissions: 5,997 kg/h

Carbon Capture and Storage

Some CO_2 removal technologies require reduction of the flue gas temperature to as low as 90 °C in order to be effective, which often is below the ADP. With the use of a V-FLEX heat exchanger constructed with PPS-GR material, it is possible to drop the temperature of the untreated flue gas to the one required by the CCS process, as well as to re-heat the treated flue gas before discharge through the stack.



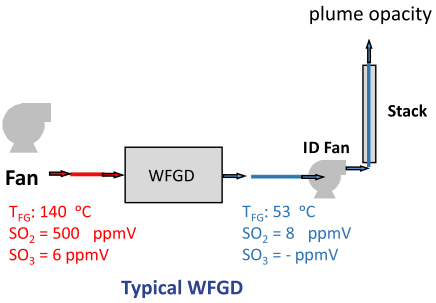
Wet Flue Gas Desulphurisation

Wet Flue Gas Desulphurization units are known for their high SO_2 removal rates, which become more important in any sector with stringent regulations for a green environment.

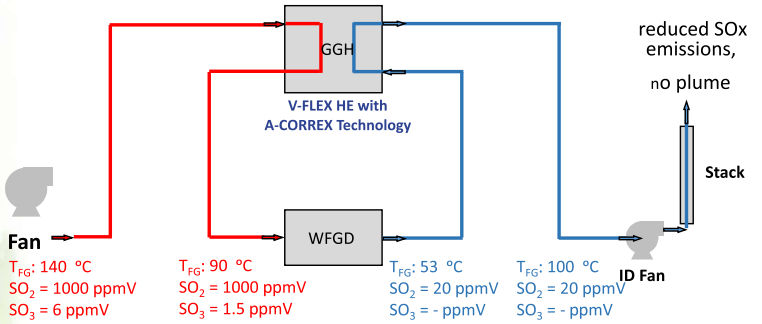
Drawbacks of classical WFGD is the generation of a white plume, as well as the corrosion of the downstream stack. Additionally, the requirement for cooling water is high due to the high inlet flue gas temperature, typically 180 °C.

APEX Group managed to overcome these issues by placing an intermediate Gas-Gas Heat Exchanger, which allows corrosion free operation below the acid dew point. This special unit is a V-FLEX Heat Exchanger with A-CORREX Technology, in which the untreated flue gas is cooled by the treated flue gas.

This results in a decreased flue gas temperature entering the WFGD, a significant reduction of needed water flow and less generation of aerosols. The flue gas temperature at the stack is increased above the acid dew point, the emissions to the atmosphere are reduced and the plume opacity disappears.



Typical WFGD



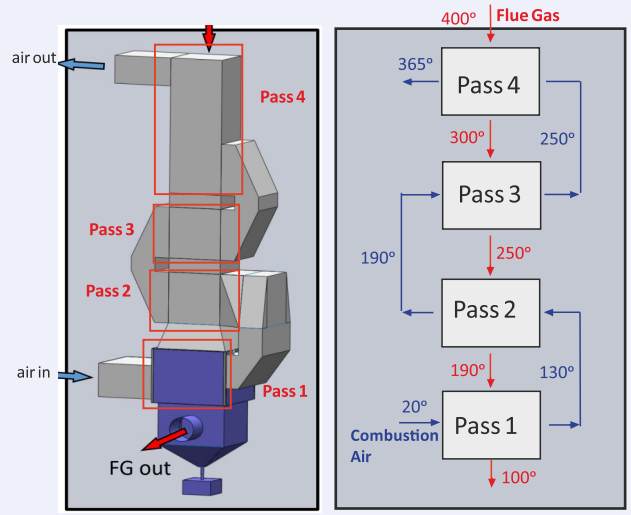
Note: Part of the SO_3, approx. 75% is retained in the GGH in the form of concentrated H_2SO_4, which is neutralized online.

untreated flue gas
treated flue gas

High efficiency WFGD with V-FLEX heat exchanger constructed from PPS-GR elements

Technical Specifications of V-FLEX Heat Exchangers Constructed from PPS-GR Composite

- Resistant to virtually any chemical attack below ADP and WDP;
- Operating temperature up to 200 °C (short term peaks: 220 C);
- Maximum differential design pressure: up to 0.1 barg;
- High thermal conductivity > 3 W / m K;
- Maximized counter flow arrangement with uniform temperature distribution;
- Modular construction, to easily adapt to different operating conditions and allowing off-line replacement of individual modules;
- Compact and fully integrated into the heat exchanger system;
- Low fouling tendency and easy cleaning with water-wash system, thanks to *APEX Free-flow Technology;*
- Light weight.



Typical Installation of HAPH / CAPH heat recovery system with metallic heat exchangers in the hot part and PPS-GR heat exchanger in the cold end

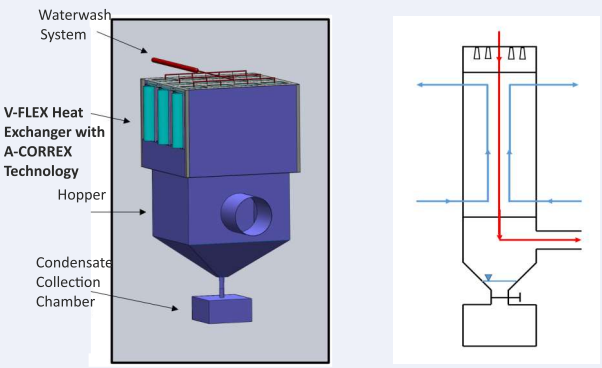
Sustainability and Innovation

Current limitations in cooling the flue gas below its acid or water dew point due to consequent corrosion issues can be overcome with the use of APEX Group's newly developed heat exchangers constructed from heat transfer elements made of the PPS-GR composite.

PPS-GR composite presents excellent and field proven chemical resistance to virtually any acid attack up to boiling temperatures, as well as good mechanical strength and thermal conductivity.

APEX Group heavy duty heat exchangers, capable of handling large volumes of gases, can be easily integrated into any kind of flue gas heat recovery or cleaning systems, such as air preheaters, mercury recovery, wet flue gas desulphurisation, post combustion carbon capture and similar. This allows operator to further improve the overall efficiency and sustainability of the process.

APEX Group continuously strives to perfect its products to suit its customers latest needs in different markets, and therefore utilises its research and development company, APEX-Research B.V., to the fullest, which brings the customers the luxury of added confidence when purchasing products from APEX Group.



Pass 1 schematics of the V-FLEX Heat Exchangers with A-CORREX Technology

V-FLEX Heat Exchanger with A-CORREX Technology

"APEX Group is dedicated to offering *engineering solutions*, not just a *commodity.*"

Mircea Dinulescu, Founder of APEX Group

Company Profile

APEX Group is specialized in designing and manufacturing high quality heat transfer equipment. Our heat exchangers are designed to bear the most extreme requirements. We provide innovative engineering solutions for high performing heavy-duty gas/gas and gas/liquid equipment for heat recovery and environmental projects.

Experience and Vision

We encompass 50+ years of experience and expertise of our founder, Mr. Mircea Dinulescu, and share his vision - ***to research, create and provide engineering solutions*** for heat transfer industrial applications. To this day, our *Credo* remains unchanged, creating the strong foundation for APEX Group's position in the international market:

Started in 1990 as a small independent business, APEX GROUP will grow into a reputable designer and manufacturer of high quality low-priced industrial heat transfer and combustion equipment for the international market operating according to the quality principles laid out by international standard ISO 9001.

M. Dinulescu, 1991

Quality and Innovation

APEX Group's strength consists of know-how, patented technology, professionalism and leading-edge engineering. Our Research and Development Department supports APEX Group's activities by providing new solutions for continuously upgrading APEX Group's products and guaranteeing optimal heat transfer, long lifetime, trouble-free and user friendly operation.

Customers Worldwide

We take pride in being a family-owned company, which allows us to build close connections with our customers and guarantees a personal approach to each project. We strive to support our customers by engaging in dialogue and developing long-term partnerships. Our company is renowned world-wide and naturally we deliver to every corner of the world.

Broadening Horizons

By encouraging feedback from customers, APEX Group develops solutions and products that anticipate market needs. To materialize our concepts we have expanded our Engineering, Research and Fabrication facilities. Apex engineers are continuously keeping up to date with the newest industrial developments in order to provide optimum design for our customers.

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