# Renewal of an EAF primary off-gas system

The primary off-gas suction system of the EAF at the French steelworks Saint-Saulve was completely renewed. The modern and innovative system now meets the requirements even of a future, higher-capacity furnace. Special focus was placed on ease of operation and maintenance to guarantee high plant availability. The installed temperature level control systems markedly reduce wear due to corrosion. Also wear due to abrasion will be significantly lower, as inside the combustion chamber highly efficient separation of the solid and mineral particles contained in the flue gas will be achieved.

The Saint-Saulve steelworks in northern France near Valenciennes supplies the French and German tube mills of V & M Tubes with cast rounds. There is one tube mill directly adjacent to the steelworks in Saint-Saulve. The other mills are located near the towns of Aulnoye-Aymeries and Déville-lès-Rouen and in Germany in Düsseldorf-Rath and Mülheim. In addition to special steels, which account for the major part of the product range, also carbon steels are produced at the steelworks. Rounds are cast in diameters ranging between 180 and 325 mm. On a forging plant also diameters of 140 mm can be produced. The steel is made in a 95 t AC EAF with a transformer rating of 85 MVA / 72 MW.

## Objectives of the modernization project

The primary off-gas system of the steelworks, which was established in 1975, was comprehensively modernized. In a first step, the filters and the fans of the primary suction system of the EAF were renewed. This resulted in the existing water-cooled off-gas cooling section becoming a bottleneck in the overall system, as it kept the dedusting effect at the EAF below the theoretically possible result. The capacity of the existing cooling section was insufficient for the enlarged suction volume of the system. Moreover, the existing system showed major corrosion and was heavily worn.

The main objective of the project was to improve the efficiency of the primary dedusting system of the EAF. Additionally, the redesigned system was to provide for the possibility of separating coarse-grained dust at a position as close as possible to the furnace and removing the separated dust during short repair shifts by means of heavy machinery. The new components were expected to have a much longer service life and be easy to assemble and maintain in order to minimize the time needed for a replacement.

Due to a previously scheduled shutdown during the summer holidays, a time window of only 21 days was available realizing the complete project.


**Figure 1. Off-gas bend connected to the EAF**



Dipl.-Ing. Olaf Huscher, Managing Director Manufacturing; Dipl.-Ing. (FH) Matthias Tönnis, Project Manager; **KSK Kuhlmann-System-Kühltechnik GmbH**, Haltern am See, Germany

Contact: www.k-s-k.de
E-mail: toennis@k-s-k.de

## Technical implementation

Prior to the concept design, the to-be-expected volume and temperature of the flue gas arising from the melting process in the EAF were calculated and taken as the basis for sizing the components of the cooling circuit. The system was designed based on process parameters electronically recorded during running production and taking into account future measures intended to increase the capacity of the furnace. The to-be-expected volumes and temperatures of the flue gas were determined by stoichiometric calculations.

Although high priority was given to ensuring optimal dedusting of the furnace during peak times, e.g. during charging with hot metal, also less intensive process phases were taken into due account with a view to optimizing the use of resources. Already at this point the system had to be laid out for the concrete requirements of a planned increase in furnace capacity. The technical data of the new primary off-gas system are compiled in **table 1**.

KSK determined the to-be-expected off-gas data based on maximal possible post-combustion in the combustion chamber. The necessary combustion air was to be fed to the process via an exactly adjustable gap between the elbow of the furnace roof and the downstream suction bend. The volume of the combustion chamber was determined based on the requirement that – even with a chamber volume enlarged to accommodate post-combustion – high separation rates were to be ensured.

Against the previous experience with the corrosive wear of the cooled components, the cooling system was designed as a closed circuit. The temperature level control system, which KSK had already used in many other installations, provides uniformly high cooling water temperatures which prevent condensation of vapour from the flue gas on the surface of the duct system, precluding the frequently observed corrosive effect.

The total scope of supply comprised the
- primary cooling circuit,
- furnace roof elbow,
- adjustable off-gas bend,
- combustion chamber,
- water-cooled hot gas duct and
- associated piping for the primary circuit.

| **Design data of the EAF (as determined by the user)** | |
|---|---|
| Hearth diameter | 5,900 mm |
| Tap weight | 95 t |
| Transformer rating | 85 MVA / 72 MW |
| Tap-to-tap time | 50 min |
| Number of buckets | 2 |
| **Determined plant data** | |
| Amount of heat during melting | 59.62 x 106 kcal/h |
| Off-gas flow rate at roof hole | 53,500 $m^3$/h (s.t.p.) |
| Combustion air flow rate | 96,500 $m^3$/h (s.t.p.) |
| Total off-gas flow rate | 150,000 $m^3$/h (s.t.p.) |
| Gas temperature at the end of the HGD | 600°C |
| **Dimensional layout of the off-gas system** | |
| 4th roof hole | dia. 2,000 mm |
| Furnace elbow | dia. 2,000 mm |
| Off-gas bend | oval 2,800 x 2,000 mm |
| Combustion chamber (h x w) | 5,250 mm x 3,200 mm |
| Hot gas duct (HGD), 5 segments | dia. 2,200 mm x 45 m |
| Hot gas duct pressure difference | 8 hPa |
| Cooling water primary circuit | 1,500 $m^3$/h |
| Cooling water temperature difference | 21.1 K |

Table 1. **Technical data of the new primary off-gas system**

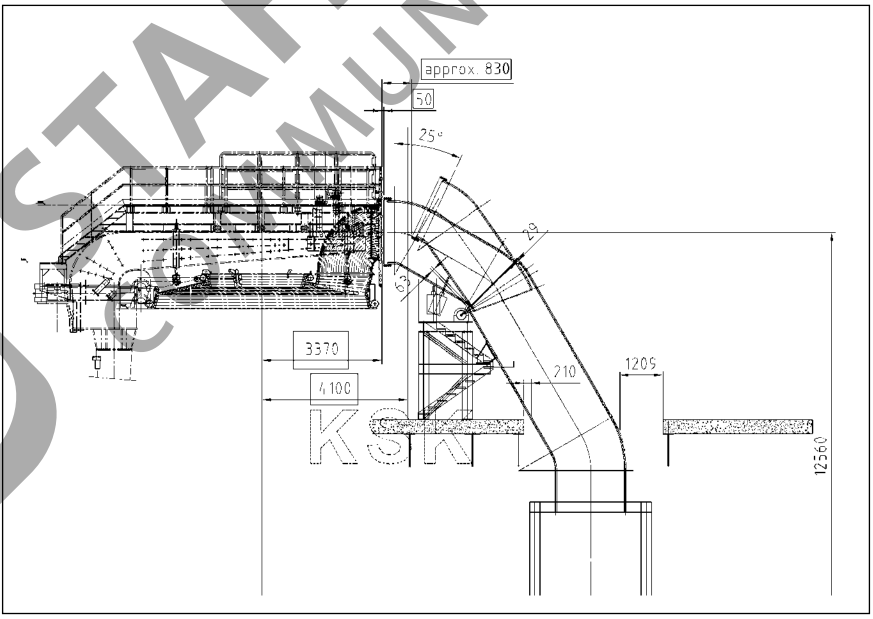


Figure 2. **Design of the first off-gas bend**

## Construction of the new off-gas system

The **off-gas bend downstream of the furnace roof elbow** (figure 1) was to be fitted with a quickly adjustable gap. Another requirement was that the gap could be opened far enough to enable virtually only ambient air from the furnace bay to be sucked into the water-cooled components in the event of unusual operating conditions. This was to avoid overheating and hence destruction of the components.

A shielded sliding sleeve, which would have been the typical solution at this position of the off-gas system,


Figure 3. Delivery of the combustion chamber

Figure 4. Lifting door at the face side of the combustion chamber

was unable to perform the opening and closing movements as quickly as required. This task was therefore solved by means of a bend consisting of two parts, a fixed segment with an enlarged internal cross section and a separate tiltable "head" (figure 2). The gap is adjusted by two water-hydraulically actuated cylinders. The gap can be adjusted through 25° or over a length of more than 800 mm within the required eight seconds. This thermally highly loaded component can be replaced as a complete unit within a few hours.

The controls of the water-hydraulic system have been designed to cope with the harsh steelworks environment. They ensure that the two hydraulic cylinders are synchronized as required. The position encoders are integrated into the cylinders. Cylinder movements are synchronized by synchronizing boards. The cylinders have been thus designed that if one cylinder fails, the other one is strong enough to lift the bend alone. A hydraulic accumulator is provided to ensure that even in the event of a failure of the power supply the off-gas bend can be completely moved up and down.

**Combustion chamber.** The necessary volume of the combustion chamber was determined based on the design calculations. A key factor was to have a flue-gas flow speed inside the combustion chamber that is below a specified value. The local conditions were limiting factors to the maximal height and width of the combustion chamber. The minimum width was defined by the fact that the combustion chamber had to be accessible from two sides by heavy cleaning machinery. The combustion chamber was designed with a total length of 18.2 m, a total width of 3.2 m and a total height of 5.2 m.

Overall a cooling surface of 270 m² was constructed into easily replaceable roof and wall panels mounted in a self-supporting, water-cooled structural steel framework. This solution provides the required ease of maintenance and allowed the equipment to be installed within the tight time frame. The upper structural steel frame was fitted with cooling panels. Then the complete upper part of the combustion chamber was transported to the meltshop for installation (figure 3). Only the eight supports, the lower row of cooling panels and the cooling water connections had to be mounted on site. At the face sides, the two doors had to be installed. The two lifting doors at the face sides of the combustion chamber allow heavy machinery to clean the combustion chamber in an extremely short time (figure 4).

The fact that most of the equipment was delivered in a pre-assembled state was decisive for being able to realize the project during the available time of the shutdown. This design principle also guarantees that individual, worn elements can be easily and quickly replaced. Additionally, the number of different panel sizes was minimized to reduce spare parts inventory.

The safety measures to protect the personnel in this area were developed and realized in close collaboration with the French customer and his operating personnel, in compliance with the applicable national regulations and guidelines.

**Hot gas duct.** 45 m was determined to be the necessary total length of the hot gas duct. Also with the objective of short replacement times in mind, the system was subdivided into five segments (figure 5). In the area of the hot gas duct the furnace off-gases are cooled by concurrent cooling, i.e. the fed cooling water moves in parallel with the hot gas flow. This frequently proven system is particularly suitable for warm-water cooling systems. The monitoring effort for reliably precluding partial overheating in individual areas is modest.

Individually adjustable cooling water rates for each circuit permit optimized use of the cooling water within the primary circuit. Each segment of the hot gas duct is fitted with a ring header at both ends which equalize by mixing any partial heating of the cooling water caused by hot spots. The inlets and outlets for the cooling water are realized by U-shaped headers and four short connected hoses. Whenever a segment of the hot gas duct must be replaced, only hoses need to be disconnected to be able to lift the segment out of the bearing shell. Also this solution is the result of a design concept in which ease of maintenance and time-saving assembly had very high priority.

## Pump container and cooling circuit

The growing share of surface-coated scrap in the charge produces an increasing amount of aggressive components during melting. Consequently also the flue gas contains higher shares of these aggressive substances. Also vapour arising from the burnt oxygen and from gas burners is contained in the flue gas. If the flue gas temperature falls below the dew point – for example, as a result of variable flue gas temperatures during the melting cycle – the vapour condenses on the colder pipe wall. The condensate contains aggressive components of the gas such as chlorine, sulfur and phosphorus dissolved in water. These acidic solutions are highly corrosive, leading to fast decomposition of the boiler materials. Dew point corrosion is additionally favoured by "cold-water cooling systems" as still commonly used in dedusting plants.

An effective remedy to the condensation of moist components in the flue gas is to raise the temperature level of the cooling water above the flue gas dew point. This calls for a closed, temperature-controlled cooling water circuit within which the complete water volume is adjusted to a specified temperature level of at least 60°C in the temperature-controlled flow pipe. The maximal temperature in the return pipe is preset at approx. 90°C. This temperature must not be exceeded. The heat from the flue gas is used to heat up the primary cooling water. Only when the desired flow temperature is exceeded, will the volumetric flow of the primary circuit be directed to the heat exchanger. Up to that point a loop-controlled valve diverts the volumetric flow into a pipe bypassing the heat exchanger.

The temperature and flow rate of the cooling water are the key operating parameters for controlling the cooling circuit. But also pressure sensors play an important role, especially for operation of the pumping plant, as they reveal the pressure conditions prevailing within the cooling circuit. For temperature control the measurements must provide actual-values. Resistance thermometers with temperature-linear output signals (PT-100 or PT-1000) and transducers installed in the connection head are frequently used for this application.

For trouble-free operation of water-cooled components at the EAF and in downstream systems, the flow rate is the most important parameter. Flow rate measurements are the basis for being able to monitor whether the flow rates are as defined. In the event

Figure 5. The hot gas duct is made up of five segments

Figure 6. Pump container without roof and side walls


Figure 7. **Delivery of the pump container**

of a leakage or trouble with a pump it is possible to take action at a very early stage to avoid disruptions in operation. Volumetric flows can be measured with a range of instruments working on different measuring principles. Among the most commonly used methods are magnetic-inductive measurements, probe measurements and ultra-sonic flow rate measurements. In the here described case, the magnetic-inductive method was used.

This method of flow rate measurement involves a magnetic field perpendicular to the flow direction. When the liquid flows through the magnetic field, an electric voltage is induced (law of induction). The voltage is proportional to the mean flow rate and hence also to the volumetric flow. The transducer is installed in the pipe by means of an immersion sleeve.

Monitoring of the flow rate, of the pressure at the inlets and outlets of the pumps and heat exchangers and of the cooling water temperature is not limited to various points within the pump house. In addition to this, field measurements of the temperature and flow rate are taken after each cooling segment. All measured values and all error messages from the internal control system of the pump house are transmitted to the furnace control desk via data exchange and visualized. Through this the operators are at all times kept up to date about the current state of the cooling circuit and they can at a very early stage identify and remedy any faults that may occur. This ensures a high degree of plant availability with the possibility of recognizing well in advance the need for maintenance measures or replacement of a component.

The pump system is laid out as a redundant system. There are three pumps and two heat exchangers. For the actual production process only two pumps and one heat exchanger must be in operation. The drive control of the pumps provides for the stand-by pump to be automatically activated as soon as one of the two pumps fails. Cleaning and maintenance of the plate-type heat exchangers can also take place during running operation.

**Installation and commissioning.** From the very beginning of the design phase it was obvious that all the installation activities for the complex equipment within a single building and all of the piping could not be completed on site during the short time window of only three weeks. Furthermore, the pump house had to be very compact due to space constraints. Accommodating all the necessary piping in a small building was an extremely challenging task. As the foundation work could not start before springtime, the option of assembling the individual pump house components on site had to be entirely discarded.

These problems were solved by completely preassembling and cold commissioning the entire container-type pump house, with all the pumps, heat exchangers, piping, electrical control and housing, in the KSK workshop at Haltern am See **(figure 6)**. Installation of the pump container was facilitated by the fact that the sandwich panels for the roof and walls were not fitted to the supporting steel frame until all installation work had been completed. Through this solution external lifting devices could be used throughout the entire installation phase.

In order to have enough time available for the piping activities, the pump container was transported to the construction site prior to the final assembly of the complete system and installed at its final position **(figure 7)**. After the container had been positioned on its foundations, the only connections left to be hooked up were those for the energy supply and cooling water pipes of the primary and secondary cooling circuits.

## Conclusions

For the renewal of the primary suction system at the EAF, a modern and innovative plant was designed, capable of meeting the requirements of a future, higher-capacity furnace. Special focus was placed on ease of operation and maintenance, which guarantees high plant availability.

The installed temperature level control system leads to markedly reduced wear due to corrosion. As a result the service life of the components is extreme long, also due to the decentralized control system, which has been specifically tailored to the special operating requirements of the water-cooled primary suction system. Also wear due to abrasion will be significantly lower, as inside the combustion chamber the separation rate of the solid and mineral particles in the flue gas will be very high. The sum of all these aspects provides the operator the benefit of high plant availability leading to a short ROI period. ■