

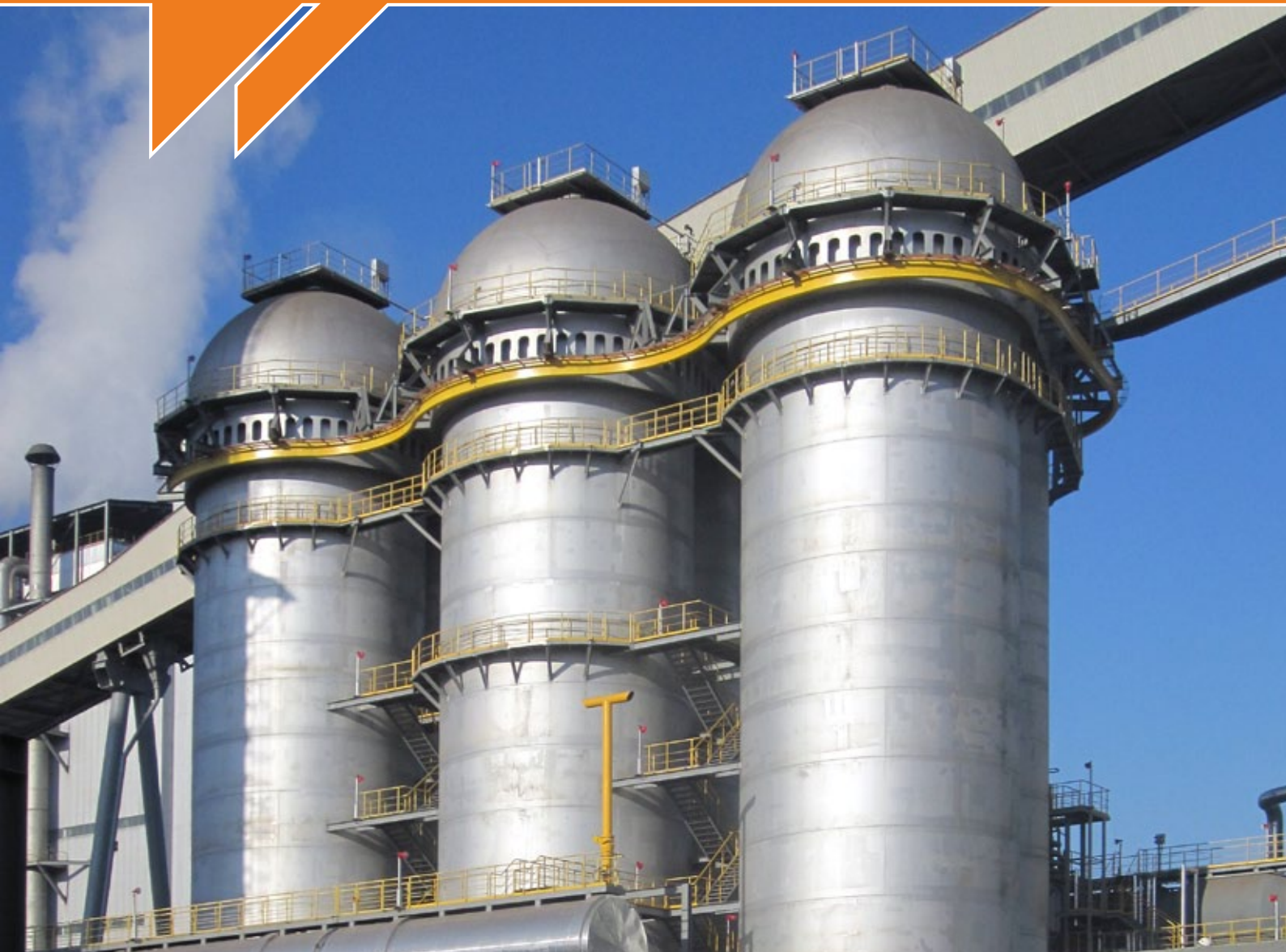
# PAUL WURTH

SMS group

## Refractory & Engineering

Solutions for Hot Blast Stoves and Blast Furnace Linings

Blast Furnace Technologies



## The Company – The Program

Paul Wurth Refractory & Engineering GmbH has been integrated into the Paul Wurth Group in December 2004. This alliance offers, on a turnkey basis, single source supply and procurement options for complete blast furnace plants.

Originally, Paul Wurth Refractory & Engineering GmbH has been founded as DME in 1993 through the merger of departments of Didier-Werke AG and Martin & Pagenstecher GmbH. Customers benefit from the unsurpassed experience and know-how that both companies have developed in the field of hot blast stove engineering, refractory lining design, and hot metal production.

Paul Wurth Refractory & Engineering GmbH is always striving for world class stove and refractory designs to meet demanding market requirements, such as larger production capacity, extended service life, optimized refractory selection, and high energy efficiency.

Paul Wurth Refractory & Engineering's answers to these challenges include customized engineering, project management and supply of:

- ▶ Blast furnace linings for extended service life
- ▶ Blast furnace cooling systems
- ▶ Turnkey hot blast stoves with internal or external combustion chamber
- ▶ Ceramic burners with ultra-low CO emission
- ▶ Highly effective stress corrosion protection systems
- ▶ Complete hot blast main systems
- ▶ Complete heat recovery systems
- ▶ Refractory linings for smelting and direct reduction vessels
- ▶ Refractory linings for coke dry quenching
- ▶ Refractory linings for pellet plants

Highly experienced and motivated teams of engineers, designers and project managers offer consulting, feasibility studies and plant assessments as well as customer services.





## Hot Blast Stove Systems

Paul Wurth's reference list of installations includes more than 300 stoves with internal combustion chambers and more than 200 stoves with external combustion chamber.

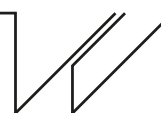
Paul Wurth Refractory & Engineering GmbH is the most experienced designer of hot blast stove systems on the world market. The company has introduced and/or influenced most of the innovations in this field.

For each plant Paul Wurth Refractory & Engineering GmbH develops together with the customer an individual concept taking into account the following aspects:

- ▶ Blast Furnace size and expected performance
- ▶ Existing systems and facilities
- ▶ Energy cost and availability
- ▶ Capital expenditure and construction schedule

In addition, Paul Wurth Refractory & Engineering GmbH offers:

- ▶ Feasibility studies for new or existing stove installations
- ▶ Evaluation of stove operating conditions
- ▶ Computer modelling of stove operations
- ▶ Modernization/enlargement of existing plants
- ▶ Repair concepts and schedules for existing plants
- ▶ Turnkey erection schedules for new plants
- ▶ Dome replacements
- ▶ Services for heating up and cooling down of hot stoves



## Hot Blast Stoves with External Combustion Chamber

Paul Wurth Refractory & Engineering GmbH recommends external combustion chamber stoves for large blast furnace operation and for plants committed to reduce carbon monoxide stack emissions.

Main construction features are:

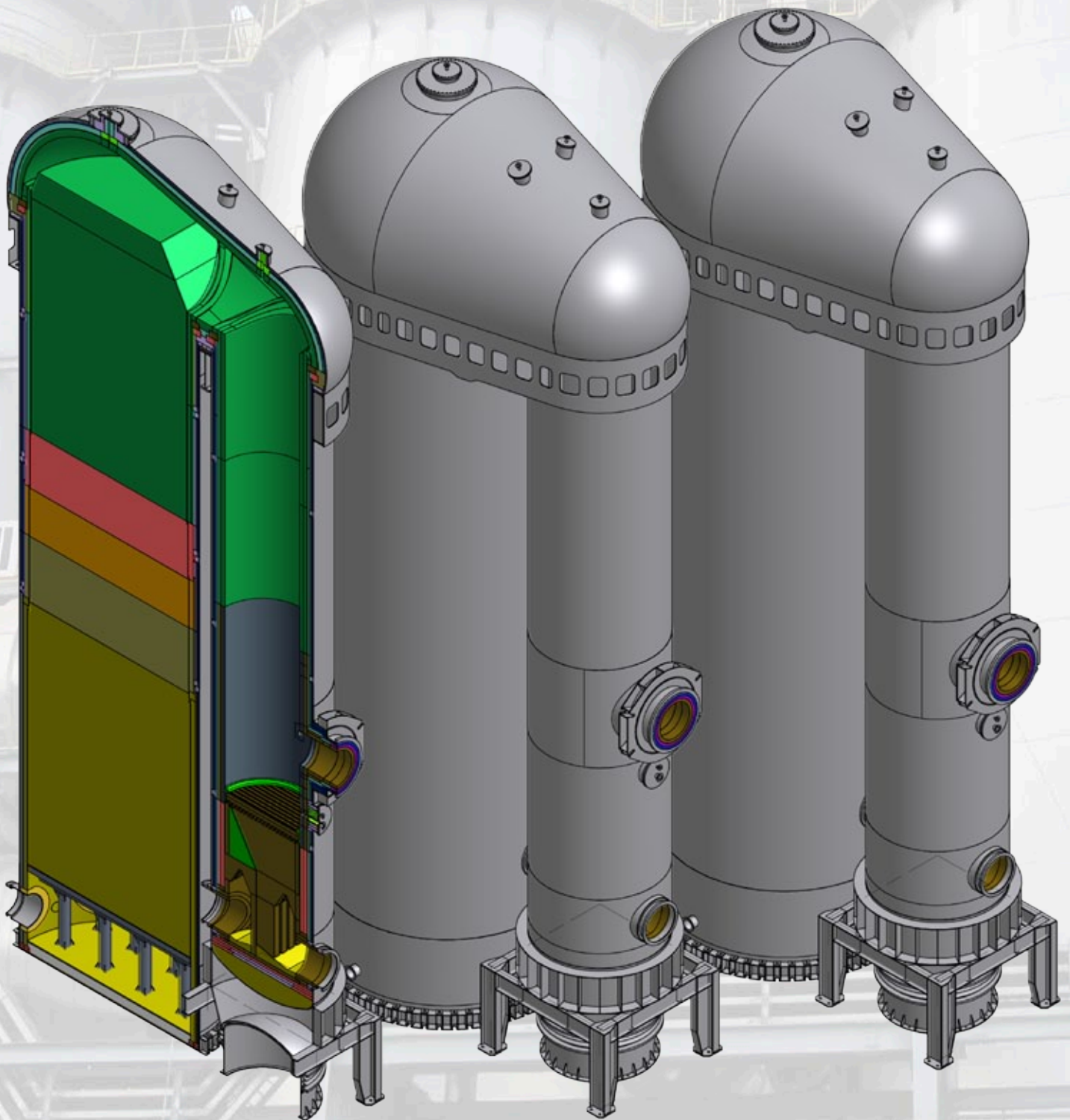
- ▶ Pressure vessel with no expansion joints.
- ▶ Elimination of tensile stress impact on stove shell and hot blast trunk through a unique combination of a box girder and a hydraulic combustion chamber support system ("Didier-Type Stove").
- ▶ Reduced hot stove height through a truncated dome design connecting both combustion and checker chamber.

- ▶ Effective stress corrosion protection system employing special high temperature epoxy resins, mineral fillers, and stainless steel foils for extra high dome temperatures.
- ▶ Independent thermal expansion of combustion chamber, checker chamber, checker bricks, and dome.
- ▶ Dome shapes with large bearing surfaces, providing stable refractory installation and extended service life.
- ▶ A special top checker pyramid arrangement that ensures an optimized flow distribution into the checkers.

A different external hot stove design can be offered as well based on the former "M&P-Design". The main technical features are comprising the expansion joint free structure without a hydraulic structure, a transition cone and a small symmetrical dome.







## Hot Blast Stoves with Internal Combustion Chamber

Paul Wurth Refractory & Engineering GmbH recommends this design for less demanding stove application or replacement of existing stoves in the limited space of old plants.

Main features include:

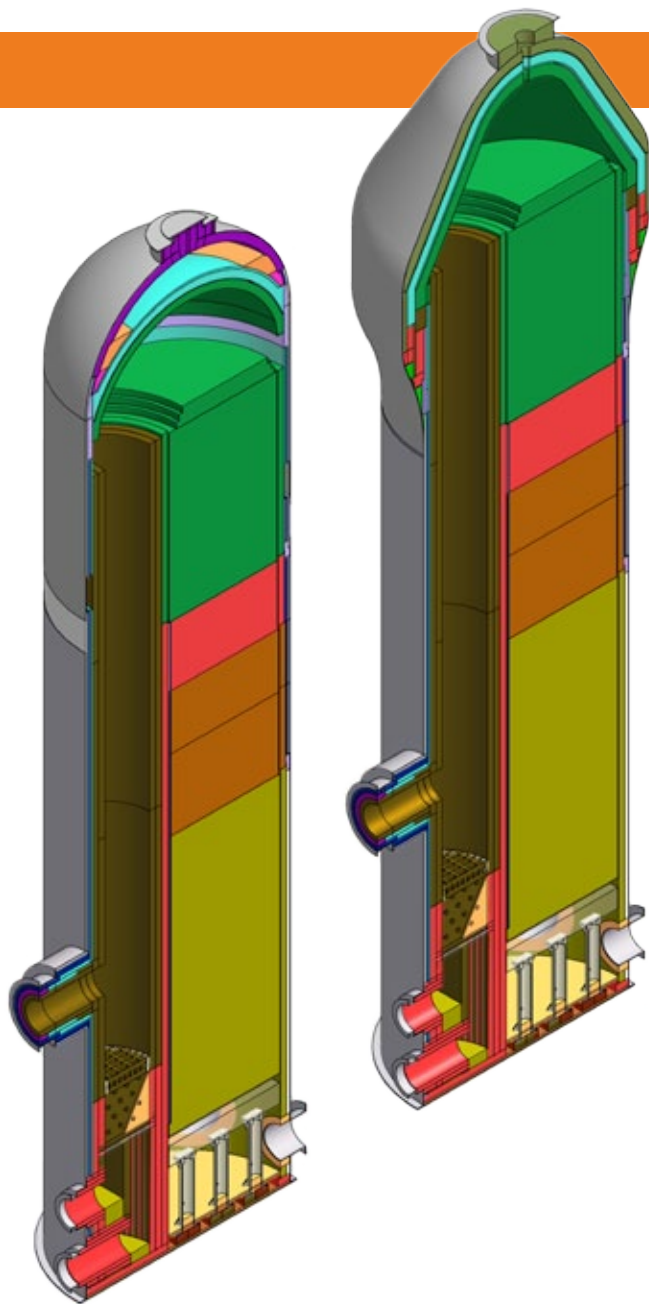
- ▶ Stove dome supported by the ring wall. No skew back band or similar is required.
- ▶ Two or three course division wall with backside insulation to prevent combustion chamber deformation.
- ▶ Designed either with internal ceramic burners or for external mechanical burners.
- ▶ For special applications external burner systems can be offered suitable for firing liquid combustion media, enriched gases and blast furnace gas.

Many internal combustion chamber stove design elements are derived from the proven external combustion chamber stove system, like ceramic burner, checker grid and the design of openings. A service life of more than 30 years has been obtained with these systems.

For large size installations and on special demand a shell supported dome design (Mushroom dome) can be offered. This design is derived from the checker chamber design of the M&P external combustion chamber system.



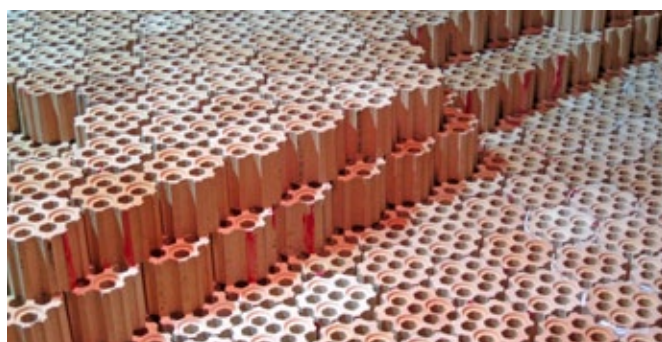




Dome of external combustion chamber stove



Combustion chamber of external combustion chamber stove



Checker work during installation

## Hot Blast Stove Burners

Paul Wurth Refractory & Engineering GmbH offers environmentally friendly ceramic burners, adapted to the individual requirements:

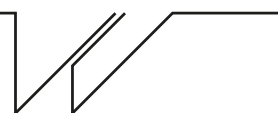
- ▶ For installation in internal or external combustion chamber stoves
- ▶ For installation into new or existing plants
- ▶ For high heat release rates up to  $50 \text{ GJ/m}^2 \text{ h}$
- ▶ For a wide range of calorific values of enriched or normal blast furnace gas
- ▶ For operation with preheated combustion media
- ▶ For enrichment of combustion air with oxygen

All ceramic burners provide low CO and NO<sub>x</sub> emission, low operating cost and extended service life.

Furthermore external metallic burners can be provided for special application and also all required auxiliary burners for heat maintenance or heating up services.



Ceramic burner – top view

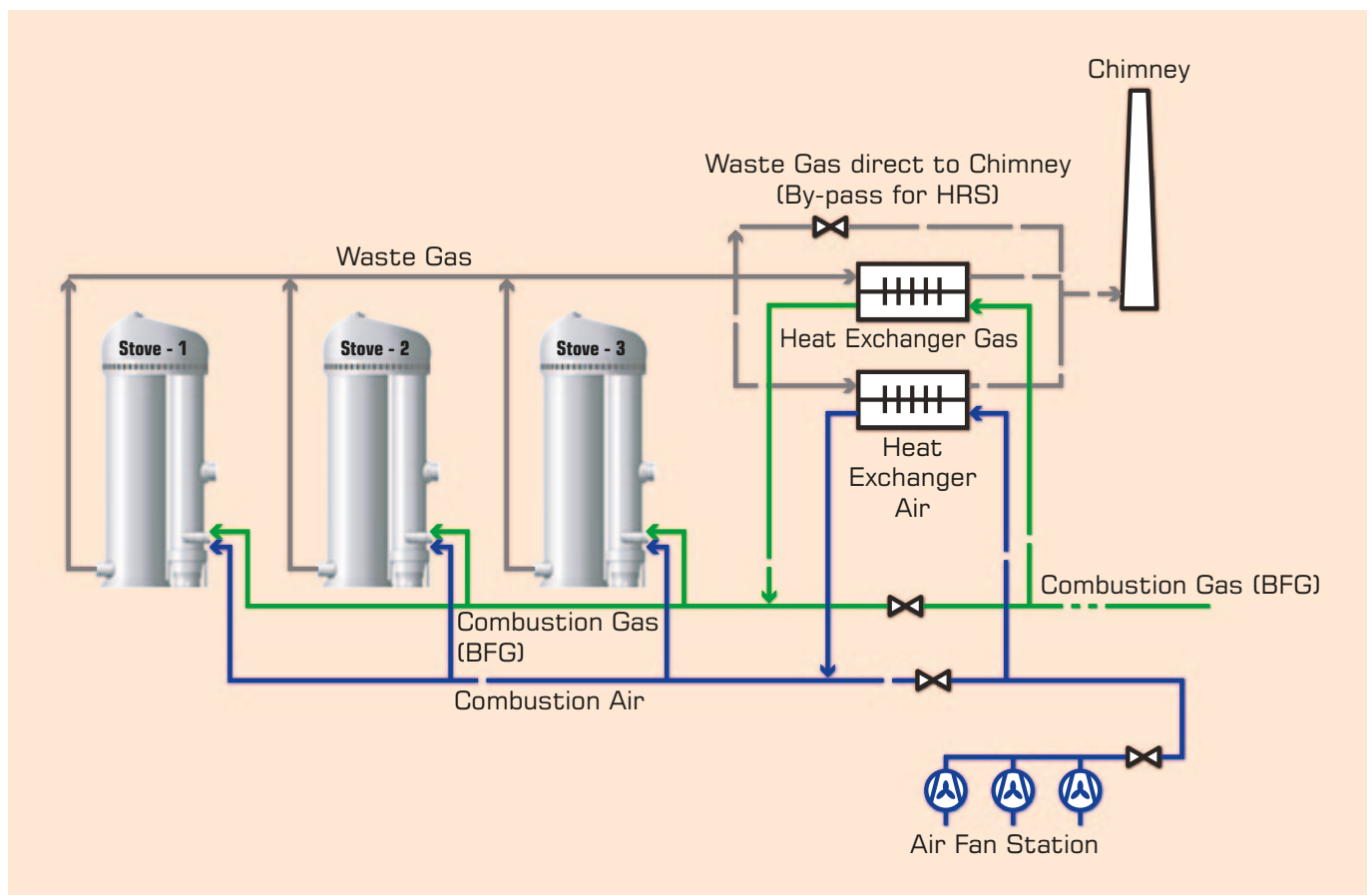


## Waste Gas Heat Recovery Systems

In general, reduction of energy consumption of stove plants is one of the top criteria of the technical plant concept. The hot blast stoves process allows the energy in the waste gas of the stove plant to be recovered in order to save energy. The recovered energy is used for preheating the combustion air and gas to the stoves. This leads to reduction in the overall gas consumption, replaces the expensive high calorific gas by BF top gas and thus reduces the operational expenditures of the BF-plant. The heat recuperation is made by heat exchangers based on heat pipe technology. Auxiliary burners increase the available energy for preheating to economize the heat utilization.

The main advantages of a heat recovery system are:

- ▶ The total consumption of energy of the hot stove plant can be reduced.
- ▶ With the increasing hot blast temperature required for more efficient furnace operation, it has become necessary to add high calorific value fuel (coke oven gas or natural gas) to achieve the required dome temperature.
- ▶ The use of preheated combustion media can considerably reduce - and even eliminate in some cases - the need for these expensive high calorific fuels. Each stove plant requires a separate study to determine which preheating system will meet the required operational parameters with the lowest capital cost.
- ▶ In most cases the distribution of energy for the whole blast furnace plant will be changed in a positive way by the installation of a heat recovery and preheating system.
- ▶ The lifetime of refractory lining in the lower combustion chamber and ceramic burner can be increased because of the elimination of condensed water from preheated combustion gas and less temperature fluctuations.
- ▶ Stove performance can be increased by operating stoves on the upper temperature limits of the checker work. At the construction of new hot stove plants the capital costs can be decreased by building of smaller hot stoves with higher performance which are calculated for higher waste gas temperatures.



Process diagram of heat pipe heat recovery system



Combustion gas and combustion air are directly heated by heat exchangers in the waste gas main of the stoves. The control of all temperatures is simply made via bypasses around the heat exchangers. Except the controlling valves in the bypasses there are no agitated parts. An example for a circuit of this type is given in the opposite process diagram.

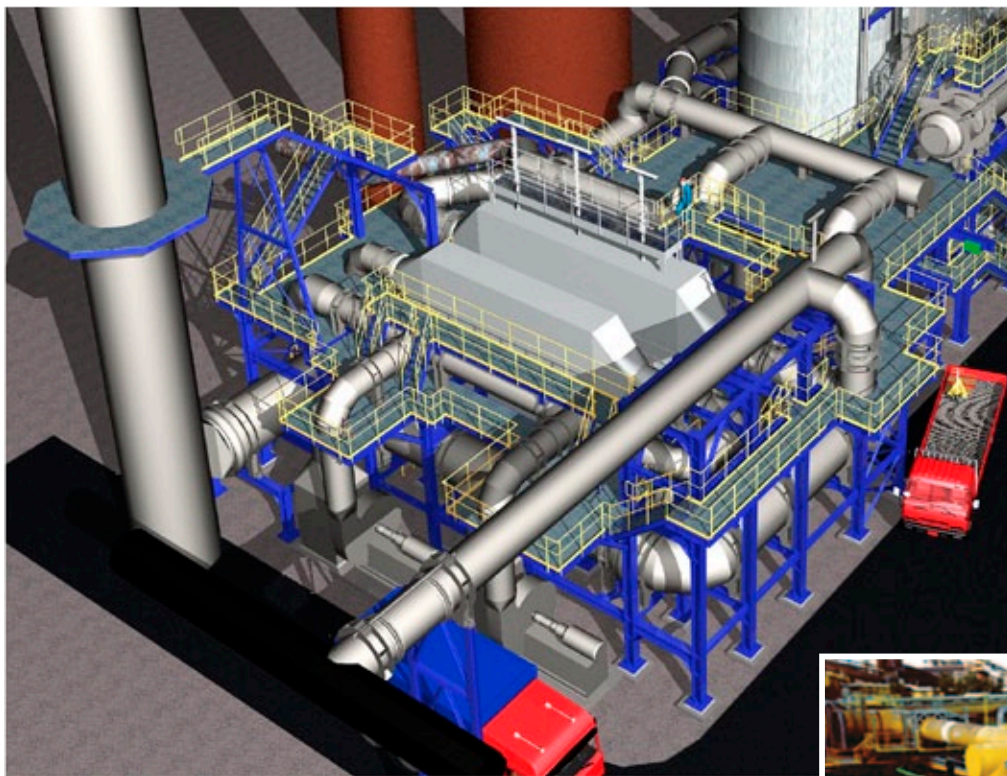
Upon request, the use of high calorific gases can be completely eliminated. This is achieved by using an additional burner which produces additional exhaust gas to be utilized in elevating the preheating temperature of the combustion media to the required level. The exhaust gas from the auxiliary burner will be then mixed with the waste gas of the stove plant. Paul Wurth Refractory & Engineering has reference for these kind of heat recovery systems as well which can reduce the operational expenditures in a significant way.

Among the different available types of heat transfer systems, the heat pipe is one of the most efficient systems known today.

Advantages of Paul Wurth Heat Pipe System:

- ▶ Simple plant geometry, compact design due to modular components (each of mounting).
- ▶ High operational reliability due to different independently working systems.
- ▶ The heat exchanger is divided in exchangeable individual modules.
- ▶ The heat pipes are assembled in the separation bottom plate by means of screws and gaskets.
- ▶ Low pressure losses due to the parallel arrangement of heat pipes.
- ▶ No additional control and safety elements are required on the waste gas temperature, as this is already integrated by the stoves control system.

- ▶ Easy inspection by manholes and passage between the heat pipes module.
- ▶ System is easily serviced since heat pipes can be replaced individually.
- ▶ Acoustic stability (lower probability of pulsation occurrences).



3D model for heat pipe heat recovery system



View of existing plant

## Hot Stove Valves

Paul Wurth Refractory & Engineering is also able to supply hot stove valves together in close cooperation with the sister company Paul Wurth, a.s. in Ostrava as a turnkey solution. Paul Wurth supplies the complete collection of valves for hot and cold blast control, chimney valves, equalizing/relief valves as well for the complete stove regulation and cares for the concept and detail engineering, manufacturing, erection and commissioning of the valves.



## Services for Hot Blast Stoves

### Hot Repairs

For hot blast stoves suffering from damages in the lower combustion chamber and burner area, for example as a result of water ingress or ignition malfunctions, Paul Wurth offers hot repair concepts and the relevant equipment. While keeping the upper part of the hot blast stove close to operating temperature, special equipment and heat flux/flow engineering provide safe working conditions in the work zone. Stove downtime and related influence on the blast furnace production are kept to a minimum.

The individual scope is always adapted to the specific requirements of the client, the extent of the damage and the necessary safety considerations.



Protection heat shield for hot blast stove hot repairs



## Double Shell Installation

Stress corrosion cracking is a phenomenon which still occurs especially on old stoves or on stoves without an appropriate protection system against the corrosive atmosphere resulting from high temperatures in the dome.

Paul Wurth has developed a system to repair such stoves during operation without extended impact on blast furnace plant operation. Several reference projects have been executed successfully and increased the lifetime of the plants significantly.

The installation of the double shell is made segment by segment to enable easy handling and proper treatment of the new shell and especially the new welding. The main part of the repairs is done with the hot stove remaining in normal operation. Cooling down is not required and stove shutdowns are only required to connect the new shell to the old one.

The main advantages are:

- ▶ Dimensioning of the new shell according to stress analysis and selection of adequate steel grades.
- ▶ Installation of a stress corrosion cracking protection system to protect the new shell and welds.
- ▶ Installation procedure and a pressure relief system on the double shell reduce the stress level on old and new shell and avoid future stress corrosion.
- ▶ Stove remains in operation during repair.
- ▶ Stove refractory is maintained except some minor adjustments on nozzles.



Dome replacement project

## Dome Replacement Projects

Different to the Paul Wurth dome system used on hot blast stoves with external combustion chamber and hydraulic combustion chamber support, most other designs try to compensate the differential movement of combustion and checker chamber by a compensator system in the dome area.

As these systems incorporate metallic compensators and expansion joints in the refractory, both being exposed to lateral movement in the most critical stove area, problems frequently arise after several years of operation, like hot spots and cracking on the metallic parts. Local repairs are difficult and not very long lasting; extended repairs with changing of the whole unit require a longer stove shutdown and do not solve the problem on long term basis as long as the system itself is kept.

To solve these problems Paul Wurth has developed a dome replacement system which allows the reuse of the existing combustion and checker chamber, including their refractory material.

The old domes including the connection pipe and its compensators are dismantled completely for the repair down to a predetermined cut line. Depending on the stove size, the access and existing lifting capacity, the new dome shell including the supporting box girder can be installed as one preassembled unit, thus reducing the stove down time for repair. Thereafter a new lining of the upper shafts and the dome is installed, with an internal protection against stress corrosion cracking on these parts, if desired. To a certain extent, depending on the given design of the lower stove and new thermodynamic calculation, additional checkers compared to the old design may be installed to increase hot stove capacity.

The first dome replacements have been executed in 1995/96 at the former Aceralia (now AM Asturias) BF-Plant on the 6 stoves at BF 1 and 2 and both plants are in operation trouble-free since then. In the meantime (till 2011) in total 27 stoves worldwide have been modified by Paul Wurth or are under relevant repair.

## Blast Furnace Linings

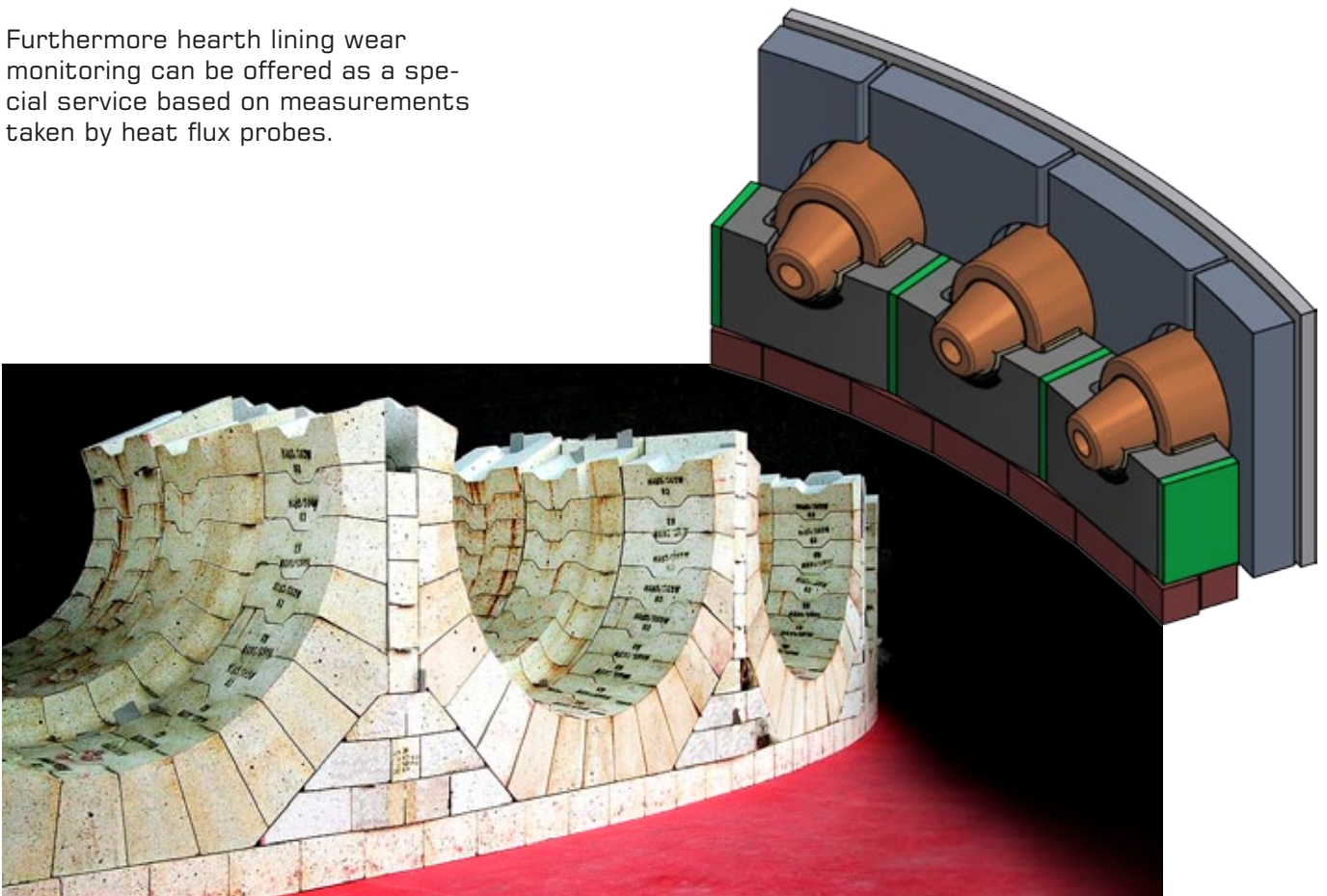
With more than 300 Blast Furnace linings supplied worldwide since 1970 – either new installations or partial relines –, Paul Wurth Refractory & Engineering is amongst the most experienced companies in the field of refractory design and application, material supply, and installation supervision.

Paul Wurth Refractory & Engineering's extensive expertise is based on the know-how gained during numerous projects and on a long-term, close cooperation with dedicated refractory workshops. On a continuous basis, Paul Wurth Refractory & Engineering pursues its own research and development activities together with plant operators and clients in the field of blast furnace linings and installation techniques. Today, Paul Wurth Refractory & Engineering offers state-of-the-art engineering services, design calculations, and supply of the complete line of blast furnace refractories.

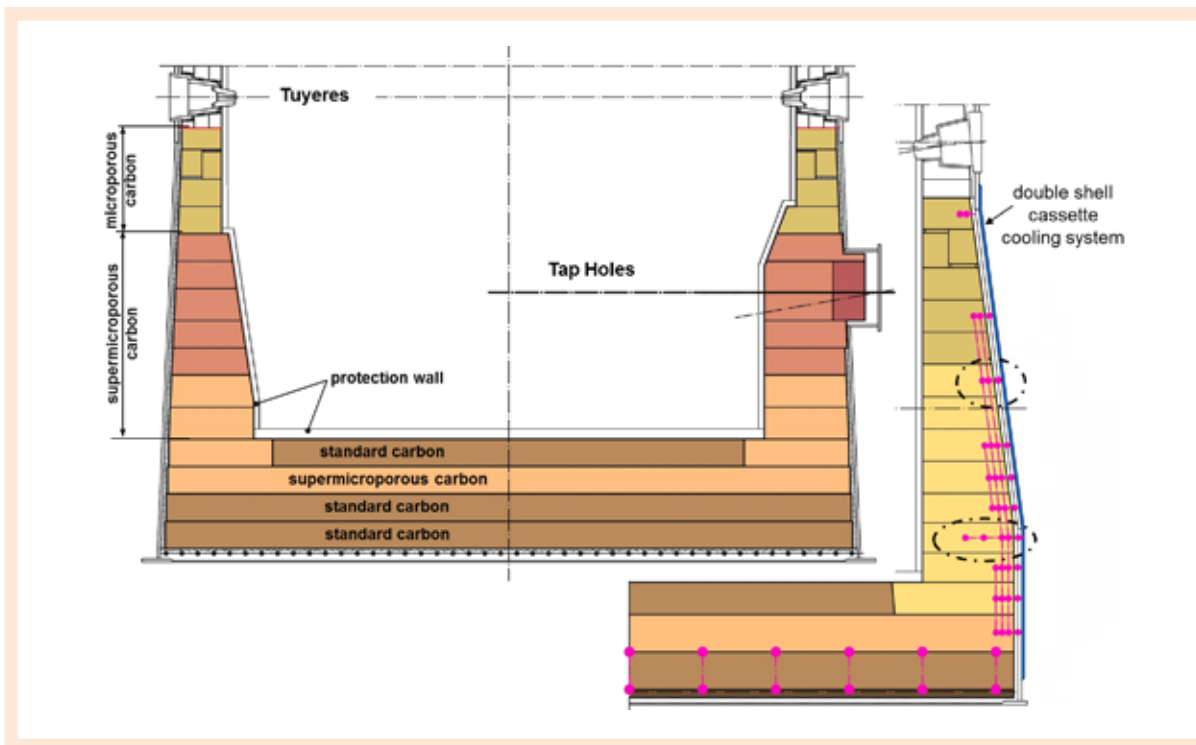
Furthermore hearth lining wear monitoring can be offered as a special service based on measurements taken by heat flux probes.

Paul Wurth's services are:

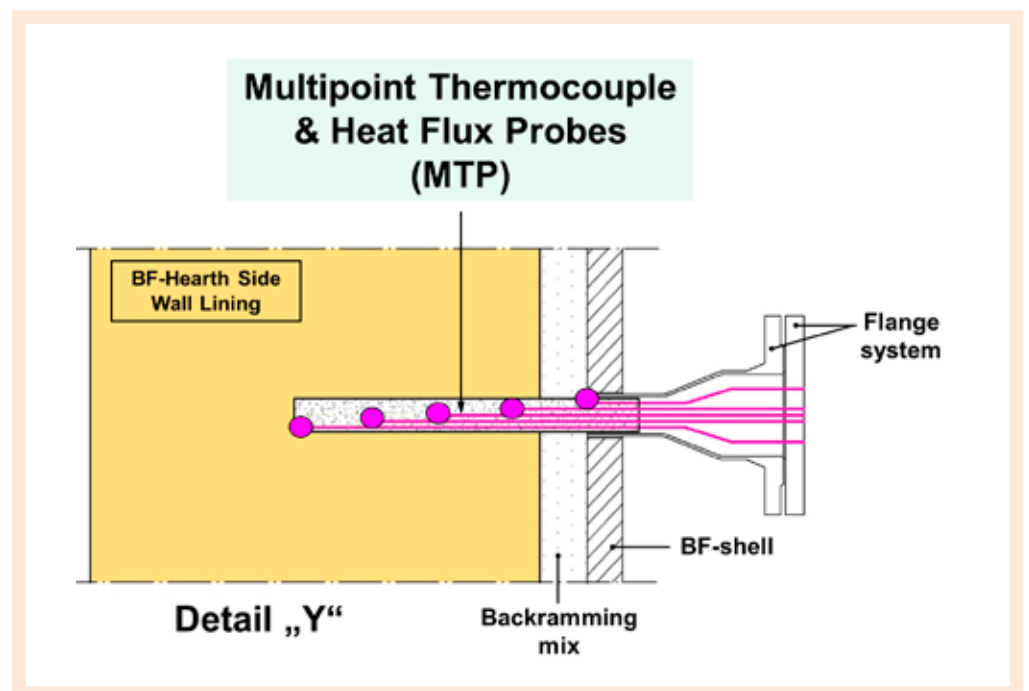
- ▶ Finite element isothermal calculations, thermal expansion, and stress evaluations for all sections of the blast furnace lining.
- ▶ Engineering and supply of BF cooling systems for the bottom, hearth, belly and stack including the optimized appropriate refractory lining.
- ▶ Heat flux and heat loss calculations for refractory linings with and without cooling systems.
- ▶ Preparation of comprehensive refractory purchasing documents, including refractory specifications and installation procedures.
- ▶ Testing of refractory grades, evaluating blast furnace wear properties and mechanisms.
- ▶ Consultation for all aspects of complete and partial blast furnace lining installations, including scheduled outages and emergency repairs.
- ▶ On-site supervisory services for complete and partial refractory relines and for repairs.
- ▶ Design, supply, installation, and maintenance of wear control systems for critical blast furnace zones.







Hearth lining concepts



Hearth lining wear monitoring by heat flux probes

## Other Linings

- ▶ Engineering, supply, installation and maintenance for linings of direct reduction plants and smelt reduction furnaces.
- ▶ Engineering, supply, installation and maintenance for linings of coke dry quenching plants.

## Recent References



**Hyundai Steel Corporation, Dangjin, South Korea**

Blast Furnaces 1, 2 & 3

Each Hot Stove Plant:

Hot Blast Flow Rate	: 506.000 Nm <sup>3</sup> /h
Hot Blast Temperature	: 1280 °C
Dome Temperature	: 1450 °C
Cold Blast Temperature	: 230 °C
Time on Blast	: 30 min
Operation Mode	: 3 Stoves



**Zhangjiagang Pros Iron Making Co. Ltd., Zhangjiagang City, P.R. China**

Blast Furnace 1

Hot Stove Plant:

Hot Blast Flow Rate	: 570.000 Nm <sup>3</sup> /h
Hot Blast Temperature	: 1250 °C
Dome Temperature	: 1450 °C
Cold Blast Temperature	: 180 °C
Waste Gas Temperature	: 400 °C
Time on Blast	: 45 min
Operation Mode	: 3 Stoves



**ThyssenKrupp CSA, Santa Cruz, Brazil**

Blast Furnaces 1 & 2

Each Hot Stove Plant:

Hot Blast Flow Rate	: 310.000 Nm <sup>3</sup> /h
Hot Blast Temperature	: 1250 °C
Dome Temperature	: 1435 °C
Cold Blast Temperature	: 120 °C
Time on Blast	: 30 min
Operation Mode	: 3 Stoves



**ANSTEEL Angang New Iron & Steel Co., Ltd., Anshan City, P.R. China**

Blast Furnaces 1 & 2

Each Hot Stove Plant:

Hot Blast Flow Rate	: 450.000 Nm <sup>3</sup> /h
Hot Blast Temperature	: 1250 °C
Dome Temperature	: 1370 °C
Cold Blast Temperature	: 180 °C
Time on Blast	: 45 min
Operation Mode	: 3 Stoves



**SSAB Emea, Oxelösund, Sweden**

Blast Furnace 2

Hot Stove Plant:

Hot Blast Flow Rate	: 90.000 Nm <sup>3</sup> /h
Hot Blast Temperature	: 1200 °C
Dome Temperature	: 1350 °C
Cold Blast Temperature	: 90 °C
Time on Blast	: 45 min
Operation Mode	: 3 Stoves



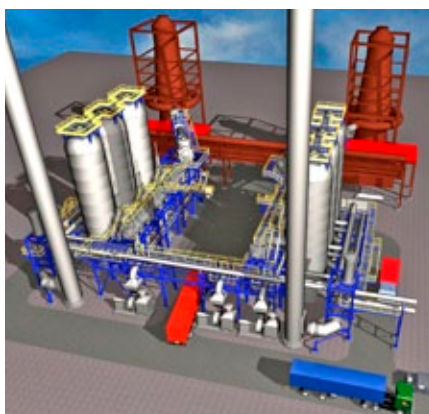


### ThyssenKrupp Steel Hamborn Works, Duisburg, Germany

Blast Furnace 8

Hot Stove Plant:

Hot Blast Flow Rate	: 220.000 Nm <sup>3</sup> /h
Hot Blast Temperature	: 1200 °C, max
Dome Temperature	: 1380 °C
Cold Blast Temperature	: 100 °C
Time on Blast	: 30 min
Operation Mode	: 3 Stoves



### Vallourec & Sumitomo Tubos do Brasil Ltda., Jeceaba, Brazil

Blast Furnaces 1 & 2

Each Hot Stove Plant:

Hot Blast Flow Rate	: 50.000 Nm <sup>3</sup> /h
Hot Blast Temperature	: 1100 °C, max
Dome Temperature	: 1300 °C
Cold Blast Temperature	: 170 °C
Time on Blast	: 30 min
Operation Mode	: 3 Stoves



### ArcelorMittal Monlevade, Monlevade, Brazil

Blast Furnace B

Hot Stove Plant:

Hot Blast Flow Rate	: 145.000 Nm <sup>3</sup> /h
Hot Blast Temperature	: 1250 °C, max
Dome Temperature	: 1400 °C
Cold Blast Temperature	: 200 °C
Time on Blast	: 30 min
Operation Mode	: 3 Stoves

## Recent References – Blast Furnace Lining and Cooling Systems



### voestalpine Stahl Donawitz, Austria

BF 4; 8 m hearth diameter; hearth lining

### ArcelorMittal Galati, Romania

BF 5; 11.6 m hearth diameter; ceramic pad, tuyere belt

### ArcelorMittal Monlevade, Brazil

BF B; 8 m hearth diameter; complete lining

### ArcelorMittal Eisenhüttenstadt, Germany

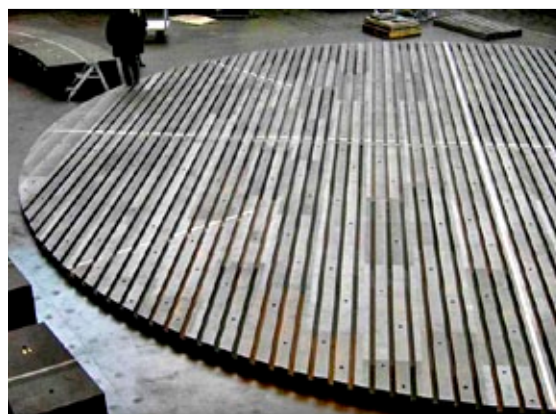
BF 5A; bosh staves: special bosh stave for inclined installation

### Rautaruuki Oy, Finland

BF 2; 8 m hearth diameter; bosh and stack lining

### SSAB Emea Oxelösund, Sweden

BF 4; 8.6 m hearth diameter; hearth, bosh, belly and lower stack lining



### China Steel Corporation, Taiwan

BF 1; 10.2 m hearth diameter; hearth lining and stave cooling for bosh, belly and stack

BF 2; 12.0 m hearth diameter; complete lining and stave cooling for bosh, belly and stack

BF 3; 12.5 m hearth diameter; hearth lining

### POSCO Gwangyang, South Korea

BF 4; 15.6 m hearth diameter; hearth lining

### Valourec & Sumitomo, Brazil

BF 1 & 2; 4,8 m hearth diameter; complete lining

# Engineering & Technology worldwide

The Paul Wurth Group is today one of the world leaders in the design and supply of complete plants, systems and processes as well as specialised mechanical equipment for

## ■ the iron & steel industry:

Blast Furnaces & Auxiliary Plants  
Coke Making Plants  
Agglomeration Plants  
Direct Reduction Plants  
Environmental Protection, Recycling & Energy-Saving Technologies

## ■ other industries:

Systems & Equipment for Non-Ferrous Pyrometallurgy, Electrometallurgy & Residue Treatment  
Intralogistics Solutions for Heavy Loads  
Engineering & Project Management for Civil Construction and Infrastructure Projects

**Feasibility Studies – Conceptual, Basic and Detail Engineering – Project Management – Plant and Components Supply – Turnkey Projects – Assistance in Plant Assembly and Commissioning – Technology and Operations Consultancy – On-site and Remote Operational Assistance – After-sales Services**

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