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IMPROVEMENT OF THE PERFORMANCE OF THE BOSH COOLING SYSTEM OF ROGESA NO. 5 BLAST FURNACE*

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Abstract

Rogesa is operating two medium sized Blast Furnaces, No. 4 and No. 5 at Dillinger integrated steel works plant. The history of the results of the cooling concepts of the intersection between tuyère belt and bosh shows failures at both furnaces. At the 3rd reline of No. 5 Blast Furnace in 2010 changes were made to improve the cooling efficiency of the mentioned area. Two rows of copper cooling plates were installed. After commissioning and a short operating time hot spots occurred in the area of the cooling plates. The decision was taken to develop a new cooling concept together with Paul Wurth Umwelttechnik GmbH, Essen-Germany by replacing the cooling plates by one row of a short copper stave. The duration of the shutdown to perform the work was only 17 days including salamander casting. The operational results after the commissioning are very satisfying with outstanding performance of the new bosh cooling system.

Keywords: Intermediate repair; Cooling bosh area; Rogesa; PW Umwelttechnik.

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1. INTRODUCTION

The company of ROGESA (Roheisengesellschaft Saar) is a joint venture for ironmaking of AG der Dillinger Hüttenwerke and Saarstahl AG. It is located in the south west region of Germany at the site of Dillingen. ROGESA is operating two Blast Furnaces with an actual capacity of 4.7 Mt of hot metal per year. Blast Furnace No. 3 is at stand-by and is actually not in operation.
The following table shows the characteristic items of the three Blast Furnaces owned by ROGESA.

Table 1. Characteristic Data of ROGESA Blast Furnaces

	BF No. 3	BF No. 4	BF No. 5
Year of construction	1971	1974	1985
Restart after Relining	2003	2003	2010
Reason of Revamping	Reline	Enlargement	Reline
Nominal Production	1800	6200	7200
Number of tapholes	1	2	2
Working Volume	1270	2358	2934
Hearth Diameter	8.5	11.2	12.0
Number of Tuyeres	20	30	32

Blast furnace No. 4 was restarted after enlargement in 2003 [1]. The BF No. 5 was relined from July to October 2010 after it's second campaign which had to be interrupted by an interim repair in December 2005 and January 2006.

2. RESULTS OF THE SECOND CAMPAIGN

The following table shows the results of the two parts of the second campaign which had to be interrupted by the interim repair in 2005. The following work was carried out:

- Replacement of the hearth wall carbon blocks.
- Replacement of the cast iron staves in the bosh by copper staves.
- Replacement of 10 cast iron tuyere staves.

This interim repair in 2005 had to be performed in an emergency situation because of the accelerated progressive wear of the hearth walls and the cast iron staves in the bosh leading to hotspots after 8 years of operation. Also after the interim repair the wear of the tuyere staves continued and in consequence the reline had to be done in 2010. The main cause for the wear was the use of low quality coke [2].

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Table 2. Operational Data of the 1st period, 2nd period and total campaign

		1st period	2nd period	Total Campaign
Start		Aug.29th 1997	Jan.30th 2006	Aug.29th 1997
End		Dec.12th 2005	Jul 12th 2010	Jul 12th 2010
Time Intervals		Before interim repair	After interim repair	total
Time duration	years	8.3	4.5	12.8
HM Production	Mt	18.9	10.2	29.1
total Productivity	t/m³WV	7318	3570	10888
Production	t/d	6577	6335	6493
Productivity area	t/m² 24h	58.2	58.0	58.1
Productivity vol.	T/m³ 24h	2.55	2.45	2.50
Burden Sinter	kg/t HM	1177	1079	1143
Pellets	kg/t HM	199	307	236
Lump Ore	kg/t HM	207	198	204
Coke Rate	kg/t HM	323	306	317
Small Coke Rate	kg/t HM	24	27	25
PCI Rate	kg/t HM	128	143	133
Reductants total	kg/t HM	475	476	475

The results of the entire 2nd campaign are satisfactory because after the interim repair the campaign could be extended to almost 13 years.
With the experiences of the second campaign a new construction of the hearth including tuyère and bosh area was chosen.

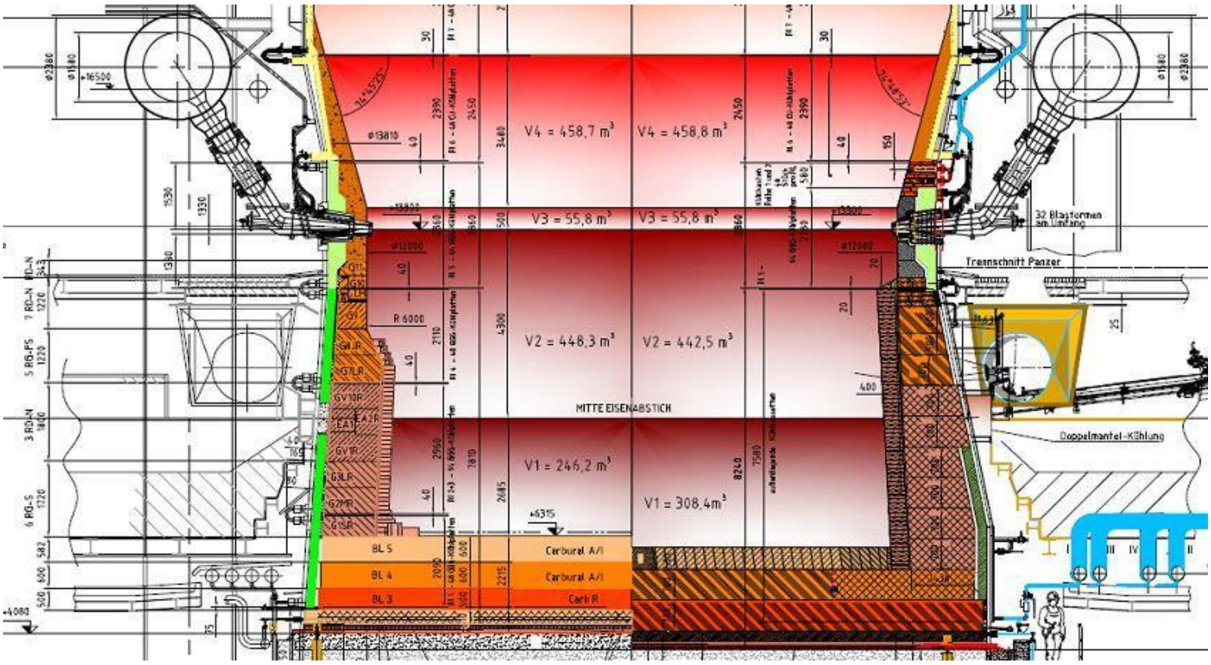

Fig. 1. Old and new design of the hearth

Fig. 1 shows the comparison of the old (left) and new design (right).

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3. SHELL COOLING SYSTEM

In the future plannings for the ROGESA blast furnaces a high performance operation with also high levels of PCI is scheduled. These conditions require consequently a cooling system which is capable to resist these higher heat loads.
In order to improve the cooling capacity at that location and also of the entire shell, the following improvements were implemented:

- The cast iron staves in the hearth were removed and replaced by an outside channel cooling,
- The hearth angle was more flat in order to increase the refractory thickness,
- The sump depht was increased
- At the the upper part of the cast iron tuyere stave was replaced by two rows of copper cooling boxes between tuyere level and bosh ,(Fig. 3)
- the copper staves of the belly and the two rows of the lower shaft were removed, overhauled and reassembled because of their good condition,
- one more row of copper staves was mounted at the mid shaft,
- four rows of cast iron stave from mid to upper shaft were renewed,
- two more rows of cast iron staves were mounted in the upper shaft up to the throat armour

The „weak point“ of the cooling system of the furnace was above the tuyere level where also a breakout occured in March 2010 which caused a three day stop of the furnace for repair. Fig. 2 shows the tuyère staves after the dismanteling after the 2nd campaign.

Fig. 2 Worn out tuyère staves after dismanteling

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The new concept for hearth cooling and lower bosh was chosen in order to improve the efficiency of the cooling and also to give a maintenance friendly construction in the case of the failure of the cooling boxes. (Fig. 3)

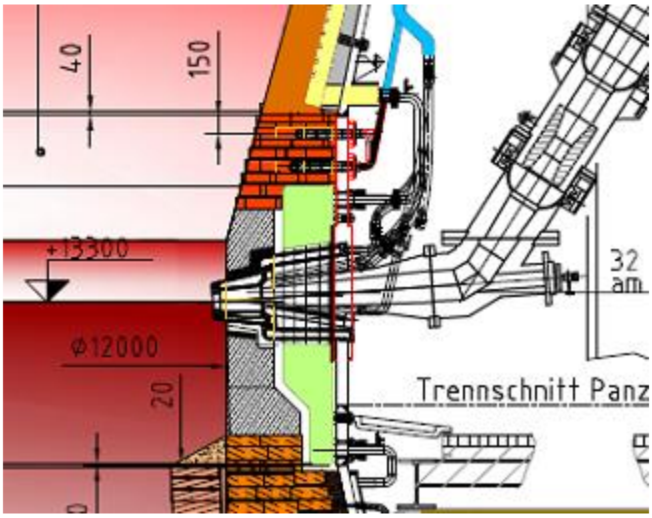

Fig. 3. Cooling system at tuyere level and bosh.

Fig. 4 Tuyère staves, cooling boxes and bosh staves during before refractory installation

Fig. 4 shows the area of the cooling boxes before the installation of the refractory brickwork.
The installation of the refractory brickwork was made with bricks and ramming mix at he joints between the bricks, the cooling boxes and the shell. The refractory quality was high alumina nitride bonded material identical to the ceramic cup. (Coranit) (Figure 5).

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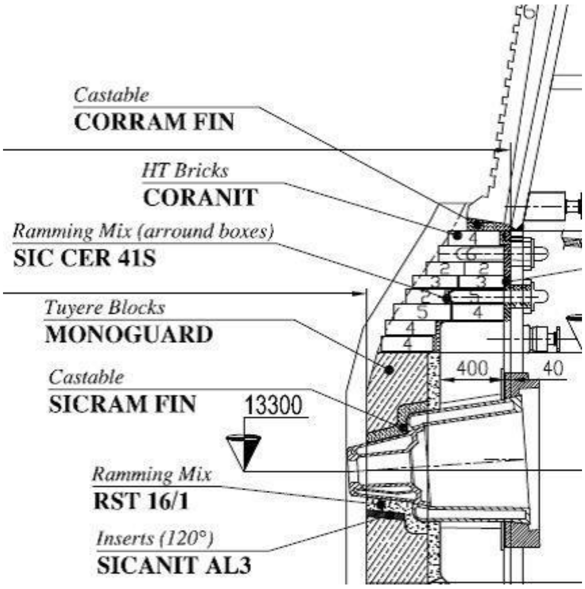

Fig. 5 Brickwork of the area of the cooling boxes

After 102 days of downtime the furnace was put on blast on 21st of October 2010. The blow-in operation proceeded without major problems and the blast volume could be raised progressively (Fig. 10). The consumption of reductants could be decreased stepwise to the scheduled value of 485 kg/t HM. Fig.11 shows the consumption of the reductants. Already after 6 days the coal injection could be taken in operation and after 15 days a rate of 160 kg/t HM was reached.

4. FAILURE OF THE BOSH COOLING SYSTEM

During the months after commissioning the PCI-rate was on a medium level of 150 kg/t HM and the productivity of the furnace was also on a moderate level between 6000 and 6500 t HM/d. In spite of these moderate conditions hot spots occurred at the shell between the cooling boxes caused by gas flowing between the brickwork and the shell. The first hot spots occurred in the area of the assembly opening of the shell, afterwards around the whole furmace. Fig. 6 shows the locations of the hot spots.

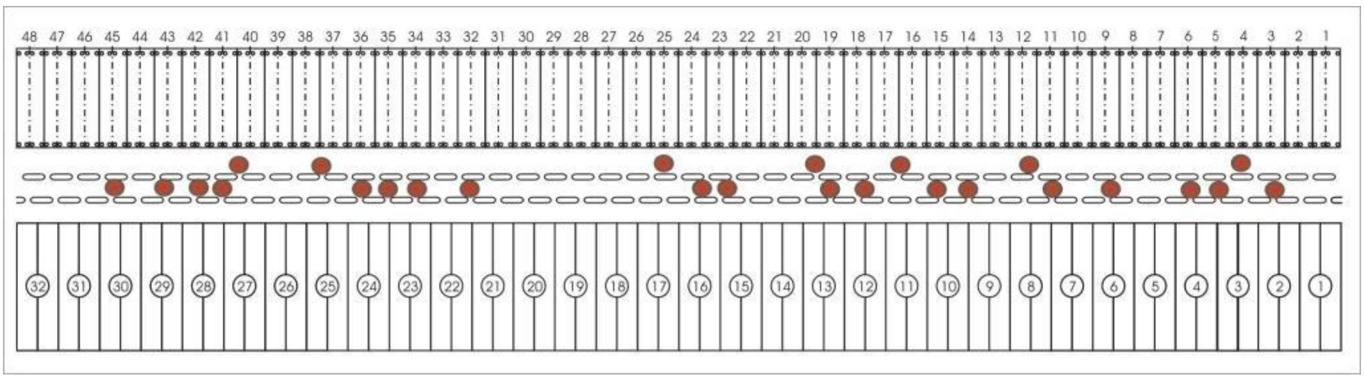

Fig. 6 Locations of the hot spots after commissioning

The intensities of the hot spots increased over the time, consequently a package of measures had to be taken in order to avoid a breakthrough of the shell like it

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happened in 2010. In the case of the appearance of hot spots the following contermeasures were taken:

- Switch off of the coal injection in the affected area
- Forced cooling by compressed air or waterspray
- Reducing of the productivity

At the same time the shell of the furnace in the affected area was intensively monitored by the following arrangements:

- Installation of Infrared cameras on the tuyère platform (Fig. 7)
- Injections of refractory castable at stoppages.
- Installation of longitudinal thermocouples on the shell
- Measurement of the temperature of the cooling water of the cooling boxes.

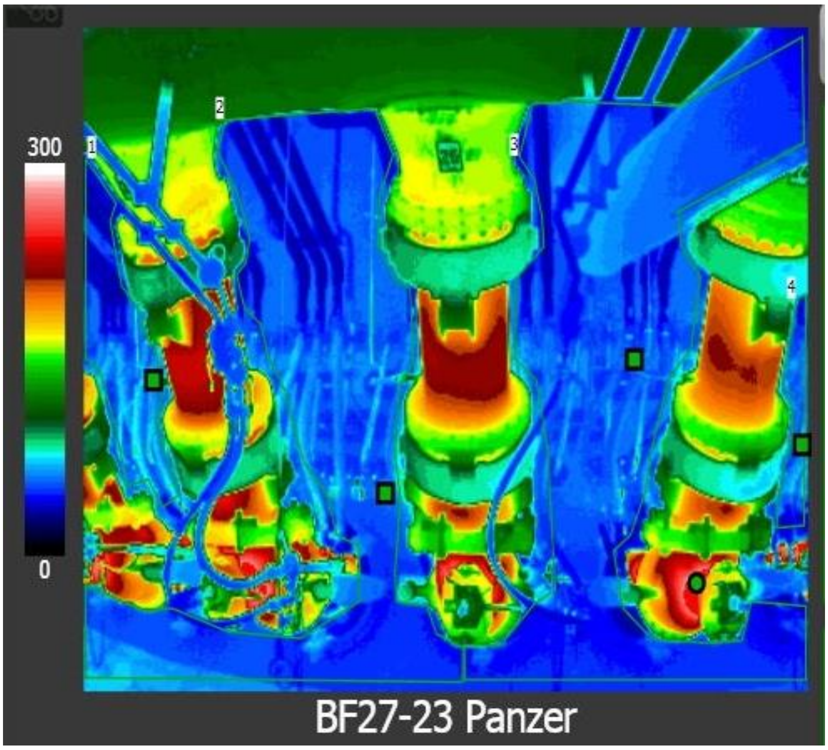

Fig. 7 monitoring by IR camera

During the year 2012 the PCI-rate was increased from 160 to 180 kg/ t HM, which resulted in a higher heat load in the bosh area with consequently more frequent occurences of hot spots. The observations during stops of the furnace showed that the complete refractory brickwork had dissappeared. Because of this reason it was decided to make an intermediate repair and to replace the cooling boxes by staves.
The advantages of a repair with a staves-solution are the following:

- Two dimensional cooling of the inner shell
- No brickwork necessary
- Integration of the staves into the existing shell cooling circuit

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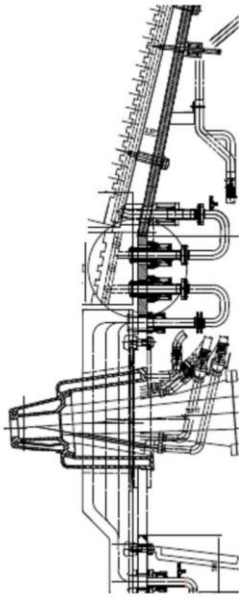

Fig. 8 New construction of the bosh cooling by staves

Fig. 8 shows the new construction: the two rows of cooling boxes were replaced by one row of 48 short copper staves. The cutouts in the shell for the cooling boxes could be reused for the attachment of the staves, so that no new borings or cutouts had to be made. The water supply for the new staves was integrated in the existing shell cooling, whereas the cooling boxes had their own water supply which could be put out of service. The construction of the new stave is compact with one waterchannel inside like a serpentine the water supply inlet and outlet and a bolt as assembling aid.

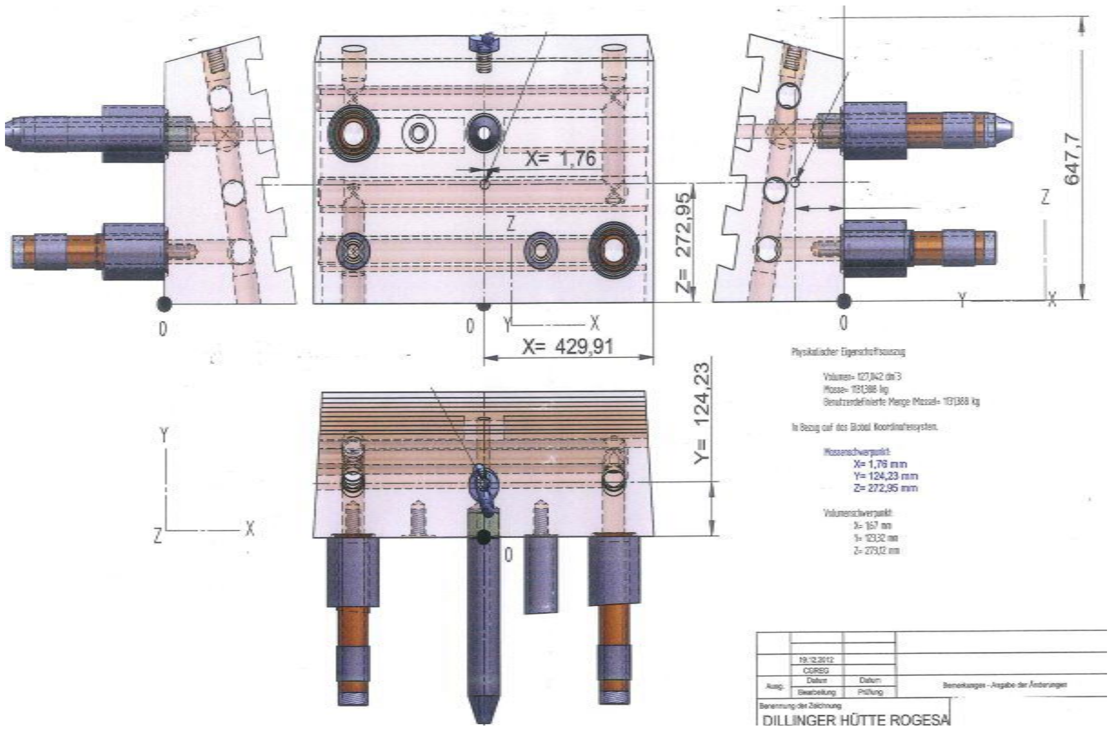

Fig. 9 Drawing of the new bosh stave

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5 REALISATION OF THE PROJECT

The project started on march 25th 2013 with the blowing down of the burden and stop of the furnace. The blowing in was on april 12th after 19 days. The following table shows the workflow of the project.

Table 3: workflow of the project

	day No.	**Procedure**
Step 1	0+1	blow down and salamander tapping
Step 2	1 to 6	dismanteling tuyéres and piping cooling boxes
Step 3	4 to 7	raking-out of the burden, mobile platform in shaft
Step 4	5 to 8	dismanteling piping, cleaning shaft, covering burden with concrete
Step 5	6 to 9	dismanteling cooling boxes, cleaning inner shell
Step 6	9 to 15	mounting of staves, welding compensators
Step 7	11 to 12	shotcreting staves, backfilling with castable
Step 8	12 to 13	breaking concrete cover, digging to tapholes
Step 9	14 to 18	installation pipework staves, dismanteling mobile platform
Step 10	15 to 19	installation tuyères and coolers, blowpipes
Step 11	19	Filling blast furnace, blowing in

One week before blowing down a special burdening pattern was set, in order to clean the shaft. Therefore the shaft was free of accretions, so that almost no cleaning had to be made. Tanks of the concrete cover the work inside the furnace could be done without breathing protection measures. The table shows that the project was realized in the scheduled time and also without major incidents. Fig. 10 shows the installation of the first copper stave with a mounting suspension.

Fig. 10 Installation of the new copper staves between tuyère stave and bosh

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6 OPERATION RESULTS AFTER THE PROJECT

After eight days the furnace reached its planned productivity and also the coal injection was at more than 180 kg/t HM after 12 days.
Each 6th of the new built in 48 copper staves is equipped with a multiple temperature measurement of four thermocouples with different depths of 100 mm distance. By this lay-out the temperature gradient inside the stave in radial direction can be monitored. The readings of the temperature measurements show that there can temporarily occur temperatures up to 190 °C resp. a heat load of 150 kW/m². It is also interesting to notice, that the heat load is the higher the better the furnace is working. Fig. 11 shows the temperature of the inner thermocouple the may 14th to 22th

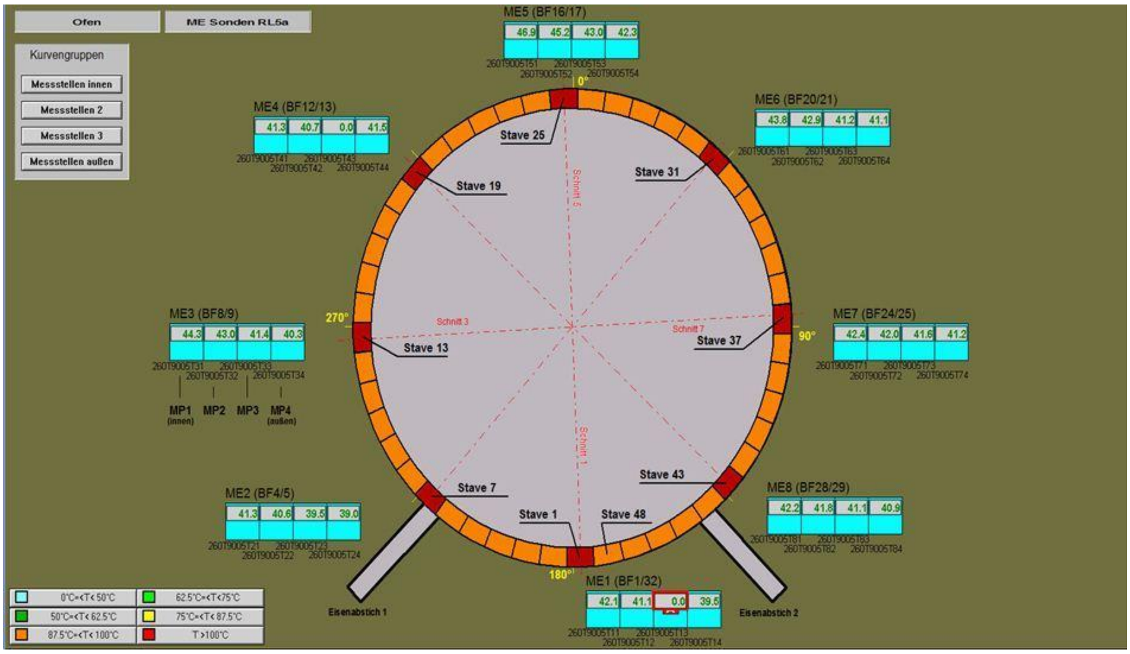

Fig. 11a. Multiple Thermocouples in the new bosh staves.

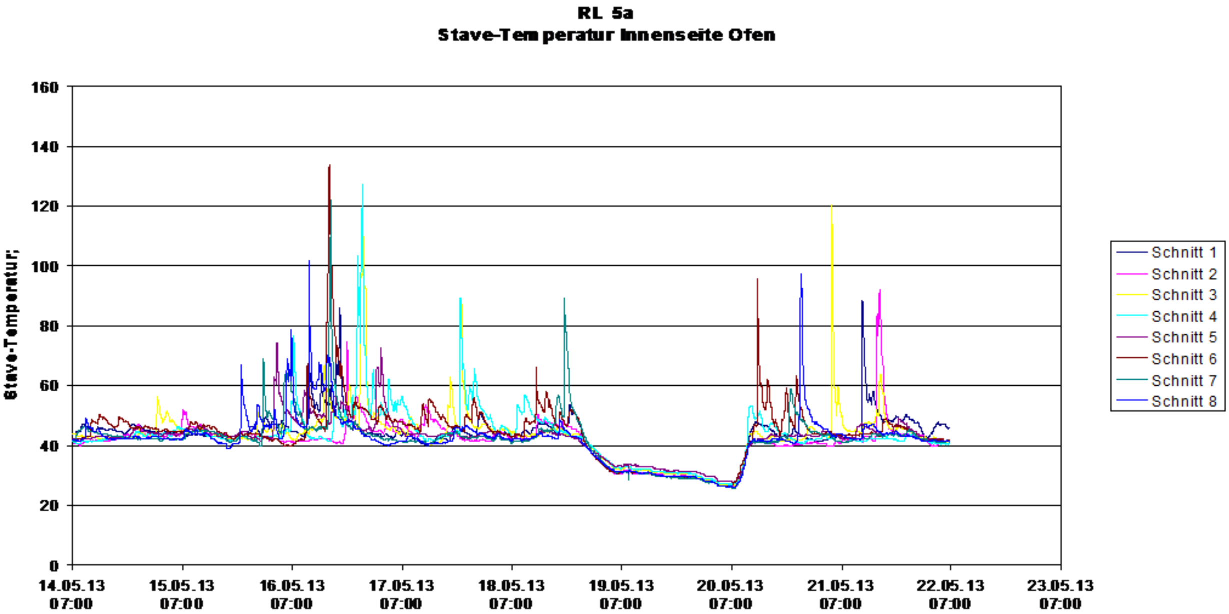

Fig. 11b Temperatures of the new bosh staves

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ISSN 2176-3135

7 CONCLUSIONS

After the second campaign Blast Furnace No. 5 of ROGESA at the site of Dillinger Hüttenwerke was thoroughly relined during a downtime of 102 days in 2010. Shortly after the reline hot spots occurred at the area of the new cooling boxes between tuyère staves and bosh stave. In order to avoid a possilble burn-out, the replacement of the cooling boxes by small copper staves was decided. The realisation was done in 2013. The project was performed during a stop of 19 days.
The results until today show that the project was successful. There were no more reductions of the performance of the Blast Furnace No. 5 due to cooling system insufficiencies necessary.
Blast Furnace No. 5 has now an excellent equipment and monitoring installations for a long and successful third campaign .

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