First operational results of new designed Plate Cooler for Salzgitter Blast Furnace A

C. Dratner; F. Böert; KME Germany GmbH & Co. KG
Dr. J. Pethke; R. Rockstroh; S. Holz; Salzgitter Flachstahl GmbH

Contact Data

Christof Dratner; KME Germany GmbH & Co. KG; 49074 Osnabrück; Tel.: 0049 541 321 3357;
Fax.: 0049 541 321 83357; E-Mail: christof.dratner@KME.com

Summary

Plate Cooler are well known as a cooling element of choice in numerous Blast Furnaces worldwide. Almost all of these conventional Plate Coolers are produced by sand casting. Plate Coolers have the advantage, that they can be changed during the Blast Furnace campaign. Another advantage is, that if refractory lining wears, the Plate Cooler can act as a ledge to support the burden, which can reduce abrasive wear.
Potential negative factors of copper cooling plate installations in Blast Furnaces is their low abrasion resistance, this can be caused by falling burden or up streaming of dust loaded gas (sand-blasting effect), these two factors can contribute to a greater problem with water leakages.

KME and Salzgitter looked at this problem in detail and together re-designed a Plate Cooler which avoids the disadvantages of the conventional sandcasted Plate Cooler design as described above.
This new designed cooling element is manufactured from hot extruded sections, welded together to form an extremely strong fabricated Plate Cooler. The first set of these plates was installed in the Salzgitter Blast Furnace A in mid 2014. The Plate Coolers were equipped with extensive thermal measuring technology to monitor the operational behaviour. In addition several sandcasted plate coolers were also fitted with thermal measuring equipment to provide direct comparison data for the different types of Plate Coolers.

The paper compares the different designs and provides performance results on the Plate Coolers in operation.

Key Words

Blast Furnace, Blast Furnace Cooling, Copper Cooling Plate, Sand casted Copper Cooling Plate; Plate Cooler, Cooling Element, Heat Transfer, Pressure Loss

Fig. 0: KME Copper Plate Cooler

Introduction

Copper Plate Cooler are a well established cooling technology in the Blast Furnaces. They are usually produced by sand casting and first used in Blast Furnaces in the United States in 1892 [1].

This design of cooling is still extensively used in Blast Furnaces even though alternative more efficient designs are available such as copper stave cooling technology [2,3].

Both alternatives are installed in the three Blast Furnaces at the Salzgitter Flachstahl GmbH (SZFG) plant Germany.
The Blast Furnaces A and B have approximately the same size with a hearth diameter of 11.2 m, Blast Furnace C is a smaller production unit with a hearth diameter of 8.2 m.

Blast Furnace A is equipped with copper sandcasted Plate Cooler and copper cooling jackets (so-called mini-staves) in the belly and lower stack zone; whereas sandcasted Plate Cooler are installed without “cooling jackets” in the whole bosh area. In the upper stack, steel cooling plates are installed, too.

Blast Furnace B is equipped with copper staves in the bosh, belly, lower and semi middle stack; cast iron staves in the upper middle stack and steel cooling plates in the upper stack.

Blast Furnace C is equipped with copper sandcasted Plate Cooler like A but without copper cooling jackets.

Blast Furnace A has reported numerous cooling plate leaks since its first blow-in in 1977 especially in the belly and lower stack area. These leakages have lead Salzgitter to find ways to reduce the abrasive wear by use of overlay welding in the front third of the plate. Further issues have caused them to review the manufacture of such cooling plates and these extensive problems caused them join together with KME to find an alternative solution with a different production method that could produce a more wear resistant plate economically. This action resulted in the development of the extruded and drawn copper Plate Cooler design (Fig. 1). The main focus was to find a technical solution but it was also recognised that any soloution must be cost effective.

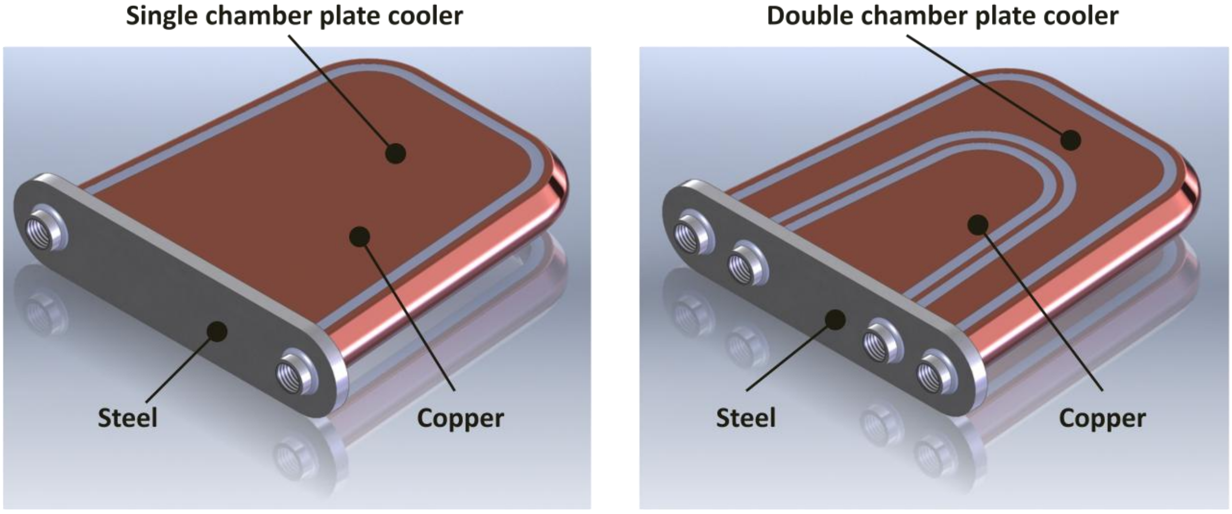


Fig. 1: New Generation of KME Copper Plate Cooler

Sandcasted versus KME new Plate Cooler design in theory

The conventional sandcasted Plate Cooler are made from as cast copper and have on the outside a steel ring which connects the Plate Cooler with the furnace shell by welding.

The newly developed Plate Cooler is made as a fabricated construction of an extruded and drawn copper profile, together with copper plates and a steel plate for ease of welding to the furnace shell.
Fig. 1 shows this Plate Cooler in both the single and a double chamber versions. The extruded and drawn hollow profile provides the water circulation.

As a result of numerous extrusion trials a profile was established with asymmetrical wall thickness (Fig. 2) with the advantage of an increased wall thickness in the normal high wear areas.

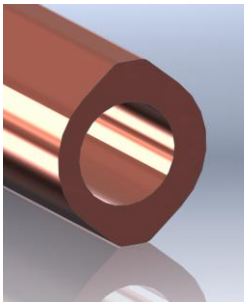


Fig. 2: Asymmetrical Copper Profile – reinforcement of wear out zones

The extrusion and drawing process produces a material with a fine grain size, this material has vastly improved mechanical and thermal properties compared to as cast copper products. It also has a major advantage in the reliability of the process to consistently produce a leak free tube without blow holes, this can be a problematic area in sandcasted Plate Coolers.
If required ultrasonic or X-ray techniques can be used for testing but this is normally not required because of the excellent reliability of the process.
The profiled tube is bent into the "U" shape of the plate cooler and then welded direct to the steel cover plate, it is worth noting that there is no welding seam in the water circuit. Only a solid tube without any welded seams is inside the furnace. The connection to the supply system is made by a screwed connection.

As mentioned the asymmetric tube profile is designed to have an increased wall thickness in the areas where potential high wear rate is most expected. The double chamber new Plate Cooler has copper plates on top and bottom to form a solid outer shape. To avoid any deformation of the plates due to the spaces, these spaces are filled with a self flowing castable product with a high thermal conductivity.

Fig. 3 shows a comparison of the cross-sections of the copper Plate Cooler with its double chamber design and the conventional sandcasted copper Plate Cooler with front-and back chamber design.

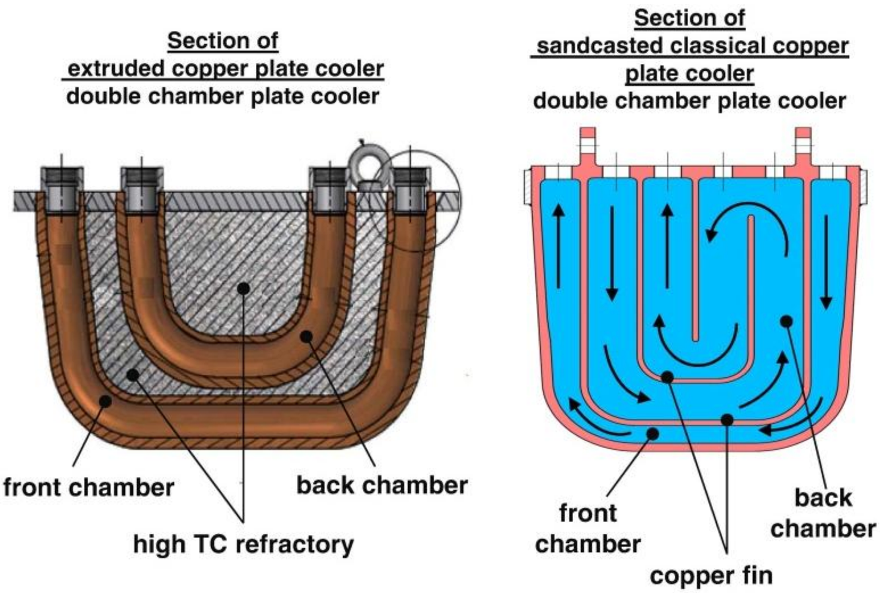


Fig. 3: Comparison of the two different copper Plate Cooler designs

The main characteristics of the new Plate Cooler compared to the sandcasted Plate Cooler are:

- Fine grain sized copper, no risk of blowholes
- Higher thermal conductivity compared to as casted material
- Use of asymmetrical copper profile to reinforce the wearout zones (Fig. 2)

- Significantly reduced water channel area reduces the water leakage risk and increases the new Plate Coolers life time in the different Blast Furnace zones
- High conductivity refractory to fill the gaps between the water circuits
- Welded copper bottom plate and top plate design to protect the refractory inside the Plate Cooler
- Simple water channel design avoids “dead water” or re-circulating water corners.
- Easy design change from sandcasted to new Plate Cooler

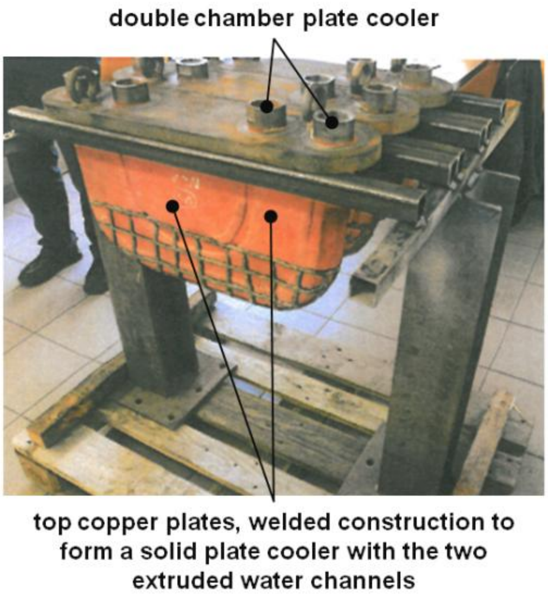


Fig. 4: New Copper Plate Cooler Design

Sand casted versus KME Plate Cooler design in practice

To compare the two designs under operational conditions two pairs of Plate Cooler were installed adjacent to each other in the lower stack of Salzgitter Blast Furnace A in row 22. The first pair was installed in June 2014 and the second pair in November 2014. Fig. 5 shows the KME copper Plate Cooler after the installation and welding onto the Blast Furnace A shell in the lower stack.

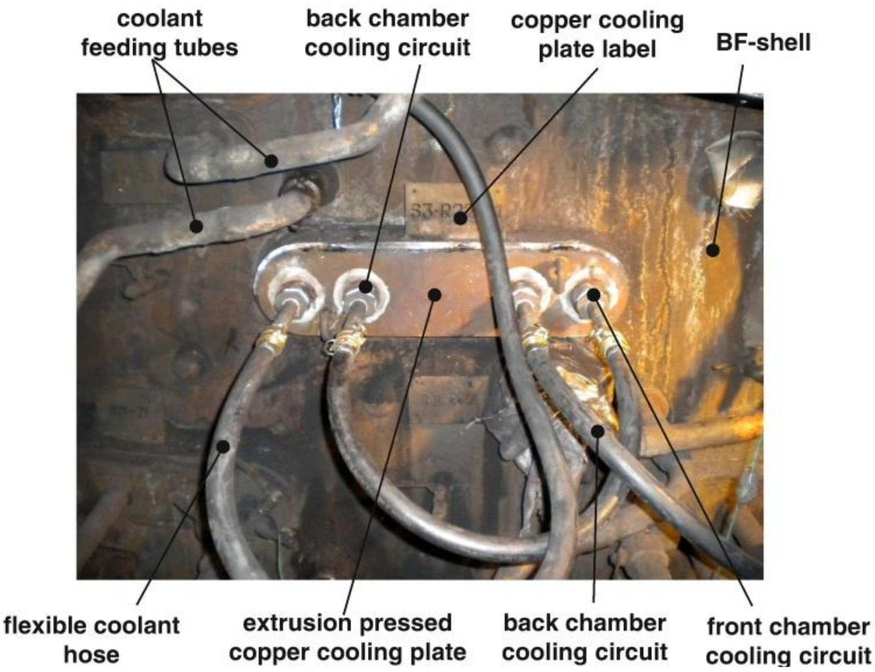


Fig. :5 New-Copper Plate Cooler installation in the Cooling Row 22 of Blast Furnace A Lower Stack

Experimental equipment at the Blast Furnace

The aim of the tests was to collect the actual operational parameters as seen by the Plate Coolers, these parameters included extensive thermal monitoring of heat supply, cooling water temperature, temperature oscillation, abrasion and other attack mechanisms. This real life data can then be used to compare performance, and allow the development “FEM design model for Plate Coolers”. Using detailed calculations we were then able to develop the most efficient and cost-effective design which met all the operational parameters as required.

By using plant data we can be very confident to be able to repeat these conditions in the model to produce the most efficient solution.

Fig. 6 shows the measurement arrangement at site in the Blast Furnace A lower stack cooling circuit.

Fig. 7 shows the necessary measuring equipment for test trials, measurements and research work.

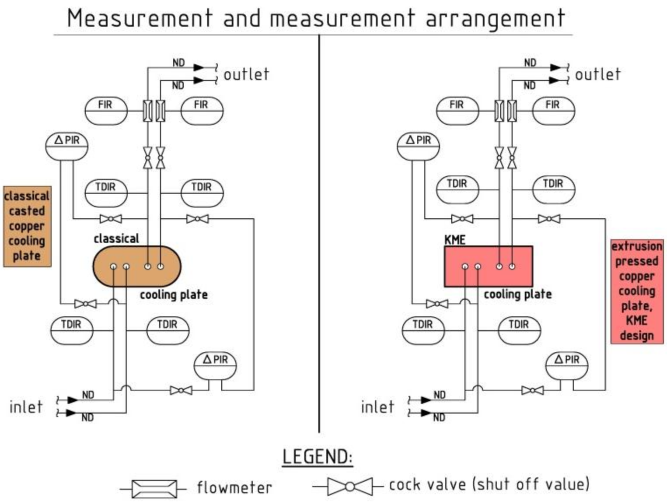


Fig. 6: Scheme of Copper Plate Cooler experimental equipment at site

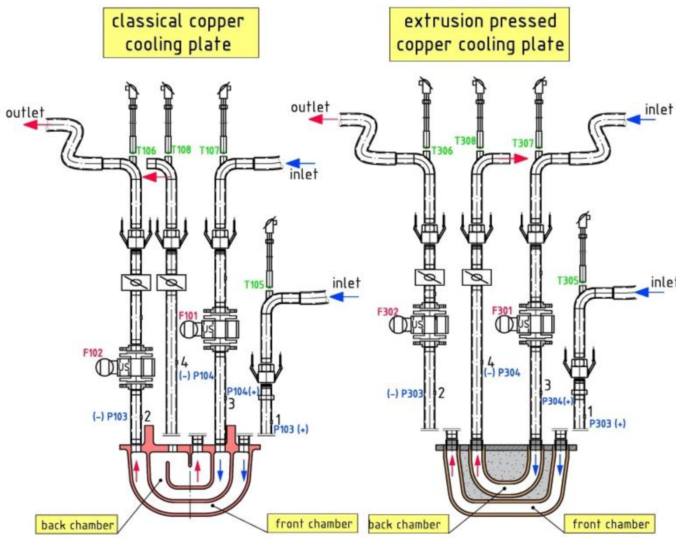
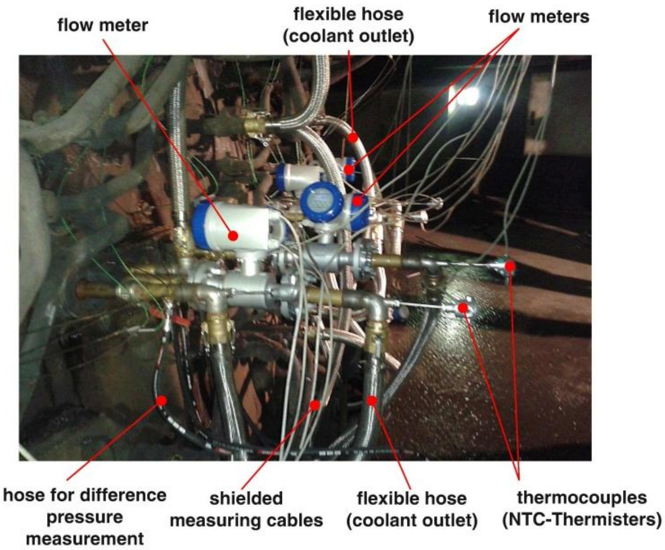


Fig. 7: Comparison measurement arrangement at site

In total about 70 different measuring signals were simultaneously recorded in a universal data logger system for the necessary evaluation. To avoid problems with dust, steam and other air impurities, the data logger system was installed in a safety protected environment box.

Fig. 8 shows the instrumentation equipment on site



The measuring equipment was installed in early November 2014, and after checking and testing of all measuring functions the first records were available as from mid of Nov. 2014.

Operational results– Heat Transfer

Fig. 9 shows the recording of the heat transfer data for the sandcasted copper Plate Cooler in comparison to the new KME copper Plate Cooler.

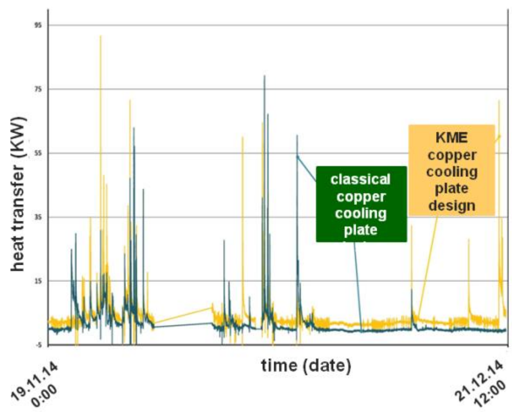


Fig. 9: Heat Transfer Comparison of two Different Copper Plate Cooler Designs

Fig. 10 and 11 shows the evaluation of the recorded total heat transfer measurement data of the sandcasted copper Plate Cooler and the new extruded copper Plate Cooler accordingly.

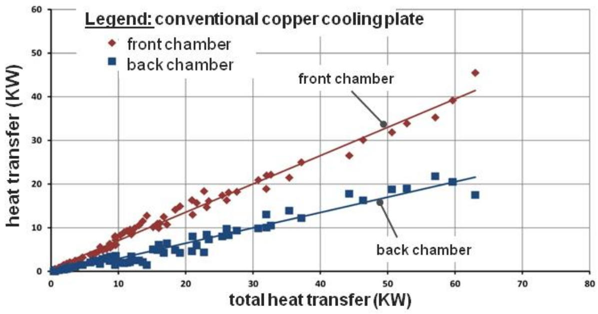


Fig. 10: Total heat transfer measurement of the sandcasted copper Plate Cooler

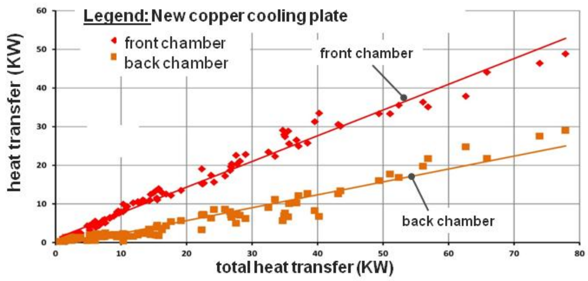


Fig. 11: Total heat transfer measurement of the new copper Plate Cooler

Evaluating the recording the following results can be found:

- The max. total heat transfer capacity of the sandcasted copper Plate Cooler was 65 kW.
- The max. total heat transfer capacity of the new designed copper Plate Cooler was 78 kW. This shows an approximate 20% increase in heat capacity compared to the sandcasted copper Plate Cooler
- The heat transfer of the front chamber of the sandcasted copper Plate Cooler is slightly lower compared to the new design.
- The heat transfer of the back chamber of the sandcasted copper Plate Cooler is slightly higher compared to the new design.
- Both designs have approximately the same thermal efficiency up to the heat transfer rate of 65 kW.

Operational results – Pressure Loss

Another test rig was necessary to evaluate the pressure drop across the Plate Cooler as this is a very important parameter, These tests were carried out on the front chambers and back chambers to provide a clear understanding.

Fig. 12 shows the pressure loss curves; measured on three sandcasted double chamber Plate Cooler and three new double chamber copper Plate Cooler.

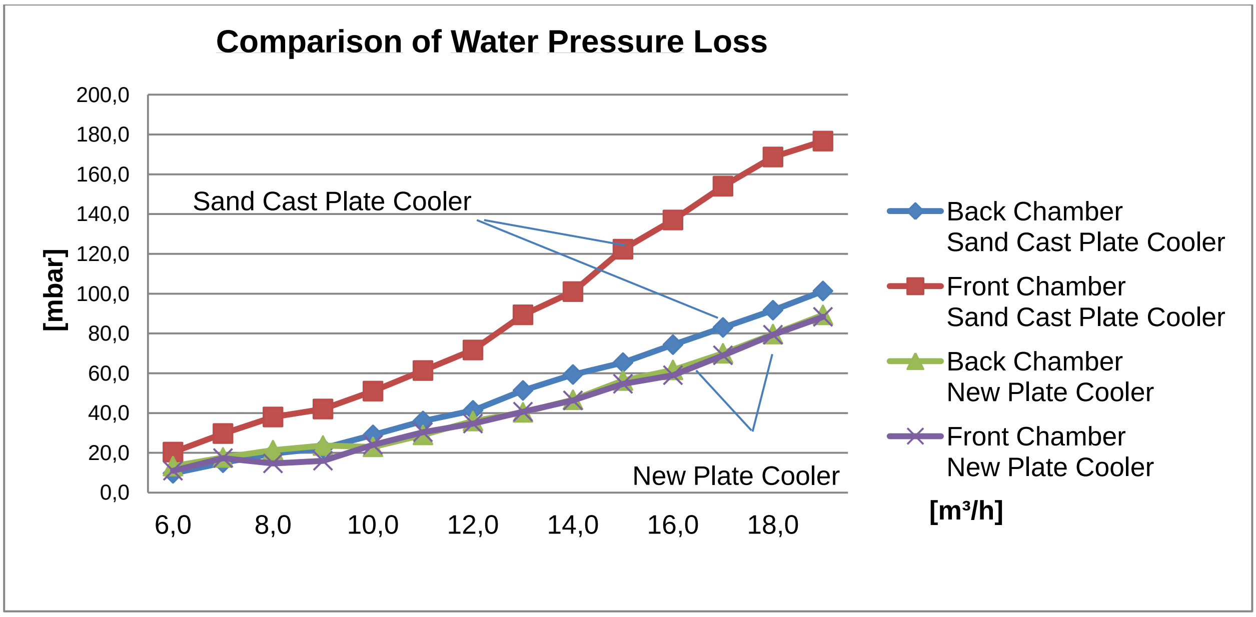


Fig.12 Comparison of water flow and pressure loss for the sandcasted and new Copper Plate Cooler

The diagram in Fig. 12 shows the following:

- comparable pressure loss for the front and back chamber of the new design and for the front chamber of the sandcasted design
- high pressure loss for the sandcasted copper Plate Cooler back chamber

In summary it was evaluated, that the total pressure loss (front chamber and back chamber together) of the sandcasted copper Plate Cooler is for the minimum water flow of 6m^3/h = 32 mbar and for the maximum water flow of 19 m^3/h = 270 mbar.

The comparable pressure loss of the new Plate Cooler design is for: 6m^3/h = 20 mbar and for the maximum water flow of 19m^3/h =190 mbar.

From above you can clearly see that advantage in terms of pressure drop the new design Plate Cooler have over the old sandcasted Plate Cooler, an average decrease of approx. 30%.

- For the minimum water flow of 6 m^3/h the conventional copper cooling plate pressure loss is 37,5% higher compared to the new design
- For the maximum water flow of 19 m^3/h the conventional copper cooling plate pressure loss is around 30 % higher compared to the new copper cooling plate

Conclusion

The new designed Plate Cooler combines the advantages of a sand casted Plate Cooler which can be changed during a blast furnace campaign with the following advantages:

- Increased resistance against water leakages (wear) by use of a extruded and drawn copper material with a fine grain structure
- Easy designed front- and back chamber water cooling system for the double chamber cooling plate
- Run of cooling water which strictly avoids re-circulations in the cooling plate
- FEM-calculations show that the thermal efficiency of the extruded new copper cooling plate is in spite of its reduced cooling water close to that one of the conventional cooling plate. The much higher extruded copper cooling plate thermal conductivity can compensate the reduced cooling water area

- It is investigated on existing Plate Coolers whether the Blast Furnace relevant main parameters of the new copper Plate Cooler are better compared to the ones of the sandcasted Plate Cooler with the first following results:

  - In general, the newly developed copper Plate Cooler shows slightly higher heat transfers rates compared to the conventional ones in the first temperature readings.
  - The measured maximum heat transfer of the tested double chamber cooling plate acc. KME-design is 20 % higher compared to the conventional copper cooling plate.
  - The measured maximum pressure loss of the new copper cooling plate is ca. 30 % less compared to the conventional copper cooling plate. Especially through avoidance of re-circulating water flow realized with an optimized cooling water channel design.

- The first extruded copper Plate Cooler were installed in June 2014 in the lower stack area of Blast Furnace A in Salzgitter. Up to now they perform very well.
- The new Plate Cooler can be offered for reasonable prices.

References:

[1] Pawlow, M. A.: Metallurgie des Roheisens Bd. III (1953); P. 180 ff.
[2] Heinrich P.; Hille H., Richert K.: Hochofenpanzerkühlung – Bauliche Ausführung und Kosten von Kühlsystemen; Stahl und Eisen 106 (1986) P. 206-210
[3] Mousel N.; Carmichael I.: Efficient Blast Furnace Cooling for a long Campaign; AISTech Conference Proceedings (2007)