PROCESS GAS COOLING SYSTEMS FOR NITRIC ACID PRODUCTION
SCHMIDTSCHE SCHACK, a division of the ARVOS Group, was formerly ALSTOM Power Energy Recovery GmbH, which was formed through a merger of the two traditional companies Schmidt’sche Heissdampf Gesellschaft mbH, Kassel and Rekuperator Schack GmbH, Düsseldorf in 1995. With headquarters and fabrication facilities in Kassel, Germany, the company also operates a branch office in Düsseldorf and has affiliated units in Wexford PA, USA and Kobe, Japan.

SCHMIDTSCHE SCHACK is a partner of the world’s leading engineering companies, contractors and operators in the chemical, petrochemical and metallurgical industries.

As a leading engineering company, SCHMIDTSCHE SCHACK specializes in product development, design and fabrication of state-of-the-art process gas cooling and waste heat recovery systems for chemical and petrochemical reaction processes.
PROCESS GAS COOLING SYSTEMS DOWNSTREAM OF CATALYTIC REACTION PROCESSES LIKE AMMONIA COMBUSTION AND $N_2O$ DECOMPOSITION

SCHMIDTSCHIE SCHACK supplies highly sophisticated and boilers, globally unrivaled in size, for mono and dual pressure catalytic oxidation processes in nitric acid and caprolactam production plants. The world’s largest vessel ever built, with a diameter of 7 meters, was designed and fabricated by SCHMIDTSCHIE SCHACK.

For the ground-breaking tertiary catalytic cracking process for adipic acid production SCHMIDTSCHIE SCHACK provides the waste heat recovery system downstream of the decomposition stage of nitrous oxide ("laughing gas") laden exhaust gases from the process.
Nitric acid production takes place in two steps. An ammonia/air mixture is oxidized to nitrogen oxides in the presence of platinum/rhodium catalyst gauze. Then nitrogen oxide is oxidized and absorbed by water to produce nitric acid. The oxidation is a strongly exothermic process which follows the equation:

\[ 4 \text{NH}_3 + 5 \text{O}_2 \rightarrow 4 \text{NO} + 6 \text{H}_2\text{O} + 905 \text{ kJ} \]
\[ 4 \text{NH}_3 + 2 \text{O}_2 \rightarrow 2 \text{N}_2 + 6 \text{H}_2\text{O} + 1260 \text{ kJ} \]

The result is a process gas with typically 68 vol.% N\(_2\), 10 vol.% NO, 6 vol.% O\(_2\), 16 vol.% H\(_2\)O. The hot process gas of 4 to 13 bar pressure and up to 920 °C is cooled by generating superheated steam and by preheating the tail gas.

Depending on the specific process requirements typical steam parameters are 18 bara to 55 bara at temperatures between 210 °C and 500 °C.

SCHMIDTSCHER SCHACK has developed and put into service reliable, maintainable heat exchanger solutions at reasonable cost. Depending on the specific plant parameters forced circulation or natural circulation systems are provided.

The heating surface bundles are fabricated from flat coil elements to allow a compact single vessel design. If natural circulation is selected vertically arranged shell & tube evaporator heating surfaces are integrated in the heat recovery unit.
The start-up of a process gas cooler is a critical phase from the perspective of corrosion.

Nitric acid (HNO₃) will be formed on the “cold” heating surfaces at the moment the process gas reaches the relevant dew point:

\[ 3 \text{NO}_2 + \text{H}_2\text{O} \rightarrow 2 \text{HNO}_3 + \text{NO} - 72 \text{kJ} \]

If NH₃ gas slips through the catalyst gauze during plant start-up, ammonium nitrate is formed in the presence of HNO₃ immediately at temperatures below 170 °C. The build-up of ammonium nitrate, a corrosive and strongly adhesive mass, is represented in the following formula:

\[ \text{HNO}_3 + \text{NH}_3 = \text{NH}_4\text{NO}_3 \]

To avoid this corrosion mechanism it is of great importance to warm up the “cold” heating surfaces to a safe temperature level during start-up. With optimized boiler design and ideal material selection SCHMIDTSCHEN SCHACK has developed outstanding methods to minimize corrosion. At the same time, our customers benefit from significantly reduced plant operation costs, e.g. due to lower start-up steam requirements.

Furthermore optimal material selection helps to avoid corrosion mechanisms.

Figure 4: Dew point of typical process gas composition

Figure 5: 3D CAD dimensioning model of an ammonia combustion process gas cooler
Environmental protection is a top-priority issue for SCHMIDTSCHE SCHACK. We undertake great efforts to make our fabrication processes ecologically sensitive and to design sustainable products.

SCHMIDTSCHE SCHACK is committed to implementing design features aimed at minimizing the environmental impact of industrial heat transfer processes.

One of the first steps taken long ago was to apply highly efficient process heat recovery methods in chemical reaction processes. This enabled heat represented as fuel-energy to be saved and reused for process applications or in steam turbine cycles for electric power generation. This results in environmental protection benefits as well as in financial benefits through cost savings in the production plant operation.

Reducing greenhouse gas emissions like N₂O gas is another measure to protect the environment being addressed by SCHMIDTSCHE SCHACK. N₂O emissions can be diminished by installing secondary abatement catalysts below the platinum/rhodium gauzes. In this case a long basket lifetime is ensured through a special SCHMIDTSCHE SCHACK designed cooled catalyst basket support system.

For optimal operation of a tertiary type catalyst located downstream of the process gas cooler unit a constant gas outlet temperature is beneficial to increase the catalyst efficiency.

SCHMIDTSCHE SCHACK’s waste heat recovery systems have the design option to operate at nearly constant gas outlet temperatures over the full plant load range of e.g. 70% to 110% nominal capacity if equipped with suitable control equipment offered by SCHMIDTSCHE SCHACK.
SCHMIDTSCHE SCHACK waste heat recovery systems are custom designed with the latest 3D CAD systems and FEM calculation software combined with SCHMIDTSCHE SCHACK engineers’ decades of experience. Fabrication is performed at SCHMIDTSCHE SCHACK’s own ideally suited workshops in Germany as well as partner workshops in Europe. All major standards, e.g. EN13445, EN12952, AD 2000, ASME, IBR, Chinese standards, customer specifications, local codes, regulations and directives (Pressure Equipment Directive 2014/68/EU) can be fulfilled.
Figure 9: Final assembly of world's largest process gas cooler
Would you like us to conduct studies for you? SCHMIDTSCHÉ SCHACK experts are pleased to share their experience with plant owners and operators to identify ways of optimizing the operation of their process heat recovery systems. A wealth of experience in designing process gas cooler systems is applied to analyze bottlenecks via recalculation of the gas cooler system. Several nitric acid plants have successfully been optimized and retrofitted on the basis of SCHMIDTSCHÉ SCHACK’s engineering studies.

Figure 10: Burner hood for ammonia combustion process gas cooler

Figure 11: CFD study for optimizing an ammonia combustion burner hood
SCHMIDTSCHER SCHACK has executed all sizes of waste heat recovery systems for different applications in the chemical and petrochemical industry (HNO₃, NO and N₂O plants).
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