

Hetragon™:

Chemically resistant heat transfer polygons for gas-gas heaters in FGD and SCR/SNCR applications

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Abstract

Due to environmental regulations, modern coal- and oil-fired power plants nowadays are equipped with modules downstream of the power generation which ensure the cleaning of the flue gas from Sulfur oxides as well as from Nitrogen Oxides. In order to perform the desulfurization and the denitrating reactions under temperature-optimized conditions, gas-gas heaters (GGH) are used as components as well in the flue gas desulfurization (FGD) as in the SCR/SNCR modules.

Inside of FGD modules, fly ash and a condensation mix of aqueous SO_x , HF and HCl are forming a highly corrosive mix, which attacks all metals, especially when the system falls below its dew point. In case these GGHs are of the Ljungstroem®-type, corrosion can be avoided if the heat exchanger is equipped with fully corrosion resistant heat transfer polygons in those regions where the system is operated below the dew point T_D of the chemical mix.

GGHs installed in SCR/SNCR modules have two functions: transfer the heat to enhance the gas inlet temperature to the required level and to collect the Ammonium bisulphate (ABS) deposit within the air preheater. ABS is the product of the denitration process.

The innovative heater elements made from PTFE may be the material of choice to make this cleaning operation more easily in the future. Temperature peaks of more than 200 °C in the hot phase of the exchanger revolution cannot damage these new elements as its service temperature range goes up to 260 °C even when aggressive chemicals are exposed to it in the long term. A new PTFE compound with enhanced heat transfer capacity is presently introduced to the market.

Introduction

In order to prevent the environment from pollution modern power plants fired with hard coal, brown coal or oil use all major types of flue gas cleaning processes: after passing the electrostatic particle separator, firstly sulfur oxides are removed from the flue gas by washing with lime water in the desulfurization unit (FGD) and secondly nitrogen oxides are eliminated by either selective catalytic reduction or selective non-catalytic reduction. These processes, positioned downstream of the power generation require accurate temperature control to work under optimal conditions. In order to achieve this target, heat displacement systems are required as well for FGD as SCR and SNCR modules. Ljungstroem® gas-gas heaters (GGH) are preferred systems for heat displacement tasks. They are made from steel or steel alloys, but

whenever the flue gas system crosses the dew point level to reach condensation status, or chemically aggressive deposits get in contact with the heat exchanger elements, corrosion protection is required. Polytetrafluoroethylene (PTFE) is the material of choice for heater elements in wet conditions which have to work under high temperatures and extremely corrosive environment.

Applications

The principle of the Ljungstroem® air preheater is described in Fig.1.

The heat transfer surface consists of thin profiled steel plates, packed in frame baskets and installed inside the rotor. Typical diameter of a rotor is in the range of 15 – 21 meters; however, also smaller types are in operation. During each revolution of the rotor, heat is absorbed by the heating surface passing through the hot gas stream and transferred to the side where the cold gas is passing the rotor segments. Thus, the cold gas is heated up while the rotor heat transfer elements are re-cooled again.

Alternatively the rotor can be kept in a fixed position while the bonnets for air inlet and air outlet are rotating.

In coal-fired power plants the so-called gas-gas-heaters (GGH) are in operation in three positions mainly:

- Preheating of combustion air before entering the heater
- Cooling the flue gas after leaving ESP before entering FGD and re-heating the desulfurized flue gas after leaving FGD
- Heating-up the flue gas between FGD and SNCR/DeNOx module to achieve an optimized nitrogen oxide removal process

These three main applications will be further described in the following:

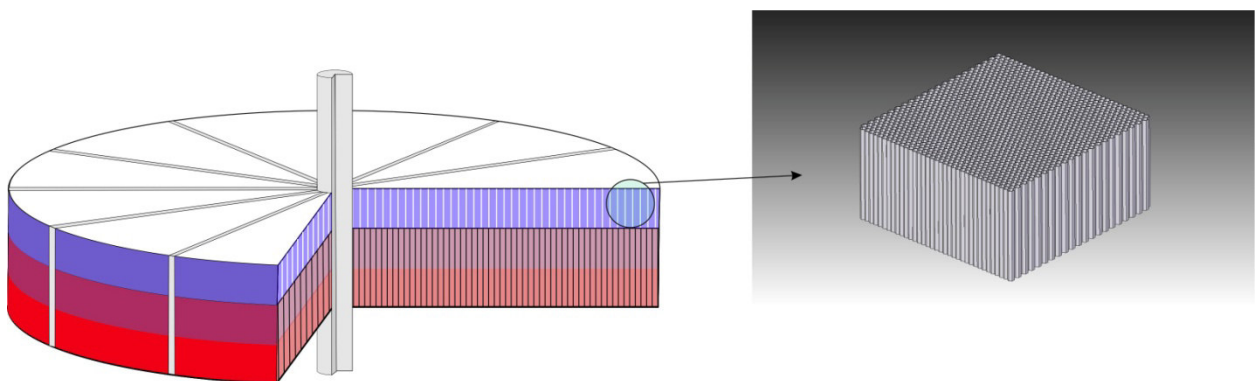


Fig. 1: The rotor of a Ljungstroem®-heat exchanger can go up to diameters of 21 meters and more. While the main part of the heat transfer elements are made from steel plates and enamel coated steel plates, due to its nearly universal chemical resistance Hetragon™ PTFE combs are the preferred heat transfer elements positioned in the aggressive environment of the so-called cold end layer.

The benefits of Hetragon™ PTFE combs

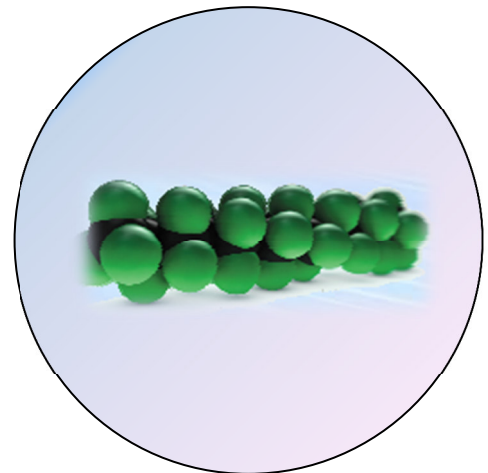
Following the flow direction of the crude flue gas through the rotor elements, as a consequence of the cooling effect, the temperature may cross the dew point level and the chemical flue gas mix starts condensing. Thus a highly-corrosive environment is generated at the „cold end“ of the heater elements and steel or steel alloys quickly start corroding. Enamel coating or other kind of corrosion protection coverings are used to protect the system elements from corrosion. Thus, lifetime expectations can be achieved for heat transfer elements in wet environment which can be in the range of several years.

As opposed to this, provided PTFE is used as the material of choice to form the rotor elements, these will withstand under the described aggressive conditions over many years with no indication of damage.

The property profile of PTFE

Polytetrafluoroethylene is a fully fluorinated resin, where fluorine atoms are protecting the carbon chain efficiently from attacking chemicals, see Fig. 2. With a bonding energy of 460 kJ/mol the carbon-fluorine bond is the strongest chemical bond known in organic chemistry. Therefore this bond cannot be replaced by any other chemical bond with winning energy by this substitution. Furthermore, simply by the size of the fluorine atom in helical ordering does not leave unprotected spots along the C-C – polymer backbone. Both effects are ending up in the nearly universal chemical resistance of PTFE.

Fig. 2: In polytetrafluoroethylene (PTFE) the carbon chain is effectively protected against chemical attack. The high bonding energy of the C-F- bond combined with the excellent sterical shielding of the C-C – chain by fluorine atoms makes PTFE a resin of nearly universal chemical resistance.



With its molecular weight of up to 10^8 g/mol PTFE has the highest molecular weight of all thermoplastic materials. It belongs to the partial crystalline thermoplastics and after sintering it is composed of about one third of amorphous region and two thirds of crystallites. The high crystalline part enables a continuous service temperature close to the crystalline melting temperature, which is in the range of 325°C up to 330°C. Permanent service up to 260°C will not damage PTFE, even not in the presence of aggressive chemicals. During short-term exposure temperatures up to 300 °C are acceptable.

The amorphous content provides the excellent anchoring of the polymer chains within the polymer matrix. This is the base for the good performance in abrasion resistance. Applied as Hetragon™ – comb this becomes visible in the excellent resistance against polymer erosion

when cleaning procedures are used frequently as standard operation procedures. In permanent service of a Ljungstroem-GGH over 12 years in a representative application, the erosion of the comb height measured was less than 5 millimeters and thus extremely small.

The complete covering of the polymer chains by fluorine atoms is the origin of the non-polar, anti-adhesive surface. The sticking of coverings formed from fly ash and aqueous acid mixtures to the surface will be reduced by this non-polarity, making cleaning easy at the same time. The contact angle between water and the PTFE surface is about 126 degrees. As a consequence the wetting of the PTFE-surface by water is significantly reduced and adhesion forces to aqueous media are minimized. In direct consequence the fouling tendency of the PTFE heat transfer elements compared to enamel coated steel surfaces is reduced and additionally, the cleaning behavior is improved. For plant owners this means enhanced availability of gas-gas heat exchangers.

The „Limiting Oxygen Index“ (LOI) of PTFE is about 95; that means, it is not flammable under atmospheric conditions (Atmosphere = Oxygen Index (OI) = 20). Glowing flue ash particles therefore are not critical for the ‚non-burnable‘ resin PTFE.

How about ageing behavior of PTFE under typical service conditions in Ljungstroem®-heat exchangers at high temperatures and repeating altering stress, combined with permanent presence of aggressive chemicals? The ageing mechanism of polymers is based on two different chemical reactions: in one respect the breaking of a polymer chain followed by its recombination leads to a progressing cross-linking of the polymer, thus enhancing brittleness. On the other hand the polymer is chemically degraded by oxidative attack with substitution of the side chains, becoming visible through enhanced crack sensitivity. Both reactions are not possible at PTFE due to energetic reasons. Therefore, even in permanent service under extreme conditions, PTFE will not show ageing effects and the original property profile remains constant over many years. Only abrasion effects, as mentioned earlier are possible.

Table 1: Technical specification for Hetrakon™ combs

PTFE combs for heat exchangers	
Dimensions and weight (example):	
Channel geometry:	combs
Element height:	150 mm or 250 mm
Stack height:	300, 450, 500 mm or more
Distance of channel walls:	14,3 mm
Channel area:	1,5 cm ²
Thickness of walls:	1,2 mm
Free cross-section:	83 %
Specific surface area:	150 m ² /m ³
Specific weight of combs:	360 kg/m ³ (1. Gen.: white) 300 kg/m ³ (2. Gen.: black, enhanced thermal conductivity)

Technical specification for Hetragon™-combs

The present comb design is the result of optimizing flow properties, cleaning behavior and specific contact area. The free cross-section of about 83% is higher than the characteristic values of packings with enamel-coated, profiled sheet metal, thus improving the cleaning behavior and reducing the pressure difference of the flue gas flow when passing the elements. The manufacturing process enables -if required- design adjustments in different directions. By increasing the channel area, the flow properties and the cleaning behavior will be improved, though the specific surface area as well as the heat absorption and desorption will be reduced. The latter decreases the heat transportation per rotor revolution. Increased wall thickness in principle will enhance the heat transportation per revolution, however the reduced specific heat absorption and desorption capability will limit the opportunity to make use out of it. Finally by increasing the free cross-section, the air flow properties as well as the cleaning behavior could be improved, however this has to be paid with lower heat transportation capacity. The feed in of strongly fluctuating regenerative energies into the power supply system enhances the demand for more flexible plant utilization of conventional power plants. As a consequence permanent changes in operation conditions occur and temperatures as well as dew point positions are varying. In order to deal with these challenges, based on the existing comb design, the trend goes to enhanced channel length to make the heat exchangers fit for moving dew points.

The replacement of steel plates as heat transfer elements by Hetragon™ PTFE combs

The working principle of Ljungstroem® heat exchangers is fundamentally different from other heat exchanger constructions such as brazed-plate heat exchangers or tube or pipe bundle heat exchangers:

By direct comparison of tube bundle and Ljungstroem® heat exchanger this difference will be explained more in detail. Both types of heat exchangers in its fluoropolymers versions are suitable in an excellent way for transferring heat under the extremely corrosive conditions in flue gas streams of power plants.

In tube bundle heat exchanger, the flue gas passes the tubes at the outside heating up the tube wall. After moving through the tube wall, the thermal energy will be transferred to the second media, typically cooling water, which is flowing inside the tubes. In reverse direction, in the second process step, the heat energy will pass the tube wall from ID to OD, heating up the surrounding cool air stream at the outside of the tubes. Thus the decisive criteria for the heat transfer capacity is **the thermal conductivity of the tube material**. As it can be seen in table 1, metals are characterized by a significantly higher thermal conductivity compared to plastics such as PTFE. Therefore tube bundle heat exchangers made from fluoropolymers must be designed with bigger tube surface as its corrosion-sensitive metal pipe alternatives⁽¹⁾. As a result the end user can decide between two differently designed tube-pipe heat exchangers showing the same magnitude of heat transfer capacity.

Table 2: The characteristic properties of materials used for the manufacturing of Ljungstroem® heat exchangers

Comb material	Colour	Specific heat capacity	Thermal conductivity	Specific gravity	Specific weight of combs	Heat transportation per revolution
		J / g • K	W / m •K	g / cm ³	kg / m ³	kJ / m ³ • K
PTFE unfilled	white	1,01	0,35	2,16	360	364
PTFE thermally conductive	black	1,24	0,43	2,13	300	372
Steel	black	0,46	40		850	391
Nickel alloy	black	0,46	15		850	391
Enamel	glassy	0,71	1			
Enamel coated steel	glassy	0,5	8		850	425

Totally different is the working principle of Ljungstroem® heat exchangers: In the first step, the hot flue gas stream passes the heat transfer elements -typically made from enamel-coated steel plate packings or PTFE-combs- heating up the elements while being cooled down itself. After rotation of the rotor or the hood, in the second step the hot heat transfer elements are heating up the surrounding cold air stream. While the surrounding air is being heated up, the heat transfer elements are cooling down, thus being prepared to take up thermal energy again in the next loop. Following this principle, it's not the thermal conductivity of the material of the heat transfer elements but it's the **specific heat of the material** which makes the difference. The specific heat is the determining criteria of the magnitude of heat transfer per rotor revolution. As it can be seen in table 1, PTFE, even unfilled, possesses a specific heat being more than double as high as those of steel resp. steel-Nickel-alloys: while the specific heat of unfilled PTFE is in the range of 1,01 J/g x K, steel or steel-alloys with around 0,46 J/g x K are much lower. And this difference can be made even bigger to the benefit of the fluoropolymers, if suitable fillers are added: thus enhancement of the specific heat from 1,01 auf 1,24 J/g x K is possible. ElringKlinger makes use of this additional benefit by currently introducing the second PTFE-comb generation to the market.

As a consequence, despite the lower weight of the PTFE heat transfer elements, a comparative quantity of thermal energy is being transferred per rotor revolution. In the opposite, equipped with sheet metal packages a Ljungstroem® rotor would be much heavier to be able to transfer the same amount of energy. The caloric details of differently equipped Ljungstroem® rotors can be seen from Fig. 3. Base for the calculation are the pure material data without any kind of flue ash covering at the heater elements, which typically show up during operation. The tendency for covering build-up in combination with the cleaning behavior are further important factors for the performance of Ljungstroem® heat exchangers in operation under flue gas conditions.

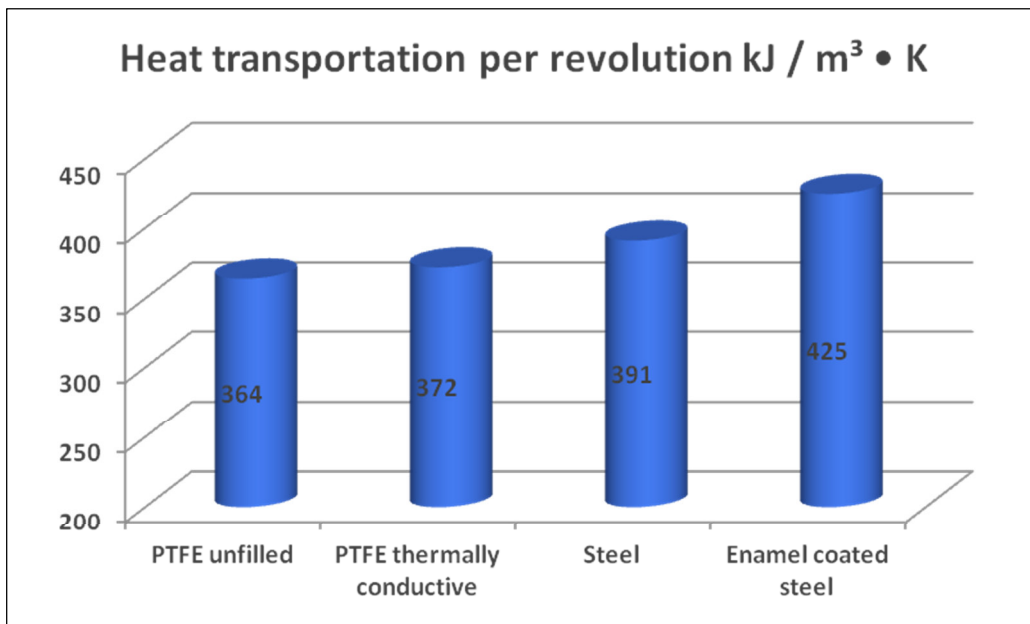


Fig. 3: Transfer of heat by Ljungstroem® heat exchangers per revolution of the rotor for different materials: PTFE unfilled, PTFE thermally conductive, steel and enamel coated steel show similar magnitude of heat transfer capacity.

The following assumptions were used for the calculation:

The specific weight of notched steel plates used as heat transfer elements in the rotor is twice the specific weight of PTFE combs.

Enamel coating has two effects:

- Enhancement of the specific heat of the system enamel-steel compared to clean steel.
- Reduction of the speed of the heat transfer from flue gas to heat transfer elements and vice versa as a consequence of the low thermal conductivity of enamel.

Conclusions:

In existing Ljungstroem® heat exchangers, steel plate packages can be replaced by Hetrakon™ PTFE combs step by step without changing the heat transfer properties of the gas-gas heat exchanger significantly. It is recommended for the replacement process to proceed according to the corrosiveness level: In a step by step replacement process, to begin either with the cold end layer or with those rotor rings, showing the highest degree of corrosion. The second PTFE-comb generation utilizing the benefits of the higher heat capacity of PTFE compounds with also enhanced thermal conductivity will further enhance the benefits of such a replacement of heat transfer elements.

Application of PTFE combs in heat exchangers in flue gas desulfurization units (FGD)

In order to prevent the environment from pollution modern power plants fired with hard coal, brown coal or oil use all major types of flue gas cleaning processes: after passing the electrostatic particle separator, sulfur oxides are removed from the flue gas by washing with water in the desulfurization unit. This process, positioned downstream of the power generation

require accurate temperature control to work under optimal conditions. In order to achieve this target, a heat displacement system is required to cool the flue gas before entering the scrubber and then transfer this heat to the cleaned flue gas leaving the scrubber to provide the gas with buoyancy to rise out of the stack and disperse. Ljungstroem® gas-gas heaters (GGH) are the preferred system for this heat displacement tasks. The heat transfer elements are typically made from plates of steel or steel alloys.

Depending on operation conditions within the heat exchangers, the system is either dry or wet.

Reasons for wet conditions can be:

- Falling below the dew point T_D of the flue gas as a consequence of the cooling process
- Wetting with gypsum containing aerosols coming from the washing tower
- Wet cleaning of the heat transfer elements with high-pressure water/steam during operation or down-time / maintenance.

For lifetime expansion purposes of the heat transfer elements, these can be protected from corrosion by coating with enamel. As a consequence of these measures, lifetime of heat transfer elements in wet environment in the range of two to five years are typical. In case, in this corrosive environment PTFE combs are used as heat transfer elements instead of enamel coated steel plates, lifetime prolongation is significant. Based on positive experiences with the resin PTFE, which did not show any corrosion effects in permanent service up to twelve years, heat exchanger designs are now made for lifetime of up to twenty years. Fig. 4 demonstrates the assembly situation of a regenerative gas-gas heat exchanger (REGAVO) utilizing PTFE comb benefits in the area of the cold end layer. The assembly with PTFE combs can be handled very flexible. Depending on the positioning of the REGAVO within the FGD and the direction of the flue gas stream, the combs can be position as well bottom-side as up-side within the rotor.

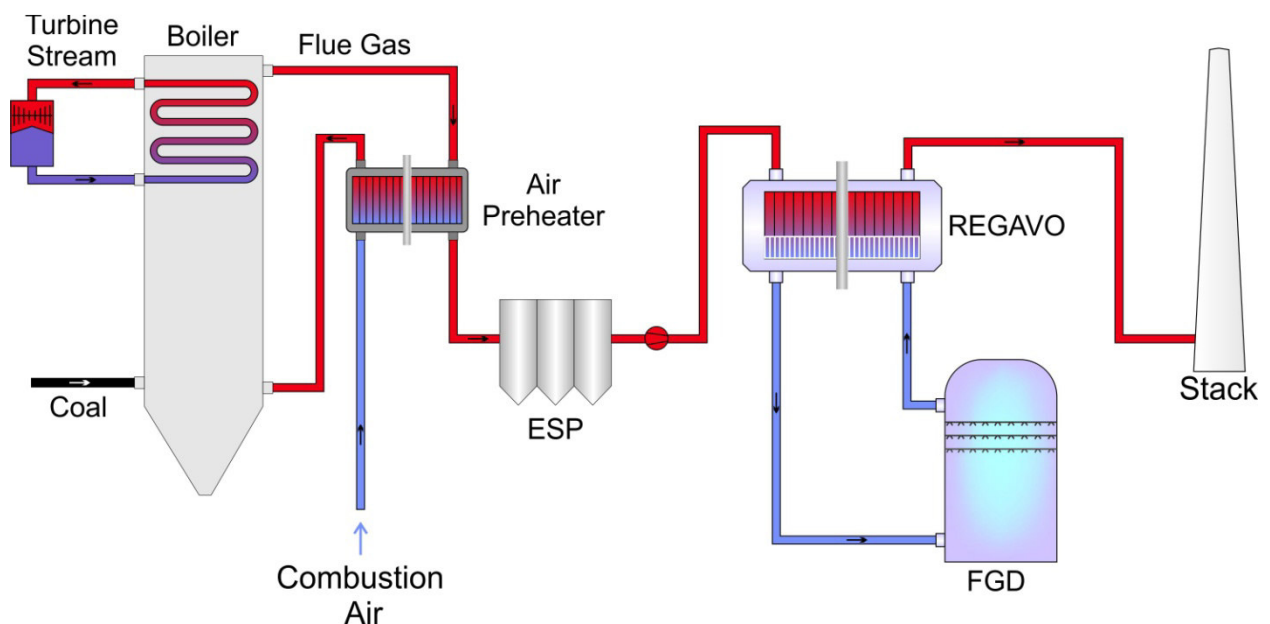


Fig. 4: Positioning of a regenerative gas-gas heater (REGAVO) of Ljungstroem® type, equipped with PTFE combs within the cold end layer, located inside a flue gas desulfurization (FGD) module.

Typical operation conditions of the Ljungstroem® rotor inside GGH of FGD with respect to temperature and chemical loading are visualized in Fig. 5a,b. In Fig. 5a, on the left side the non-purified flue gas flows upwards through the rotor, while cooling down from 150 °C to 85 – 90 °C; chemical loading remains to be the same during this process step. Afterwards, the flue gas is cleaned in the washing tower (scrubber), which brings the temperature further down to 45 - 50 °C, and at the same time reduces as well the content of SO_x as fly ash significantly. The concentration of NO_x, which is in the range of about 200 mg/m³, remains to be nearly the same in this cleaning step. The second pass of the cleaned flue gas through the rotor, right side, gas stream from top to bottom, is re-heating the gas stream up to 95 – 100 °C to provide the gas with buoyancy to rise out of the stack and disperse.

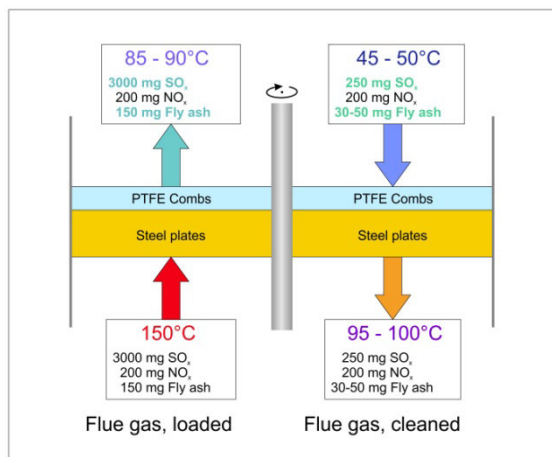


Fig. 5a

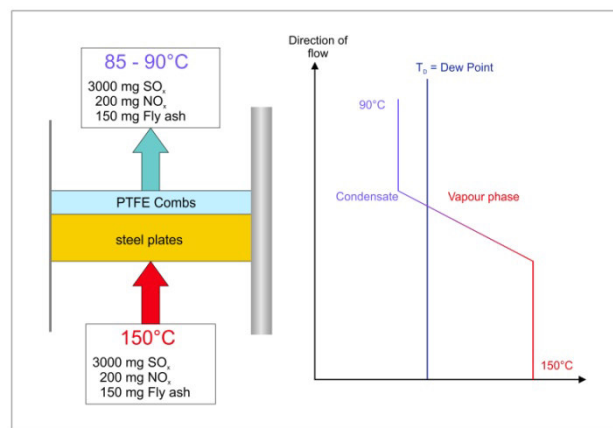


Fig. 5b

Fig. 5a and 5b: Typical operation conditions inside a rotor of a Ljungstroem® heat exchanger positioned within a FGD module. Fig 5a: During the first pass through the rotor, the flue gas is cooled down from 150 °C to about 85 – 90 °C (left side), while being reheated in the second pass, coming from the scrubber after cleaning, from about 45 – 50 °C up to 95 – 100 °C (right side). Fig. 5b: As a consequence of the cooling effect of the first pass, the temperature falls below the dew point T_D and the corrosive chemical mix starts condensing. The equipment of the rotor with PTFE combs as heat transfer elements will help to avoid corrosion in this area safely.

One of the reasons for the arising of dry and wet areas inside the Ljungstroem® rotors is demonstrated in Fig. 5b. As a consequence of the cooling down of the flue gas during the first pass through the rotor, the temperature falls below the dew point T_D and the mixture from steam, fly ash, SO_x, NO_x, hydrochloric acid (HCl), hydrofluoric acid (HF) and further contaminates is condensing. Thus, for the rotor itself and its heat transfer elements extremely corrosive conditions are generated, although the condensate and the coverings from mainly fly ash are removed by cleaning periodically. Therefore it is essential that at least the wet zone of the rotor is equipped with Hetrakon™ PTFE combs as heat transfer elements. This helps to safely avoid corrosion in this area over long time. Experiences from the field can be taken as a proof that under this extreme environment with permanently changing conditions, PTFE will not show measurable changes of its original properties over many years. Right now, field experiences are available from permanent service over twelve years with showing no indications for corrosion or ageing phenomena. When power plants are operated under strongly varying degrees of plant utilization, the dew point level T_D within the rotor will move and the zone of the cold end layer will change its height constantly. Therefore, currently a new demand

is arising requesting PTFE combs with increased channel length to ensure corrosion protection even under these varying conditions.

Application of heat exchangers in SCR / SNCR modules

In order to prevent the environment from pollution modern power plants fired with hard coal, brown coal or oil use all major types of flue gas cleaning processes: after passing the electrostatic particle separator, firstly sulfur oxides are removed from the flue gas by washing with water in the desulfurization unit and secondly nitrogen oxides are eliminated by either selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR). These processes, positioned downstream of the power generation require accurate temperature control to work under optimal conditions. In order to achieve this target, heat displacement systems are required as well for FGD as SCR and SNCR modules. Ljungstroem® gas-gas heaters (GGH) are preferred systems for heat displacement tasks. They are made from steel or steel alloys, but whenever the flue gas system crosses the dew point level to reach condensation status, or chemically aggressive deposits get in contact with the heat exchanger elements, corrosion protection is required.

The SCR/SNCR Ljungstroem® GGH unit located just before the stack recovers heat from the cleaned flue gas leaving the SCR and transfers this heat to the untreated flue gas on its way from FGD to SCR/SNCR.

Thus the flue gas, which leaves the FGD module with relatively low temperature, is brought up to the optimal temperature for performing the DeNO_x-process with high efficiency – making any further heating unnecessary.

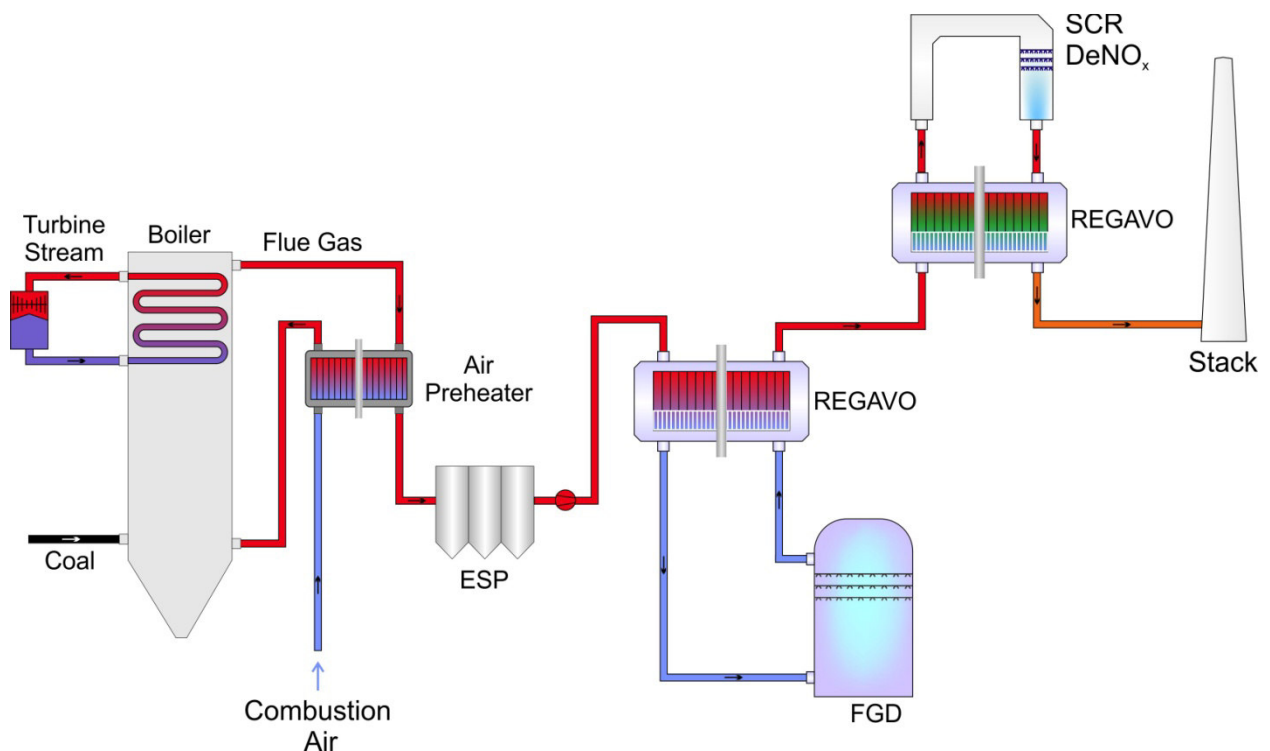
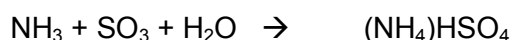


Fig. 6: Positioning of a REGAVO in order to optimize the DeNO_x – process: Thermal energy is taken from the cleaned flue gas to enhance the operation temperature inside the SNCR DeNO_x module.

Ljungstroem® gas-gas heaters for SCR applications are very deep in order to achieve the ultra-high efficiency needed to heat the untreated flue gas to the minimum temperature required by the SCR. Because the operating temperatures in the range of 150 – 190 °C are slightly higher than within FGD applications, corrosion is a minor issue but heat-resistance of all materials applied is a must. PTFE with its service temperature of 250 °C fulfills even this requirement.

Besides heat transfer, the rotor elements must fulfill a second function: They work as a collector of the deposit material Ammonium bisulfate (ABS), formed by the neutralization reaction of ammonia with sulfur oxides:

Ammonium bisulfate (ABS) is formed by the following reaction:



The excess amount of ammonia, together with sulfur trioxide and water is forming Ammonium bisulfate. The reaction product is collected as a sticky deposit within the regenerative air preheater (REGAVO). Periodically performed cleaning processes remove the ABS deposit from the rotor elements. This generates temporarily highly-corrosive conditions for the heat transfer elements. PTFE due to its anti-adhesive surface properties supports the cleaning operation efficiently. Thanks to its nearly universal chemical resistance, PTFE withstands these attacks without any material change.

The flexibility of the manufacturing process of Hetragon™ – combs enables to design these according to the special needs of the collection and cleaning processes.

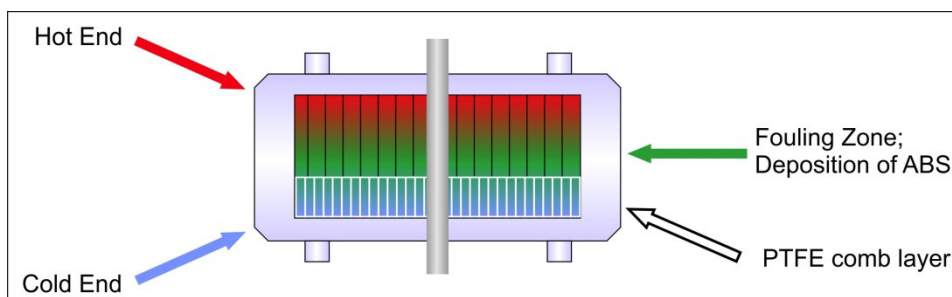


Fig. 7: Double-function of a REGAVO in SCR DeNO_x – Module application: In addition to the heat transfer function, the collection of the ABS deposit is the second job of the PTFE comb heat transfer elements. Periodically performed cleaning processes enable permanent operation.

Successfully avoiding the formation of catalyst poison

The catalysts use for the removal of nitrogen oxides in SCR modules can be poisoned by silicon tetrafluoride, SiF₄, which causes a rapid decay of the catalyst efficiency.

As the main source for the formation of this catalyst poison, the reaction between HF (component of flue gas) and silicon dioxide (SiO₂), component of enamel coating, can be considered. Depending on concentration and reaction conditions, besides SiF₄, also H₂SiF₆ is formed. Both reactions in the long-term reduce the thickness of the protective enamel layer. The reaction details are shown in Fig.8. When applying the steel enamel system, left side, the catalyst poison SiF₄ can be generated. The use of corrosion resistant Hetragon™ PTFE combs in heat exchangers successfully eliminates the formation of SiF₄.

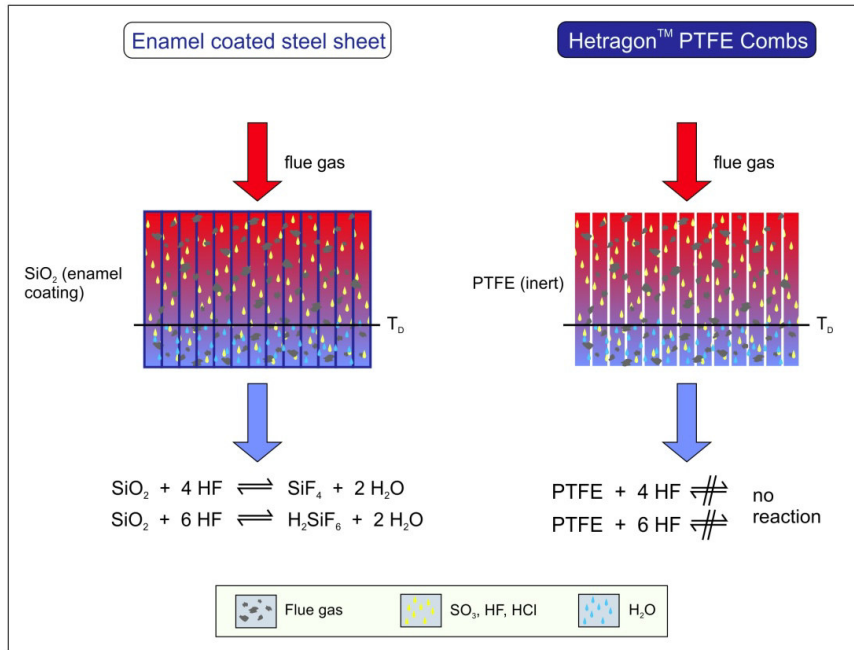
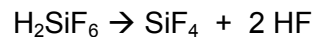


Fig. 8: Enamel corrosion protection layers together with traces of HF, a component of flue gases, are forming SiF_4 and H_2SiF_6 . The use of corrosion resistant PTFE instead of enamel coating makes these reactions impossible and the formation of SiF_4 is eliminated.

Hexafluorosilicic acid can undergo a further decomposition reaction, following the equation:



which also leads to the catalyst poison SiF_4 .

Following these chemical reactions it is recommended, to not make use of enamel corrosion protection, if the avoidance of the formation of SiF_4 is required. This is true at least for the components coming into contact with flue gas before entering the SCR / SNCR module. Suitable alternatives are full-fluoropolymers solutions, as in this case described for PTFE combs used as heat transfer elements in GGH. Containers and tanks for chemicals as well as duct systems for flue gas handling can also be equipped with corrosion protection systems using fluoropolymers. Typical, well approved system solutions for these applications are so-called bonded systems for tank lining or 'loose-shirt-linings' for duct systems and heat exchanger modules.

Weight savings opens up new options for the application of PTFE combs

In Fig 4, besides the application in flue gas desulfurization units, a second field for the application of Ljungstroem® heat exchangers is mentioned, the function as air pre-heater (APH) for pre-warming the combustion air before entering the boiler. The pre-heating of combustion air enhances the overall efficiency of the power plant and has a positive impact onto the combustion process. Due to high service temperatures of the flue gases coming into contact with the 'hot side' of the heat exchanger, corrosion problems do not occur in this application.

Exchanging steel by PTFE therefore is not required for corrosion protection reasons. The PTFE's high continuous service temperature of about 260°C, in short-term exposure going up to 300 °C, as well as the opportunity for enabling significant weight savings of the GGH rotor when equipped with PTFE combs makes the exchange of the heater elements from steel to PTFE in APH applications obvious. The heavy mass of the moving Ljungstroem® rotors in permanent motion creates an extreme stress onto the bearings and already caused downtime and shorter maintenance intervals for the power plants.

The potential for weight reduction of the moving mass of a Ljungstroem GGH is demonstrated in Fig. 9. Base for the calculation are the characteristic values from table 1. The dimensions of the rotor, for which this calculation is valid, are as follows: diameter of the rotor is 20 meter, equipped with heater elements of one meter height. The volume share of the heat transfer elements in relation to the overall rotor volume is to be 80%. The weight of the rotor construction itself as well as the weight of the baskets carrying the heat transfer elements, remain to be out of consideration - and will be the same, no matter whether the rotor is equipped with steel elements or PTFE combs. Fully loaded with steel elements as heat transfer elements the overall weight of this part is calculated to be 213 tons. In case of complete equipment with PTFE combs, this weight part however is 90 tons only. Thus the maximum weight savings possible of this single rotor is in the range of 125 tons!



Fig.9: The potential for weight reduction of Ljungstroem® rotors by replacing steel packages with PTFE combs -keeping the same level of heat transfer capacity- is significant: Just as an example, if a rotor with twenty meters in diameter and with a height of the heat transfer elements of one meter, a complete replacement of the steel packages by PTFE combs will reduce the rotor weight by about 125 tons (!): From left to right in Fig.9: successive replacement of steel packages by PTFE combs.

Flexibility in rotor equipment with PTFE combs

At present, Hetragon™-PTFE combs are mainly used for upgrading existing Ljungstroem® heat exchangers and therefore, flexibility is a must, as the adjustment of the comb design combined with the fixation within the rotor is an essential assumption for realizing such projects.

The end user has the choice between many different ways how to proceed to transform his own system into the PTFE comb version. If steel baskets are used to pick up the heat transfer elements, then this system can be applied in the same way for PTFE combs. In detail, when the old heat transfer elements are being replaced by new ones as a maintenance action, the new steel elements are manufactured with reduced length and the free space, either on top or at the bottom of the basket, is filled with PTFE combs. Thanks to a special welding technology, the individual comb segments can be connected up to an overall segment size of 1020 x 1030 mm, enabling to fill the rotor segments of the most existing Ljungstroem® GGH as a one-piece-construction. Larger volumes can be filled with more-component-constructions, requiring nothing more than additional support bars at the baskets. The comb segments are produced with standard height of 150 mm or 250 mm. For larger filling height, which is equivalent to larger channel length, the combs can be assembled in stacks in multiplies of 150 mm or 250 mm. For optimized air stream conditions and easy cleaning behavior, the comb stacks can be fixed in line. As another fixation method besides the use of baskets, the PTFE combs can directly be fixed at the rotor walls by the help of support bars. This way of assembly makes it very easy, to adjust the lifetime of the fixation elements by selecting corrosion resistant steel for those, to the significantly longer lifetime of PTFE comb heat transfer elements.

A new assembly method is currently developed by ElringKlinger Kunststofftechnik GmbH for the assembly version „cold end layer on top“ which is characterized by a ‚rotor wall free PTFE full plastic version‘ in the region of the cold end layer. Thus the challenge is overcome, which was generated by mixed constructions using materials with different corrosion resistance and different lifetime. In order to demonstrate the different ways being possible how to assemble PTFE combs within rotor segments, Fig. 10 shows the example of basket-free direct fixation at the rotor wall.

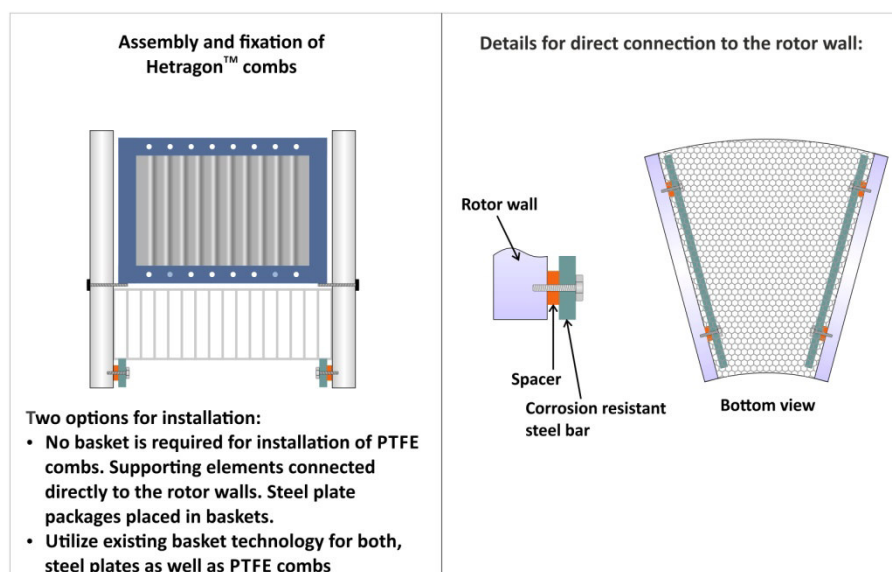


Fig. 10: As an alternative to the fixation with the use of baskets, PTFE combs can be fixed directly at the side walls of the rotor supported by corrosion resistant fixation bars. This assembly method enables easily the full utilization of the extended lifetime of the PTFE combs.

Summary and outlook

Through the substitution of steel packages as heat transfer elements in Ljungstroem® GGH by Hetrakon™ – PTFE combs, the application spectrum and the lifetime can be significantly enlarged. The nearly universal chemical resistance of PTFE, combined with its high service temperature and the anti-adhesivity of the comb surface which makes the cleaning very easy, makes PTFE the material of choice for the application as heat transfer elements in Ljungstroem® heat exchangers. This durable technology of heat exchangers provides the same level of heat transfer capacity as their metal plate-equipped predecessors. Thanks to its flexibility in design and assembly techniques, it can be adjusted to the dimensions of all currently used heat transfer rotors. The replacement of the heat transfer elements can be realized partially or in full. In the past mainly used in FGD modules, thanks to new additional applications in the SCR / SNCR DeNOx – modules as well as in air pre-heaters (APH) for pre-heating of the combustion air, continuous growth of this durable heat transfer elements, designed for long lifetime, can be expected.

New developments, such as the second PTFE resin generation with further enhanced specific heat and thermal conductivity, will further accelerate this trend.

Literature:

- (1) Wallstein Ingenieur-Gesellschaft mbH, Recklinghausen. Comparison AIWaFlon vs. A59