COMPARISON OF DIFFERENT BF-HEARTH LINING DESIGN TECHNOLOGIES[1]

Jean-Philippe Houde[2]
Rudolf Hebel[3]
Volker Dulz[4]

Abstract

One of the BF-owner's important requirements is the BF-hearth lining life time extension up to 20 years or more, without any intermediate repairs. A number of different hearth lining designs were developed in the last decades. Some well experienced and successful hearth lining technologies were presented. The main targets of this paper are explanations of excellent hearth lining life times as well as good operation experiences. Further on, the paper shows that the goal to reach the main targets is depending on a number of different boundary conditions. The most important boundary conditions to extend the hearth lining life campaign will be illuminated and explained with the assistance of different lining design examples.

Key words: BF-hearth lining life time extension; Hearth lining wear reduction; Hearth characteristic indexes; Hearth lining design comparison.

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[2] *Chemical Engineer, Head of Blast Furnace Department, Paul Wurth Refractory & Engineering GmbH, Mainz-Kastel, Germany.*

[3] *Dipl. Engineer, Consultant, Paul Wurth Refractory & Engineering GmbH, Mainz-Kastel, Germany.*

[4] *Civil Engineer, Deputy Head of Blast Furnace Department, Paul Wurth Refractory & Engineering GmbH, Mainz-Kastel, Germany.*

1 INTRODUCTION

The evolution of technologies in the last decades has leaded the BF owner to expect long campaign life time as shown on Figure 1.

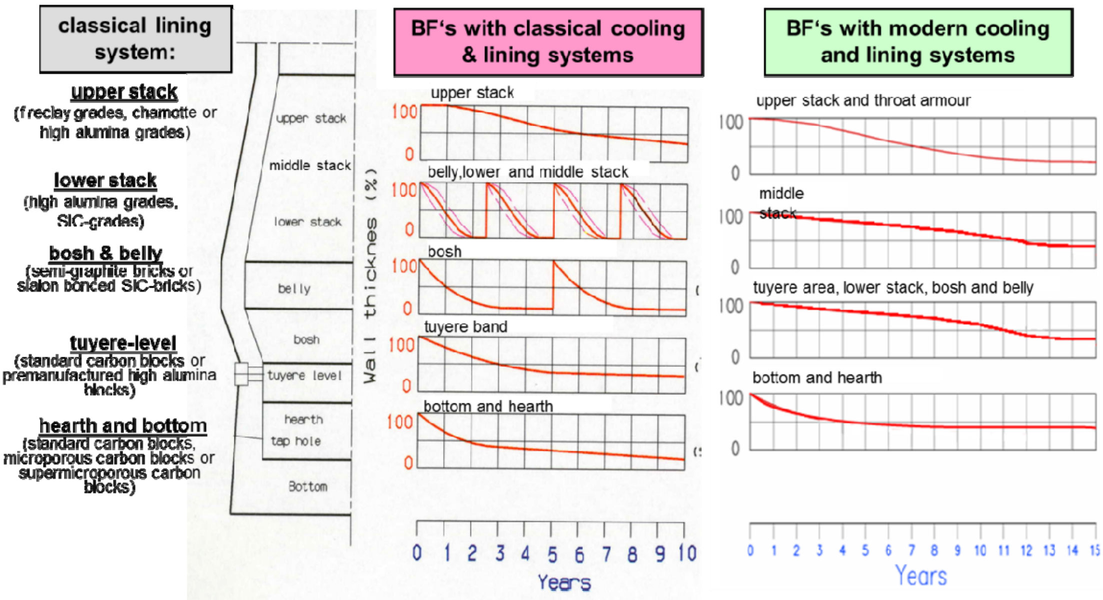

Figure 1. Blast Furnace repair cycle.

Concerning the BF-hearth life time campaign, the requirement is now of 15-20 years and even more. The achievement of this requirement depends on different parameters: raw material qualities (burden, coke, fuel), BF-operating conditions (like output rates), BF-production stoppages (because of maintenance or market demands), BF-hearth profiles (like designing features), BF-hearth lining (material selection).
Paul Wurth Refractory & Engineering (PWRE), as an engineering company, has an influence on the important two last parameters, which will be highlighted in this paper.

2 DESIGN FEATURE: HEARTH CHARACTERISTIC INDICES

Through its extended world-wide references in BF engineering and well experienced lining technology, PWRE was able to follow numerous blast furnace lining life campaigns. Along the years and through special hearth monitoring as well as hearth post-mortem evaluation, important design parameters could be highlighted, the so-called hearth characteristic indices.
The main hearth characteristic indices are the following:

- the pool depth ratio: H/R;
- the real pool depth ratio: H_{real}/R;
- the taphole length ratio: L/R;
- the upper hearth height ratio: A/R.
- Where:
- R = inner hearth lining radius;
- H = distance between the bottom lining and taphole axis;
- H_{real} = real distance between the initial bottom lining wear and the taphole axis;
- L = taphole length;

- A = distance between the taphole axis and the tuyere axis.
- Respecting the main hearth characteristic indexes, under normal BF operation, enables lower hearth lining wear rates, independently from the hearth lining quality as shown on the Figure 2.

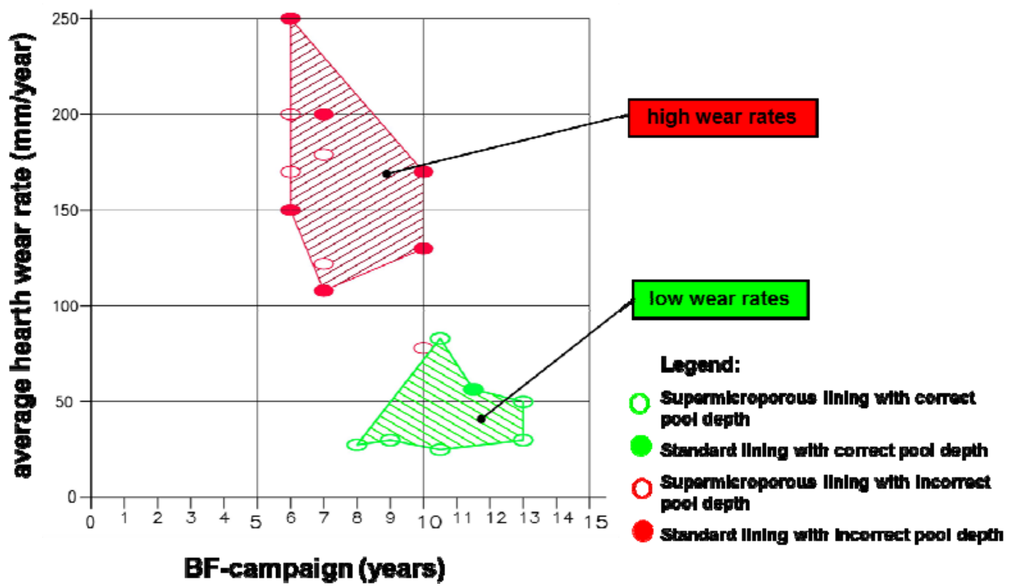

Figure 2. Campaign length and average hearth wear rates (without ceramic cup).

Figures 3 and 4 illustrate this concept on two similar hearth linings.

Term:	H/R	H_{real} /R	L/R	A/R
existing	0,30	0,30	0,38	0,792
critical	≤ 0,45	≤ 0,45	≤ 0,333	≤ 0,667
remark	critical	critical	not critical	not critical

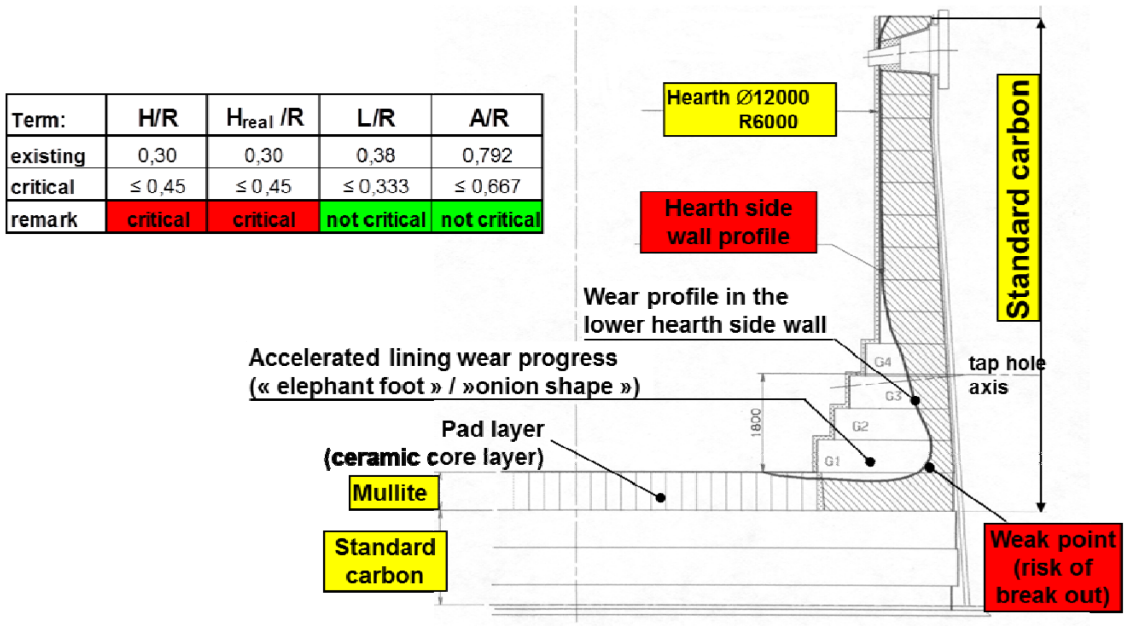

Figure 3. Incorrect hearth characteristic indexes leading to “elephant foot” lining wear.

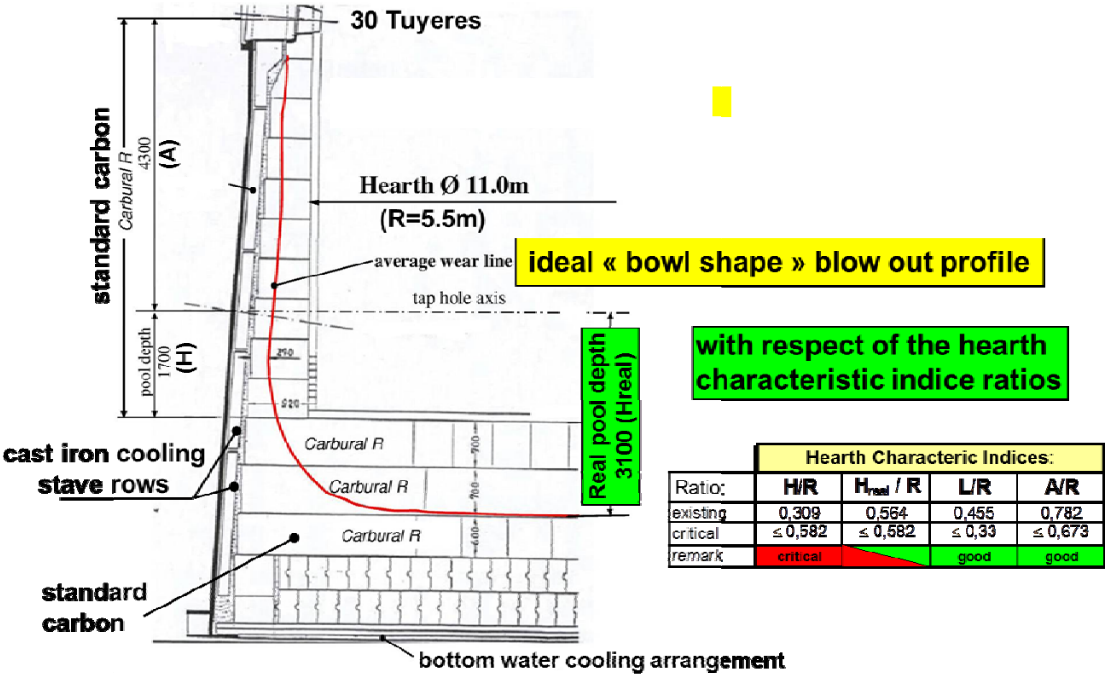

Figure 4. Ideal blow out profile due to the respect of the hearth characteristic indexes.

3 BF-HEARTH LINING

3.1 Physical And Chemical Attack Mechanisms

It is well known that the refractory material of the BF-hearth lining attack mechanisms are thermo-chemical and thermo-mechanical ones. The consequence of those attacks (erosion, skull formation, infiltration, crack, brittle layer, hearth lining resistance) can be seen in the Figure 5.

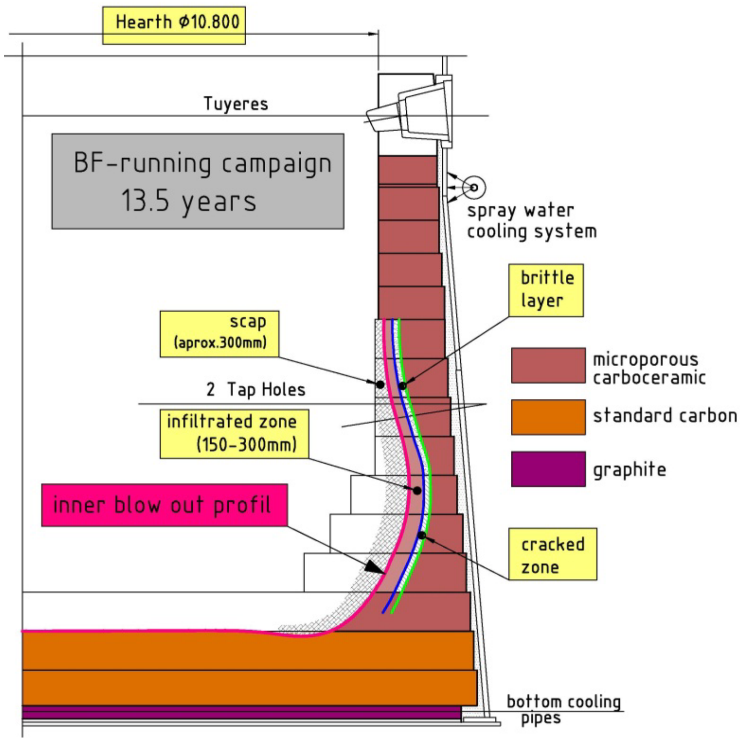

Figure 5. Blast Furnace hearth lining wear.

To solve the hearth lining wear features created by thermo-chemical and thermo-mechanical attack mechanisms, different hearth lining designs were developed.

3.2 Classical Hearth Lining Design

The classical hearth lining design consists of a single quality wall composition. An example of classical hearth lining design with graphite border bricks is shown on Figure 6.

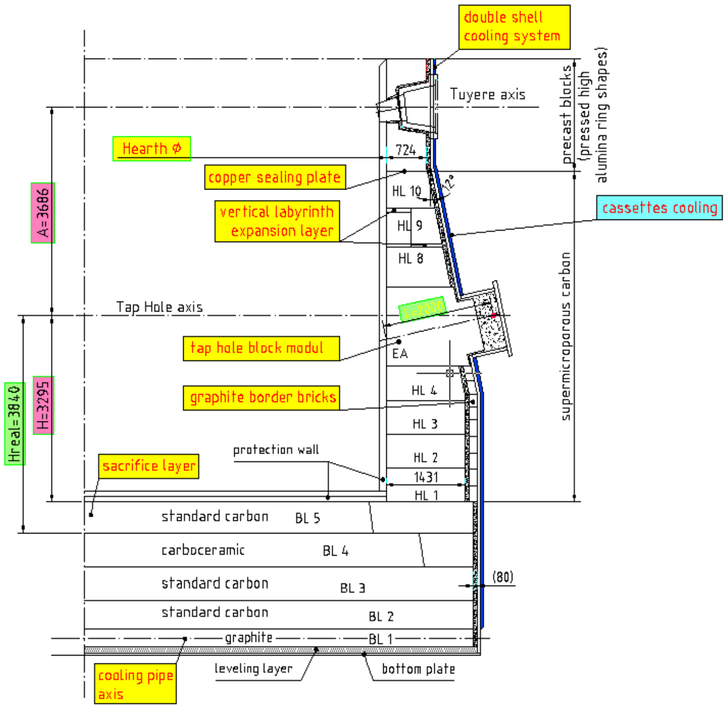

Figure 6. Classical hearth lining design.

This is a quite well experienced hearth and bottom design. The purpose of the graphite border brick solution is to act as an outside safety cup by freezing the pig iron close to the graphite border bricks.

3.2 Double Hearth Side Wall Design

An example of double hearth side wall design is shown on Figure 7. This design is characterised by two hearth wall lining separated by a circumferential ramming gap. It allows an inside (hot) layer optimization regarding erosion and corrosion wear attack mechanisms of liquid hot metal as well as an outside (cold) layer optimization regarding alkali and zinc oxide attack mechanisms.
Furthermore, as the hearth side wall is split into two courses, a significant reduction of the thermo-mechanical stress can be expected due to the remarkable carbon length reduction.

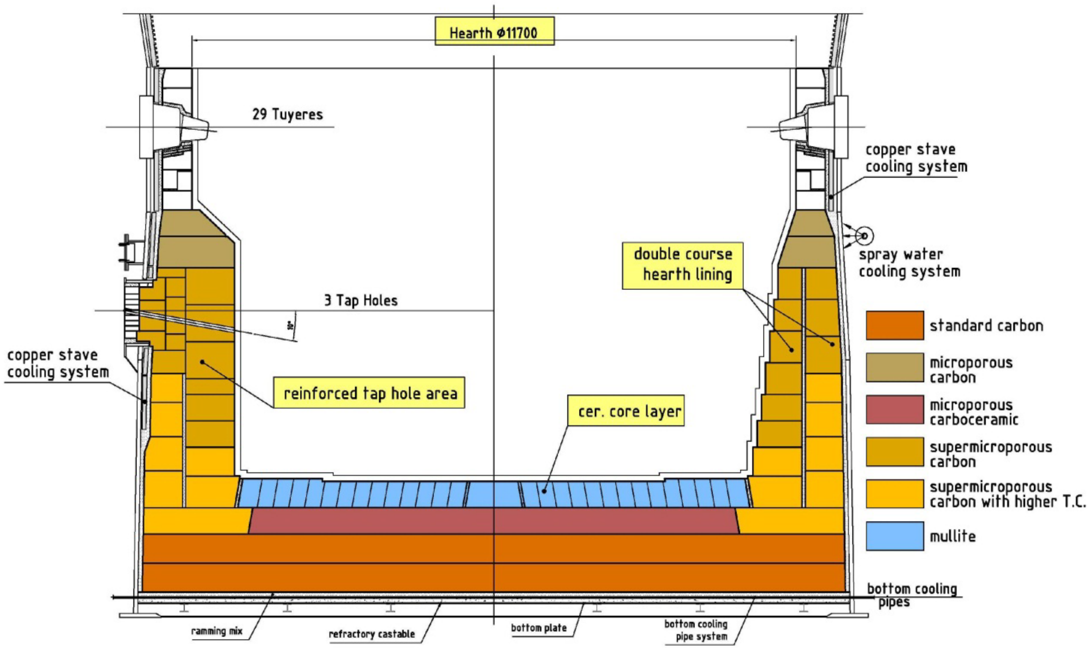

Figure 7. Double hearth side wall lining design.

3.3 Ceramic Cup Hearth Lining Design

An example of the classical ceramic cup design is shown on Figure 8. This is a well experienced design where sialon bonded high alumina bricks are installed in front of the carbon lining. This so-called insulating design allows, on one side, a good resistance to erosion and corrosion wear attack mechanisms and, on the other side, a significant heat loss reduction in the hearth.

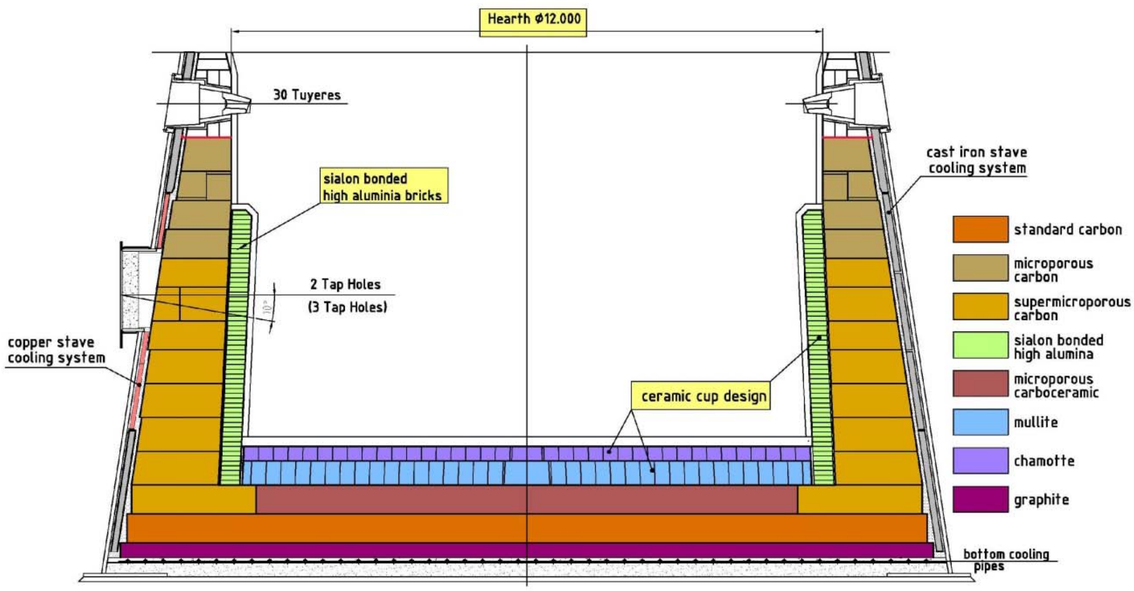

Figure 8. Ceramic cup lining design / Projeto de cadinho com revestimento cerâmico

3.4 Composite Hearth Lining Design

An example of composite lining design is shown on Figure 9. The particularity of this design is the possibility to glue two different carbon qualities together. This concept, developed by PWRE, allows an inside (hot) layer optimization regarding erosion and corrosion wear attack mechanisms of liquid hot metal and slag as well as an outside (cold) layer optimization regarding alkali and zinc oxide attack mechanisms. Furthermore, this concept, which is more flexible in the length choice of each carbon quality, allows a tailor-made lining well adapted to the important isothermal lines as well as the necessary inner lining design, like reinforced tap hole areas a.s.o.

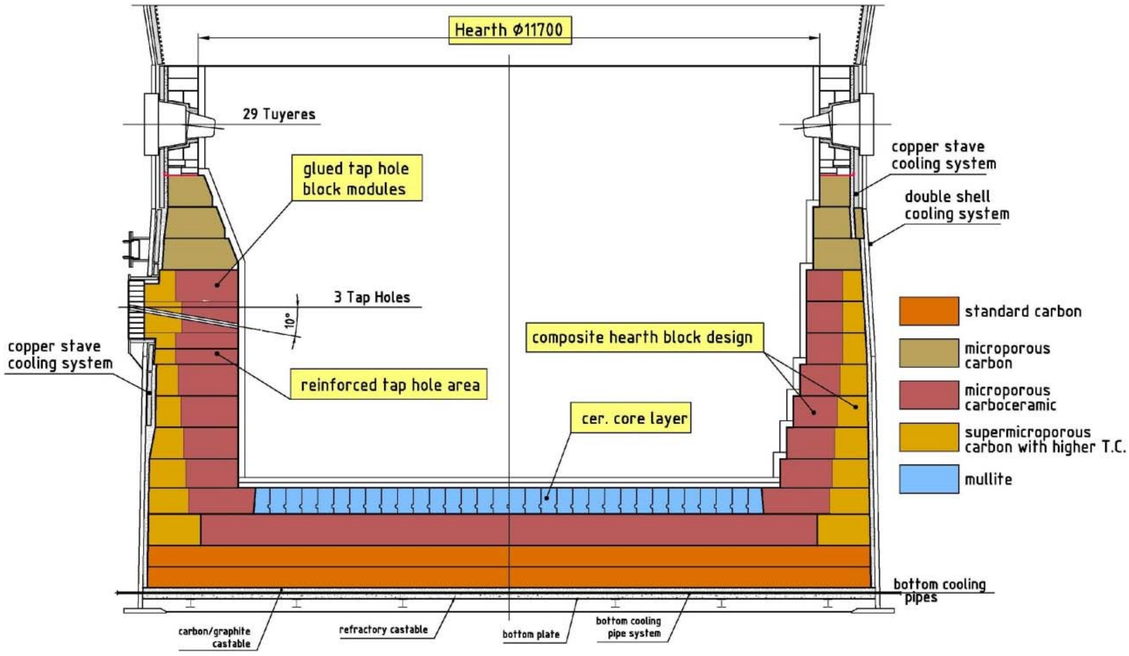

Figure 9. Composite lining design.

4 SUMMARY

With the development of the technologies, the BF-hearth life time campaign could be extended and the current requirement is now of 15-20 years.
Along the last decades, PWRE has identified, through special hearth monitoring and hearth post-mortem evaluation, design parameters, the so-called hearth characteristics, to achieve this requirement.
To resolve the thermo-mechanical and thermo-chemical attacks mechanism, different BF-hearth lining design have been explored by PWRE: The classical hearth lining design, the double hearth side wall design, the ceramic cup hearth lining design and composite hearth lining design. The numerous BF-hearth lining design followed by PWRE along the last years is shown on figure 10.

5 CONCLUSION

A good BF-hearth lining design is a fine tuning between design features and adequate material quality choice.
The different presented linings are adapted to fight the different physical and chemical attack mechanisms and can reach the expected campaign life time, but the non-respect of the presented hearth characteristic indices will surely lead to unexpected advanced wear progress, like “elephant foot”, reducing therefore the benefit of a high-tech wall lining.

6 REFERENCE LIST

Chart 1. Reference list of BF-Linings furnished by PWRE

Items	Costumer	Country	BF N°	Year	Hearth Ø
1	SAIL Rourkela	India	1	2000	7,4
2	CSN Volta Red.	Brasil	2	2000	9,0
3	AM Atlantique	France	4	2000	14,0
4	POSEC / POSCO KY	Korea	1	2000	13,2
5	VOEST Donawitz	Austria	1	2000	8
6	AM Galati	Romania	3	2000	9,1
7	Stahlwerke Bremen	Germany	3	2000	9,2
8	Acesita	Brasil	2	2001	6,5
9	Rautaruukki Oy	Finland	1	2001	8,0
10	VOEST Donawitz	Austria	4	2002	8,0
11	AM Asturias	Spain	B	2002	11,3
12	Stahlwerke Bremen	Germany	3	2002	9,2
13	Rautaruukki Oy	Finland	2	2003	8,0
14	VOEST Linz	Austria	A	2003	12,0
15	ROGESA	Germany	4	2003	11,2
16	Salzgitter Flachstahl	Germany	B	2003	11,2
17	Salzgitter Flachstahl	Germany	A	2004	11,2
18	Rourkela	India	4	2004	9,0
19	China Steel Corporation	Taiwan	2	2004	12,0
20	Trinecke	Czech Republic	4	2004	8,2
21	EKO Stahl	Germany	5A	2004	9,8
22	AM Asturias	Spain	A	2004	11,3
23	ISDEMIR	Turkey	3	2004	10,2
24	VOEST Donawitz	Austria	1	2005	8,0
25	AM Bremen	Germany	3	2005	9,2
26	ROGESA	Germany	5	2005	12,0
27	V&M-Tubes	Brasil	2	2006	4,2
28	VOEST Donawitz	Austria	4	2006	8,0
29	Salzgitter Flachstahl	Germany	C	2006	8,2
30	HKM	Germany	A	2006	10,6
31	China Steel Corporation	Taiwan	3	2006	12,5
32	AM Belgium	Belgium	6	2007	9,75
33	China Steel Corporation	Taiwan	3	2007	12,5
34	AM Ostrava	Czech Republic	3	2007	8,5
35	ROGESA	Germany	3	2007	8,5
36	SAIL Bokaro	India	2	2008	10,2
37	POSCO Gwangyang	Korea	4	2008	15,6
38	SSAB Oxelösund	Sweden	4	2008	8,6
39	Rautaruukki Oy	Finnland	1	2008	8,0
40	China Steel Corporation	Taiwan	1	2008	10,2
41	Vallourec Sumitomo	Brazil	1+2	2008	4,8
42	VOEST Donawitz	Austria	1	2008	8,0
43	V&M-Tubes	Brasil	1	2008	5,5
44	ROGESA	Germany	4	2009	11,2
45	Rautaruukki Oy	Finnland	2	2009	8,0
46	AM Monlevade	Brasil	B	2010	8,0
47	AM Galati	Romania	5	2010	11,6
48	VOEST Donawitz	Austria	4	2011	8,0
49	AM Termitau	Kazakhstan	3	2011	12,0
50	China Steel Corporation	Taiwan	4	2011	12,6
51	FN-Steel	Finnland	1	2011	6,9
52	China Steel Corporation	Taiwan	1	2012	10,2