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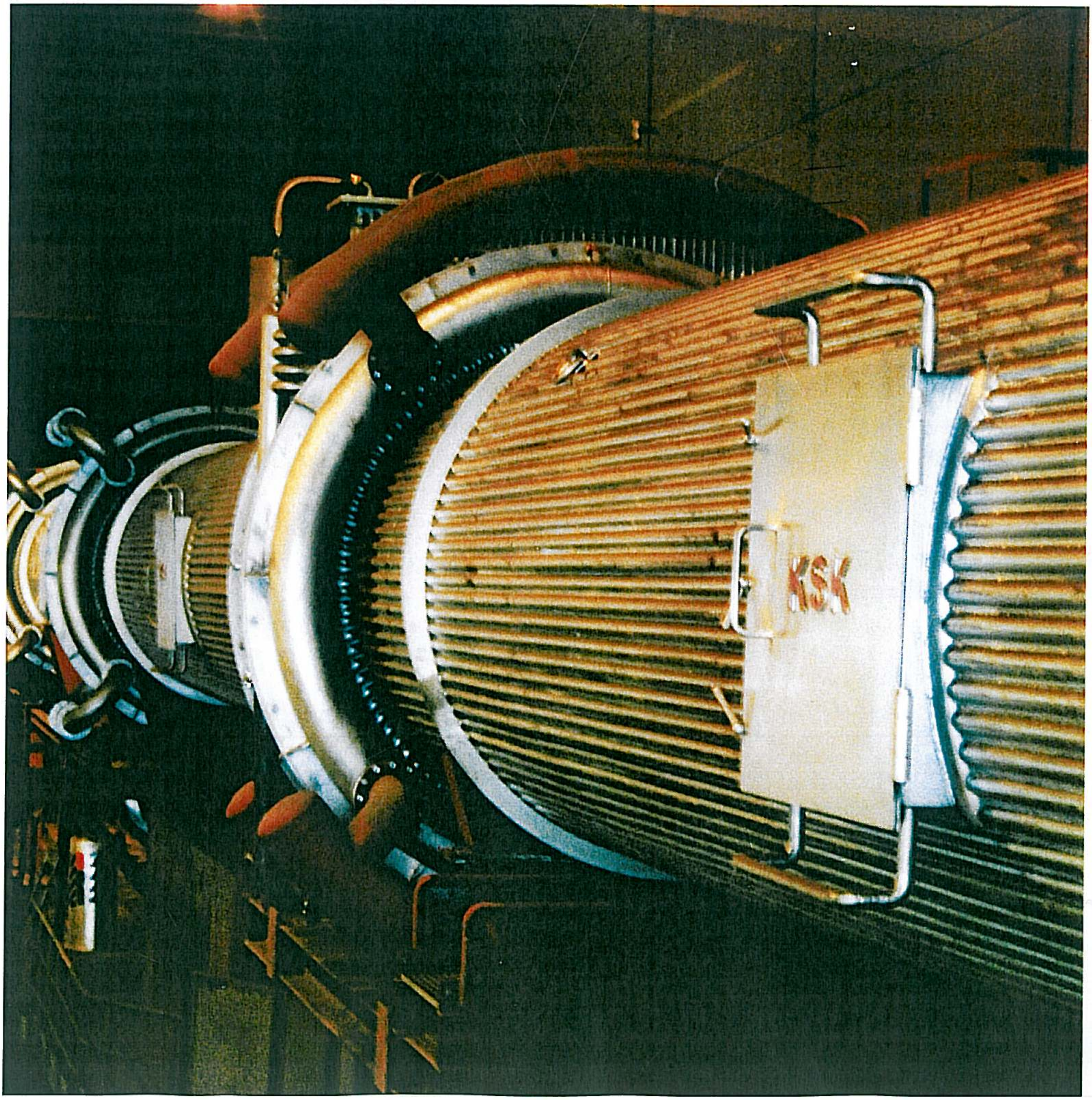

Newly designed hot gas duct system for a DC electric arc furnace

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The hot gas duct system for the 100 t electric arc furnace of Salzgitter AG was completely redesigned and replaced. The hot gas duct has six exchangeable round pieces. Two separate parallel cooling water strands, vortex devices for the off-gas as well as flow, temperature and pressure control systems guarantee high plant availability and low maintenance costs. This new design concept can be used for both new projects and modifications to existing plants.

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Original situation and solution concept

The electric steelmelting shop. In December 1995 Salzgitter AG tapped the first heat with the DC electric arc furnace at its Peine works, **table 1.** With a tap weight of 100 t, this high-performance plant today achieves a tap-to-tap time of 40 min. Its best 24 h production result since start-up has been 41 heats. The downstream pollution control system is so designed that after the direct extraction of the furnace off-gas through the furnace elbow the hot fume is guided and regulated by an air gap into a cooled collar. The collar first leads into a cooled chamber. From here the fume is guided through a large-volume, refractory lined combustion chamber to the discharge point into the hot gas duct. All equipment parts – especially those in contact with the fume – must feature excellent wear resistance properties due to the extremely high loading from the gases. Under operating conditions the off-gas flow rate at the entry into the hot gas duct downstream of the combustion chamber amounted to approx. 94 500 m^3/h (s.t.p.) at a max. temperature of some 1 200 °C. In the furnace design a single-piece, octagonal duct with a mean diameter of 2 250 mm in a pipe-web-pipe construction (pipe: 51 mm dia. × 4.5 mm; ST 35.8 I; DIN 2448) was chosen for the off-gas duct and cooling system. This hot gas duct, whose design is very similar to a converter cooling chimney, was laid out for a cooling water flow rate of around 1 200 m^3/h in a closed circuit of conditioned water. The water-cooled components were designed for a cold water cooling range up to a max. temperature of 100 °C.

Problems and experience with the first hot gas duct. Until the end of 1998 a continuously growing amount of corrosion was detected on the cooling pipes exposed to the fume. The necessary repairs to the single-piece duct system were very time consuming and costly. When the temperature falls below the dew point or there is intensive combustion activity, humidity arises in the hot gas duct, forming acids or acidic solutions with aggressive elements (e.g. chlorine, sulphur and phosphorus) contained in the fume. Moreover, it was found that the geometry of the duct and the complete primary dust extraction system gave spin to

Table 1. Main data of the DC arc furnace

Furnace data		
Tapping weight		100 t
Furnace shell inside diameter, top part		7 300 mm
Electrode diameter		750 mm (max. 800 mm)
Tapping system		eccentric bottom tapping (EBT)
Installed transformer output		150 MVA
Connected load		170 MVA
Melt-down power		90 to 95 MW
Natural gas/oxygen burners		
– wall panels		3 x 5 MW
– slag door		5 MW
Steel grades		
Grade group		
I	80 %	St 37, St 44, ASTM 36 and the like
II	18 %	St 52-3 StE 355 offshore grades; grades for mine support workings
III	2 %	Alloyed and non-alloyed case hardening and heat-treated steels, stainless steels

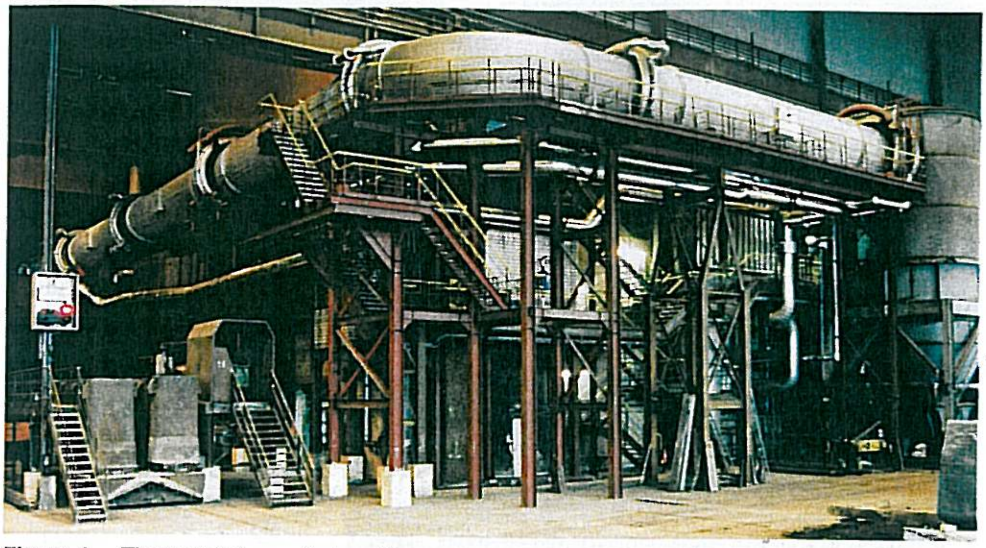

Figure 1. The new hot gas duct system

the gas flow. This effect caused higher wear on the impact side and more corrosion in the "lee" as a result of dust deposits. It was also found that the thermal load on the circumference of the hot gas duct was quite uneven. As a result of the insulating effect of dust depositing in the lower part of the duct, here the cooling water was much cooler than in the top area, throughout the whole length of the duct. This causes different stress areas within the duct system. A further location-related problem was the unfavourable position of the hot gas duct which could be only reached by the bay cranes, and even mobile cranes, with great difficulty. Carrying out the necessary repairs was always a major effort. As there were only very few measuring points along the original duct, it was not possible to get a clear picture of the operating conditions in the pollution control system and the duct. Plus, the possibilities for integrating new components were limited by the available cooling water volume, the max. allowable pressure loss along the hot-gas duct and the max. allowable water temperature differences.

Things to be improved. Based on these findings, the following proposals were made for the construction of a new hot gas duct. The most important prerequisite was that the new system perfectly fitted into the existing plant, i.e. no additional components, such as pumps or cooling units, should be necessary. The specifications for the water management system with the existing closed circuit and for the pollution control system were also not to be changed. Operating parameters had to be kept unchanged. Further important demands were easy accessibility – to be achieved through the relocation of the duct – and minimisation of corrosion in the cooling pipes. To this end, the new concept had to foresee a temperature level control capable of keeping the cooling water within a temperature range of 70–100 °C. Moreover, the new hot gas duct was to be made of a small number of easily exchangeable module types in order to avoid lengthy repairs of leaks with the defective part installed. These modules were to feature an improved flow cross-section which, at the same time, was to reduce the spinning effect of the fume. To achieve a clearer picture of the complete water-cooled duct and better regulating efficiency, additional measuring points were to be provided.

Solution concept. Taking into consideration the above demand profile the following concept was provided, namely, a modularly designed duct system with a round cross-section, in a simple and sturdy construction with five identical straight pieces and one rectangular bend, **figures 1 and 2.** Each module features a ring-type cooling water distributor at its head end and a ring-type cooling water collector at its tail end. The complete duct system consists of two sections with three consecutive modules and a separate cooling water strand each. The cooling water flows according to the

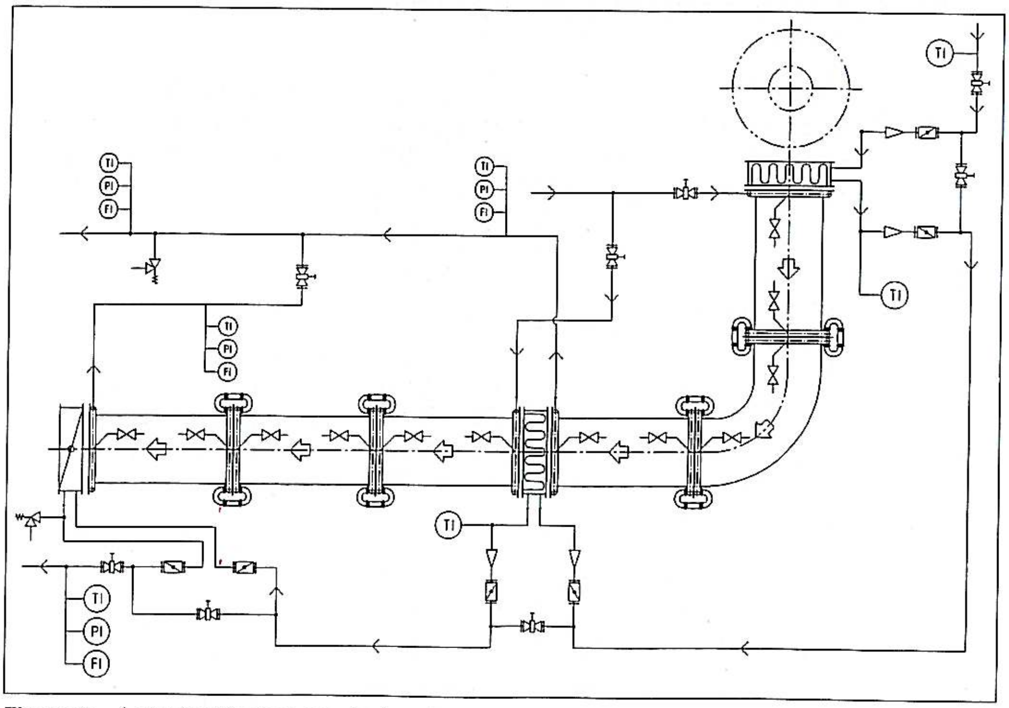

Figure 2. Layout of the hot gas dust system

uniflow principle. The distributor/collector design of the individual modules connected in series ensures that the cooling water is thoroughly mixed through and features a homogeneous mean temperature when entering the next module. The two individual cooling water strands can be regulated based on the return temperatures of the cooling water. Additionally, two off-gas vortex register devices with exchangeable inserts have been installed in the hot gas duct, one at the entry into the duct and one between strands 1 and 2. At the end of the duct an off-gas control valve has been arranged. The supporting structure for the complete

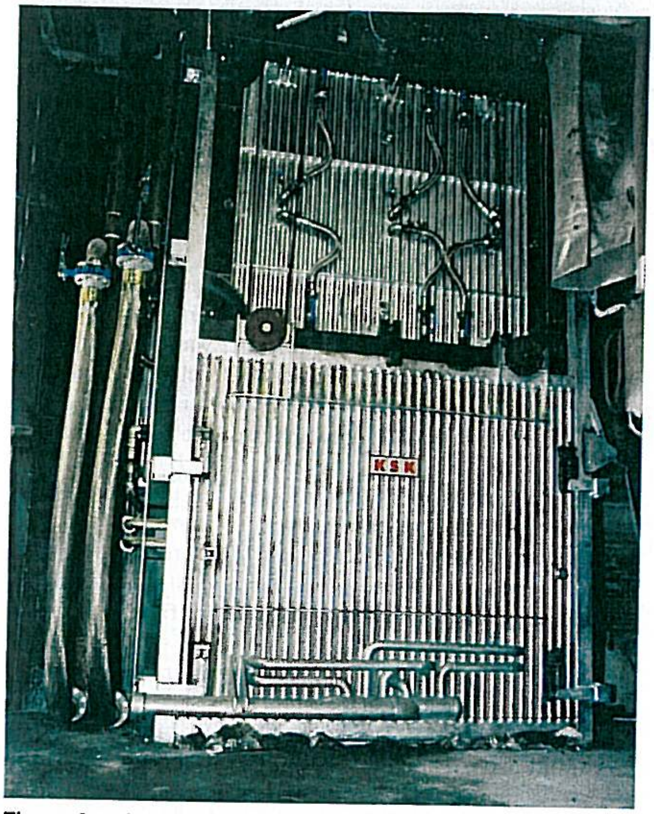

Figure 3. Coarse dust separator between electric arc furnace and hot gas duct system

hot gas duct is so designed that each module rests independently on the steel structure. Thus the modules can be very easily replaced. The new position of the duct makes for perfect accessibility. The operating conditions of the duct system (temperature, flow rate and pressure of the cooling water) can be monitored from the furnace control room at all times on the basis of the measured values acquired along the duct.

The new hot gas duct

Off-gas collar and combustion chamber. The furnace off-gas is sucked off through an elbow mounted on the furnace roof and then guided into a collar. This collar is designed as a rectangular bend with an oval cross-section in a pipe-to-pipe construction subdivided into sections. At the gas entry side the collar features an electrically actuated cooled sliding sleeve which regulates the false air volume. The collar has a mean cross-sectional area of 4.5 m^2. It is made of 1.4571 grade stainless steel. The off-gas then enters a cooled, rectangular off-gas chamber with two electrically actuated lifting doors enabling access to the chamber for the removal of the coarse dust. The 120 m^3 chamber consists of a strong supporting framework with individually exchangeable panels in pipe-to-pipe construction. In the meantime an additional water-cooled post-combustion chamber has been implement just behind the electric arc furnace, **figure 3.** Large dust particles are precipitated and can be easily removed by vehicle when opening the door shown in the figure. It is made of boiler steel of the St 35.8 I and H II grades. The fume then flows through a refractory lined combustion chamber consisting of two compartments. One compartment has the form of a horizontal, the other of a vertical cylinder. They both have a common downward dust discharge. With some 240 m^3 the overall volume of the combustion chamber is relatively large. This ensures that, provided that the right chamber temperature has been set, the fume remains in the combustion chamber sufficiently long.

The "uniflow principle". In contrast to subdivided elements, cooling pipes designed according to the "uniflow principle" are all flooded simultaneously with or parallel to the flow direction of the fume at their circumference. The modules are connected to each other in series. In order to limit the water pressure loss, more than one cooling circuit is needed. As at each entry into a module there is a uniformly mixed temperature, the increase of the temperature level from one module to the next takes place in a controlled manner, i.e. there are no temperature differences at the circumference. With the uniflow principle the thermal exploitation of the cooling water is considerably better, because it is remixed after each module. Monitoring the hot gas duct on the basis of measured values as well as its safety requirements is relatively simple, efficient and therefore cost-effective. The uniflow modules feature an uncomplicated and sturdy design. They are installed without any tubing work. In contrast to subdivided components with a cascade-type water flow, they can be completely emptied, e.g. for frost-proof storage. The gradual adjustment and control of a higher temperature level is only possible with an acceptable effort with uniflow cooling modules.

Main elements of the new plant. The hot gas duct consists of two parallel cooling water strands, each with three modules arranged in series and flooded according to the uniflow principle. The overall cooling water flow rate of approx. 1 200 m^3/h is distributed among the two strands according to the thermal requirements. The system features two vortex register devices, one at the beginning of the hot gas duct, the other between the two strands. At the end of the duct a water-cooled valve has been arranged for regulating the off-gas flow. The two register devices and the valve have a separate water supply (approx. 80 m^3/h) and are connected to each other in series. From the cooled hot gas duct the fume is guided to the downstream pollution control facilities via an uncooled and brick-lined duct.

Design features. The complete piping consists of five identical 13.5 m long straight pieces of duct with a round cross-section and a mean diameter of 2 261 mm. Each piece weighs approx. 11.5 t, **figure 4.** It is designed as a gas-tight welded pipe-web-pipe construction made of St 35.8 I (1.0305) and H II (1.0425) boiler steel. As an alternative, also acid-resistant, austenitic stainless steel (1.4571) has

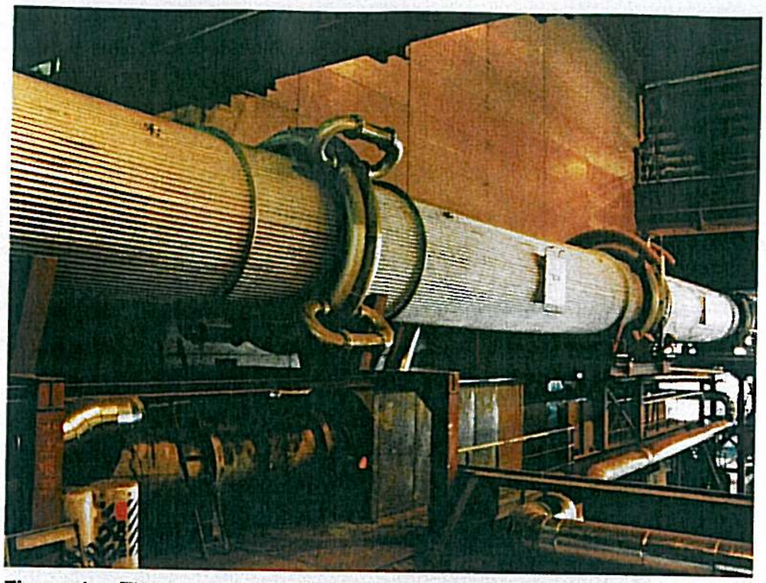

Figure 4. Three modules of the hot gas duct

been used. Each duct piece features an opening for maintenance purposes (800 mm × 800 mm) and a ring-type distributor / collector (DN 250) at each end, with four connections (DN 200) to the next module. Connection of the water supply between the modules is by means of short corrugated flexible stainless steel tube. There is a vent on each collector/distributor. The modules are screwed together by flanges. Each module rests on two duct brackets fixed to the steel structure. The hot gas duct also features a 90° bend with a developed view of 8.6 m and the same mean diameter as the rest of the duct. It weighs about 8 t and its design is in principle the same as that of the straight pieces.

Register device. The register device is a short round duct section (mean dia. of approx. 2 200 mm) in a pipe-to-pipe construction (St 35.8 I / H II) with a specially designed rectangular dome. It is about 440 mm long and has a total height of about 3.6 m. The water-cooled vortex insert mainly consists of a tube coil inserted from above into the duct section and fixed by means of a flanged connection. This module is subdivided into sections, i.e. the collector/distributor complete with vents is a closed system within this module. Both ends of the register device are connected by screwed flange joints. The main purpose of the exchangeable, and thus variable, insert is to intensify the whirling movement of the gas flow in order to achieve a better heat transfer to the downstream cooling pipe. The design of the vortex insert can be modified in order to comply with changing operating requirements. The design and mounting position of the register device depend on a number of important factors, such as maximum allowable gas pressure, amount and composition of the dust as well as efficiency of the hot gas duct system.

Off-gas control valve. The single-flap control valve is completely water-cooled. It has a round cross-section and is also designed as a pipe-to-pipe construction (St 35.8 I). It is about 425 mm long and has an outer diameter of about 2.8 m with a 4 m^2 flap area. The flap is actuated by an electric motor and the water supply is via flexible hoses. The control valve features a dividable housing. The parts are sectionally divided, each featuring an own collector/distributor. Depending on the meltdown phase in the furnace the valve controls the relationship of the off-gas flow rate between the primary and secondary dedusting system. This control circuit takes into account not only the position of the sliding sleeve at the off-gas collar but also the off-gas and cooling water temperatures.

Measuring technology. To monitor the most important operating parameters of the hot gas duct, resistance thermometers, pressure sensors and magnetic-inductive flow meters have been installed. The temperature and flow meters have been installed in the returns of the two strands and in the overall system return. The acquired measured values provide all the information needed to have a clear picture of the thermal conditions in the hot gas duct at all times. The flow rate control immediately detects any leakage, pump failure or overload condition in the system, thus enabling direct intervention. The amount of extracted heat can be calculated at any time, e.g. for an energy balance, based on the flow rate values, the temperature and the most important and informative operating parameters of the hot gas duct. The pressure sensors provide data among others relevant for downstream plant components, such as heat exchangers and cooling units. However, the pressure measurement alone is not capable of providing reliable leakage control.

Temperature level control. This control system is a temperature-controlled circuit within the main cooling circuit which can be switched in whenever required. This system can bring the total cooling water volume up to and maintain it at a uniform temperature level by means of an own pumping stage and automated control devices. This requires a closed system of conditioned water. The temperature control system was not part of the KSK scope of supplies.

Operating experience

Since the installation of the new equipment during the winter shutdown 1998/99 and after about half a year of operation, corrosion on the cooling pipes is substantially less than before. The service lives of the duct modules and maintenance intervals will most likely be longer in the future, which will translate into higher availability and better economy of the plant as well as a reduction of the costs for spare parts, storage and maintenance. The temperature level control system has proved successful in preventing the humid fume temperature from dropping below the dew point and condensing. The new design of the duct modules has proved very convenient during the initial installation and the first test replacement of an installed module by a stainless steel variant. If necessary, even other materials or cross-sections can be tested in the future. The gas and water pressure loss values have fully come up to the operator's expectations. Also none of the other plant components has been overloaded. The installed measuring technology has made the operating conditions of the duct and its peripherals highly transparent. The new round cross-section (formerly octagonal) and the installation of the two register devices have improved the heat exchange without increasing the heat exchange area. The spinning effect of the fume could not be prevented.

As the duct modules can now be very easily accessed and there are a great number of openings for maintenance purposes available, inside inspections can be carried out with no effort. The design principle of this new hot gas duct – enabling easy replacement of a module instead of lengthy and inconvenient repair work with the defective component installed – has gained widespread acceptance by Salzgitter AG.

Outlook

A primary dedusting system incorporating a water-cooled hot gas duct must – as long as possible – run problem and failure-free in order to meet the requirements of an efficiently and economically run operation. The system must be reliable, easy to maintain and involve minimum operating and spare part costs.

Therefore, the concept presented above is considered a milestone in the design and operation of hot gas duct systems.

Operators of modern electric arc furnaces have been installing gas burners and other devices to further shorten the tap-to-tap times of their furnaces. These burners produce rather humid fumes. As soon as the fumes condense, highly aggressive media arise.

These destroy components made of less costly boiler material in no time. However, it cannot be generally recommended that these components be made of expensive stainless steel, because the heat transfer of stainless steel is lower than that of conventional boiler materials by a factor of 4, i.e. a stainless steel component extracts much less energy from the fume than a component of the same size made of boiler material. This can naturally have considerable effects on the downstream systems.

To achieve a lean inventory management with low space requirements and little tied-up capital, a new hot gas duct system should generally be designed according to a concept based on the use of very few different types of components that can, above all, be very easily replaced. The presented design principle ensures high plant availability while at the same time considerably reducing maintenance costs. As these aspects will continue to have high priority for all performance-oriented plant operators, it would be a wise decision to use the presented design principle for plant modifications as well as the erection of completely new plants. ■