SYNGAS COOLER SYSTEMS FOR GASIFICATION PLANTS
INTRODUCTION

Hydrocarbons accompany us in all areas of life in a variety of chemical compounds such as plastics, fertilizers, paints, lubricants and fuels. The dominant basis for their production is still formed by natural gas and oil.

However, the industrial gasification of coal, refinery wastes, e.g. petroleum coke, and biomass is also steadily growing in importance in this context.

Gasification, a chemical process, converts hydrocarbon material by substoichiometric incineration under intense temperatures and often high pressure to synthetic gas, or syngas. Syngas is composed primarily of carbon monoxide, hydrogen and carbon dioxide and serves as a starting point for the production of a variety of chemical compounds, fertilizers, pure hydrogen, methane or liquid transportation fuels. It can also be used directly for electric power generation, for example by firing gas turbines.

Gasification technology represents an alternative feedstock-based chemical and fuel production system. Gasification breaks down virtually any carbon-based feedstock into its basic constituents.

This enables the separation of pollutants and greenhouse gases to generate clean gas for the production of chemicals, clean liquid fuels and electricity.

Gasification vastly expands the fuel base beyond natural gas and oil to include more abundant and lower cost resources, e.g. locally available coal and refinery waste.

The flexibility to co-produce multiple chemical commodities and different fuels makes the technology economically attractive for a broad range of industrial applications.

Excellent energy efficiency, lower emissions and the potential of waste recycling are clear advantages of gasification technology.
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2.2 QUALITY

The quality focus is a guiding principle through all stages from process and layout calculation and basic engineering through to detail and manufacturing engineering and fabrication. A strict quality assurance procedure is defined and secured. SCHMIDTSCHE SCHACK is certified according to ISO 9001.

Design and fabrication take place in conformity with customer requirements, according to all common national standards and in-house know-how acquired over decades.

SCHMIDTSCHE SCHACK fabricates all sophisticated heat transfer components in its own specialized workshops in Kassel, Germany and with well-proven fabrication methods.

SCHMIDTSCHE SCHACK’s outstanding heat transfer equipment quality ensures customer value through highest availability, best performance and longest service life.

2.3 FABRICATION

SCHMIDTSCHE SCHACK fabrication shop in Kassel – birthplace of Schmidt'sche® Syngas Coolers

Figure 7: SCHMIDTSCHE SCHACK fabrication shop in Kassel – birthplace of Schmidt'sche® Syngas Coolers
ARVOS | SCHMIDTSCHE SCHACK’s area of excellence is process heat transfer technology in the high temperature and pressure range, often combined with additional challenges like high dust loads or aggressive operation conditions.

The internationally renowned company is a leading developer, designer and fabricator of apparatuses for the chemical, petrochemical and metallurgical industries.

Based on mature design concepts, customized to meet process and customer requirements, SCHMIDTSCHE SCHACK supplies Schmidt’sche® Transfer Line Exchangers, Reactors, Schack® Fired Heaters and Convection Banks.

Chemical process improvement is always accompanied by the development of new, increasingly powerful apparatuses. The excellent reputation of SCHMIDTSCHE SCHACK stems to a vast extent from the ability to furnish the most suitable and reliable heat exchange equipment solutions for innovative new processes, e.g. reactors for catalytic processes, syngas cooling systems for gasification processes, reaction gas heating systems, superheaters for high temperatures and special designs for coal, shale oil/gas and heavy oil refinery residue.

SCHMIDTSCHE SCHACK’s decade-long experience in meeting technological challenges from the basic idea to the finished product manufactured in its own specialized workshops makes the difference. Optimal quality and performance are thus ensured and allow our customers to focus on economic excellence. Individual service support assures trouble-free plant operation.

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Figure 6: Large particle flow true the funnel shaped tube inlet

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3.1 DOUBLE TUBE SYSTEM

The SCHMIDTSCHE SCHACK design has various key features ensuring long, durable and reliable operation of the syngas cooler.

3.1.1 FUNNEL SHAPED TUBE INLET, NO FERRULES!

The Schmidt'sche® Double Tube/Oval Header System has no tube sheets in the classical sense, which would need to be refractory lined, nor does it need ferrules for the tube inlets. Aerodynamically optimized tube inlets together with intensively cooled oval headers have been shown by experience to offer the best protection against tube inlet erosion and the formation of gas-side deposits, see figure 10.

The high velocities on the water/steam side maintain the tube wall temperature at safe levels. The Schmidt'sche® design thus avoids the use of ferrules, resulting in the most reliable technology for this application.

The funnel shaped tube inlet reduces the propensity for deposits forming due to eddy currents, thus minimizing erosion of the tubes by managing the velocity profile at the tube inlet.

Furthermore, high alloy composite tubes can be used for the inner tubes and all gas bearing surfaces can be clad with alloy material in order to avoid high temperature H₂S corrosion.
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3.1.2 REGISTER

The basic element of the Schmidt’sche® Double Tube/Oval Header Heat Exchanger is the double tube register. This element consists of a row of double tubes (tube within a tube), which are welded to oval headers at either end to form the double tube register as shown in figure 11. Double tube registers with different numbers of tubes are assembled to form one body by gas-tight welding of the adjacent oval headers. The ends of the oval headers are connected to downcomer distributors and headers for connection to the water circulation system. The cylindrical connections for the gas inlet and outlet chambers are welded to both tube sheets formed by a row of oval headers.

The process gas at temperatures up to 1,400 °C flows through the inner tube and is cooled by the water/steam mixture that flows through the oval headers and the annulus between the inner and outer tubes.

The water side of the exchanger operates in natural circulation. Water from the steam drum is fed through the downcomer to individual bottom oval headers for distribution to the annulus between the inner and outer tubes. Steam is generated in the annulus at pressures up to 140 bar. The water/steam mixture flows to the top oval header and returns to the steam drum through the risers.

Since each process gas tube (inner tube) in the Schmidt’sche® Double Tube/Oval Header Heat Exchanger has its own cooling element provided by the annular gap between the inner and outer tubes, the amount of cooling required for each process tube is individually determined by the heat input, thereby self-adjusting to the heat load in each tube. This is an important advantage of the system which is able to compensate for uneven gas flow distribution.

Proprietary software developed in-house is used to calculate water flow conditions in each set of double tubes based on individual process-side input data. The result of the calculation provides specific operational data for each process tube as well as the aggregate performance data for the exchanger as a whole.
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3.1.3 ADVANTAGES OF DESIGN PRINCIPLES

• High flow velocities in the top and bottom oval headers and in the annulus between the inner and outer tubes ensure maximum cooling of the oval headers and each process tube. It also ensures removal and transport of particles carried over by the feedwater or that may settle during shutdowns.

• High velocities and turbulent flow in the oval headers and in the annulus between the inner and outer tubes provide for high heat transfer coefficients. This maximizes the cooling of the tubes and protects the high heat flux areas by keeping the gas-side metal skin temperature as low as possible. In addition, the high turbulence and the defined flows within the oval headers ensure disturbance-free removal of the steam bubbles and prevent the undesired formation of steam cushions.

• The oval header acts as a flexible membrane that compensates for the difference in thermal expansion between the inner and outer tubes, in effect reducing the mechanical stresses on the system.

• Mechanical and thermal stresses are reduced by using thin-walled oval headers, inner and outer tubes. A thin-walled system is mechanically more flexible and assures a lower temperature gradient across the wall thickness.

• By effectively mitigating and/or eliminating high thermal and mechanical stresses, the magnetite layer on the process tubes is protected and ensures the operational longevity of the Schmidt’sche® Double Tube/Oval Header System.

The Schmidt’sche® Double Tube Design with Oval Headers is a unique heat management system for cooling gases on one side and generating high pressure steam on the other. This design principle has been applied successfully for more than 60 years worldwide to cracked gas coolers, so-called Schmidt’sche® Transfer Line Exchangers in ethylene plants (more than 7,000 units have been delivered). And for more than 20 years this type of heat exchanger has been successfully operating in various coal and biomass gasification processes.

Many plants using the Double Tube/Oval Header design have been running for over 20 years using the original equipment and without a single failure. The longest running exchangers were taken off line after 35 years of operation without failure. These exchangers were replaced during a revamp and redesign. This record has given Schmidt’sche® heat exchangers a worldwide reputation for durability and reliability, which translates to lowest maintenance costs, highest productivity and thus optimal plant operation economy.

Figure 12: Stable magnetite protection layer, mandatory for long durability, due to low tube wall temperature amplitudes

Figure 13: Mounting of a Schmidt’sche® Syngas Cooler into steel structure

Figure 14: Final assembly of Double Tube Registers to a Schmidt’sche® Syngas Cooler

Figure 15: Arrival of a Schmidt’sche® Syngas Cooler at site in India

High steam bubble dislodge-ment in water tube boilers and Schmidt’sche® TLEs
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3.2 SYNGAS COOLER DOWNSTREAM PARTIAL OXIDATION OF LIQUID AND GASEOUS FEEDSTOCKS

The development of syngas coolers, which are installed downstream of partial oxidation reactors, requires a high level of technological know-how and practical experience that address the complex technical and physical issues of processing heavy residual oil and for hydrocarbons which are loaded with heavy metals.

Continuous efforts by SCHMIDTSCHE SCHACK in R&D, engineering and fabrication techniques have permitted higher operating temperatures and enabled pressures at the syngas coolers/steam generators to be increased to as high as 100 bar on the synthesis gas side and 150 bar on the steam side.

3.3 RADIANT SYNGAS COOLER (RSC)

One of the key elements of the Integrated Gasification Combined Cycle (IGCC) process is the Radiant Syngas Cooler (RSC), which generates high pressure steam by means of heat transferred from the hot raw gas. Compared to a gasifier without heat transfer but with direct water quenching, the syngas cooler increases the process efficiency by approximately 5 percentage points. The steam produced can be utilized for process purposes or to generate electric power.

Advanced radiant and convective syngas cooler concepts, developed and supplied by SCHMIDTSCHE SCHACK and predecessor companies, were put into operation 2007 in “Ningxia” the first coal gasification plants in PRC using radiant cooler technology in a Coal to Methanol Plant.
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3.4 SCHMIDTSCHE® RAW GAS – CLEAN GAS HEAT EXCHANGER

The efficiency of an IGCC can be further enhanced by installing a Raw Gas – Clean Gas Heat Exchanger in front of the gas cleaning system. The latent heat of the raw gas preheats the clean gas fueling the gas turbine. SCHMIDTSCHE SCHACK has developed a heat exchanger concept based on the well-proven Schmidt’sche® Double Tube System. This special design achieves highly uniform flow distribution on the shell side and therefore identical thermal input (load) on all tube surfaces.

Typical operating conditions are:
- Raw gas pressure and clean gas pressure 10 to 30 bar
- Raw gas temperature 600 to 350 °C
- Clean gas temperature 250 to 530 °C

Depending on the type of gasification process the syngas downstream of the steam generator may be further cooled by a steam superheater (special SCS design) and economizers.

4.1 SPIRAL COIL STEAM SUPERHEATER

The SCHMIDTSCHE SCHACK Steam Superheater with the special spiral wound heating surfaces is able to operate under high steam-side as well as high gas-side pressure and high dust load. A large number of wound tube spirals are interlaced to form a compact tube bundle with circumferential gaps. Steam flows through the spiral tubes, whereas the syngas to be cooled flows through the circumferential gaps to the outside of the tube bundle.

Due to the high flexibility of the spirally wound tube bundle, thermal stresses remain at safe levels even at all operating temperatures. Use of high alloyed steel permits operating temperatures of up to 850 °C on the gas side and 560 °C on the steam side. Down flow arrangement and specially shaped gas inlet channels, optimized by CFD modelling, allow operation with gases featuring high dust loads. For such applications or difficult fouling conditions, SCHMIDTSCHE SCHACK has developed efficient mechanical cleaning devices.
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4.2 SCHMIDT'SCHE® BAYONET-TUBE STEAM SUPERHEATER

Growing demand for SNG (Substitute Natural Gas) is driving investors' interest in the methanation stage behind syngas generation, mainly from petcoke, coal or biomass gasification.

The Schmidt’sche® Bayonet-Tube Steam Superheater based on its well-proven, reliable and robust tube-in-tube design principle provides a controlled gas and coolant flow and thus ensures supremely efficient heat exchange at low pressure drop. In addition a smooth material temperature distribution at a moderate level is achieved in the mechanical structure and the tube sheet.

In consequence, uniform thermal expansion and low thermal stresses lead to a robust design, which is of particular importance for cyclic operation. The minimal use of inner refractory and the application of internal cooling ensure low maintenance and high availability.

Operational experience with the Schmidt’sche® Bayonet Tube-in-Tube design principle proves the reliability of this robust concept.

The Schmidt’sche® Bayonet-Tube Steam Superheater is able to operate at gas-side temperatures of up to 640 °C at 40 bar and steam-side temperatures of 540 °C at 120 bar.

Syngas from gasified biomass like wood and straw contains solid particles, tar and chemical components like chloride which need to be taken into consideration for dimensioning and material selection. Heat recovery equipment can be designed as water tube or fire tube heat exchangers, with natural or forced water circulation systems.

SCHMIDTSCHE SCHACK designs and manufactures Schmidt’sche Syngas Coolers with Double Tube/Oval Header System for biomass gasification processes.
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BLACK LIQUOR GASIFICATION

Black liquor, a secondary product of the pulp and paper industries with a high caloric value, is usually incinerated in special furnaces in order to make use of the thermal heat. Black liquor can be converted into “green liquor” by means of dedicated gasification processes and rerouted into the paper production process. Downstream of the gasifier, heat transfer equipment like cooler condensers is installed to collect the green liquor produced and to recover the heat energy from the gasification process.

SCHMIDTSCHER SCHACK implements highly sophisticated heat transfer technology and has a wealth of excellent know-how with the radiant shield cooler. SCHMIDTSCHER SCHACK also offers suitable products to meet the continuously growing demand for plastic waste gasification systems.

Figure 28: Gasifier with cooler condenser

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Figure 29: Radiant screen cooler
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**PLASTIC GASIFICATION**

![Radiant screen cooler](image)