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PAUL WURTH'S MODERN TOP AND STAMP CHARGING TECHNOLOGY*

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Abstract

A high productive coke making process in connection with stringent emission control has clearly become a demand of plant operators and stakeholders. Further to this, availability, quality and coal costs are key concerns for the iron and steel industry in its efforts to optimize raw material cost. Today, the optimization of raw material cost in integrated steel works has further gained priority. Coking coal reflects up to 20% of the cost of steel. In top charged batteries coal preparation and blending is one of the concerns to lower coal cost by maximizing the percentage of non-coking coals in the blend. Stamp charging technology is technologically and economically an effective solution in the process of pre-carbonisation. Paul Wurth's jumbo top charged oven as well as proven stamp charging technology have recently set new benchmarks in Europe, India and Brazil in terms of productivity, stability and emission control.

Keywords: TOP; STAMP; Charging technology.

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1 INTRODUCTION

In the last fifteen years Paul Wurth (PW) has achieved brilliant results in the international coke making market becoming a global top player also in this technology.
All of the PW projects are characterized by state-of-the-art solutions as far as coke making technology and environmental measures are concerned.

2 “JUMBO OVEN” TOP CHARGED TECHNOLOGY

2.1 “JUMBO OVEN” CONCEPT

7.6 m tall “jumbo oven” battery represents worldwide the state of the art and consolidated technology for coke making plants.
Here below is reported a comparison table between a reference project considering conventional 6.25 m vs. 7.6 m tall “large chamber” oven battery, based on a coke production of 1,9 Mt/y.

Table 1. Conventional 6.25 m battery vs. “Jumbo oven”

Coke Production 1.9 Mt/y	Conventional 6,25 m	Jumbo Oven
Oven Height	6.25 [m]	7.6 [m]
Oven Width	410 [mm]	550 [mm]
Oven Volume	≈ 40 [m^3]	78.92 [m^3]
Number of Batteries	4	2
Number of Ovens	160	118
Pushing per Day	226	116
Coke Oven Door	320	236
Charging Lid	640	472
Stand Pipe Lid	160	118
Set of Operating Machine	2	1

Referring to the table 1 the following advantages result:

2.1.1 Environmental

Being each charging/pushing operation a highest source of fugitive emissions, conventional 6.25 m has 95 % sources more than “jumbo oven”.
Being each door a source of possible leakage source, conventional 6.25 m has 26% sources more than “Jumbo oven”.
Being each charging lid a source of possible leakage source, conventional 6.25 m has 26% sources more than “jumbo oven”.
Conventional 6.25 m has 12% oven door sealing length more as possible leakage source.

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2.1.2 Operation / investment

Reduced number of pushing per day of the “jumbo ovens” batteries allows having only 1 set of machine in operation instead of 2 for the conventional 6.25 m batteries, with advantages in terms of:

- Coke oven machine investment and operating cost.
- Ancillary plants investment cost (e.g. coal tower, quenching system, coke wharves).

Reduced number of pushing per day of the “jumbo ovens” batteries increases the battery life in comparison with conventional 6.25 m batteries. Referring to table 2 considering an average number of pushing that each oven can perform during its life, the result is that the expected lifetime is considerably increased.

Table 2. Battery Life comparison

	Conventional 6.25 m	Jumbo Oven
Coking Time	17 [h]	24.5 [h]
Oven width	410 [mm]	550 [mm]
Pushes per day per oven	1.41	0.98
Pushes per day per years	515	358
Expected Lifetime per battery (16000 pushes per oven)	31	44

Reduced number of oven and batteries has advantages in terms of manpower requirement and maintenance cost for all the plant.

2.1.3 Coke quality

The long coking time of the “jumbo oven” has positive effects in terms of CSR and CRI.

2.2 PAUL WURTH “JUMBO OVEN” TECHNOLOGICAL HIGHLIGHTS

2.3 Heating System

The coke oven battery can be operated with both coke oven gas (COG) and mixed gas (MG).
COG distribution pipes are located in the cellar, where 38 riser pipes embedded in the nozzle deck feed each heating wall (odd and even alternatively).
This solution (underjet type) allows a dedicated regulation of gas flow ratio on each heating flue.
In order to avoid graphite deposits in the refractory COG ducts, forced air connected to COG cocks is provided for de-graphitizing operation.
MG distribution pipe is located on pusher side; before reaching the heating wall, MG is pre-heated passing through regenerators for the optimization of heat consumption.
Waste gas coming from combustion is conveyed into waste gas channel on coke side (Figure 1).

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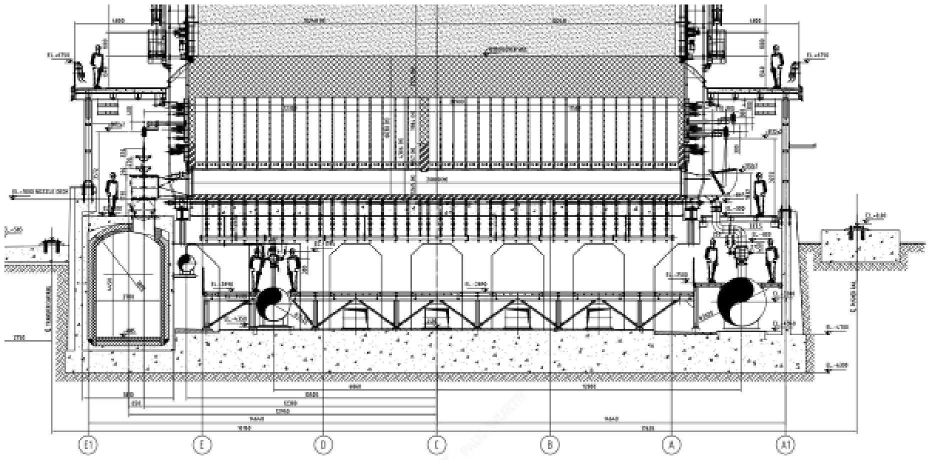

Figure 1 – Heating system cross section

Each heating wall is composed by 38 heating flues with the following configuration:

- Twin flue, with partial re-circulation of waste gases for low NOx production.
- 3 levels of staggered air inlet in order to minimize NO_x formation and keeping a proper vertical temperature distribution.
- Mixed gas and air flow rate easily adjustable by means of regulation plate placed in the bottom part of the regenerator level.

2.4 SOPRECO® Single Oven Pressure Control

The need to reduce the high gas emissions at the start of coke distillation and the intake of air through the oven doors at the end of the distillation phase represents an ecological and operating challenge for the owners of coke oven plants. Paul Wurth has therefore developed the SOPRECO® (Single Oven Pressure Control) which is capable of controlling the pressure for each individual oven in a coke oven battery.
The suction effect in the first phase of coking is optimized, along with an enormous reduction of the emissions through poorly sealed doors caused by excess oven pressure. During the coking process, the pressure control guarantees a minimum positive pressure at the base of the oven, also in the end phase, thus preventing air intake into the ovens.
Each single oven can have an independent set point provided that there is a ΔP between the collecting main and the oven.
SOPRECO® is suitable to be installed on both stamp top charging batteries.
SOPRECO® regulation system consists of the main following equipment (Figure 2):

- Oven pressure measurements (probe plus transmitter)
- Dedicated PLC for pressure control loop measurement
- SOPRECO valve with relevant actuator

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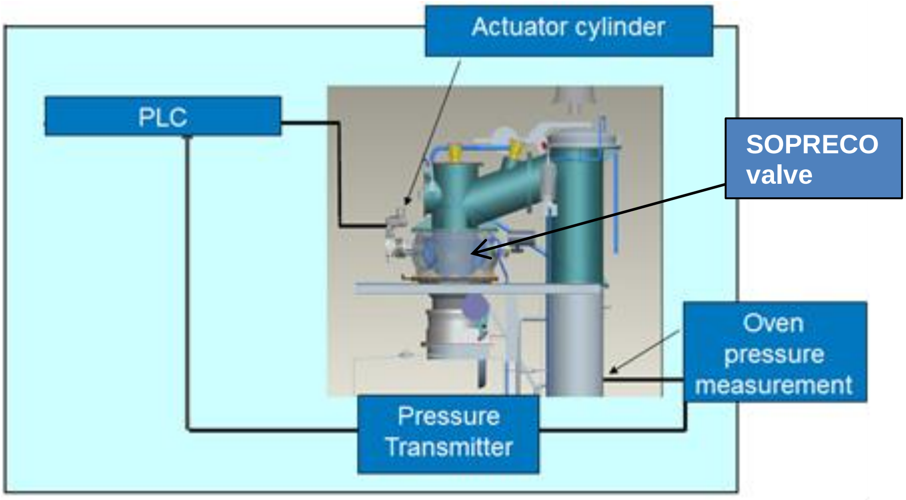

Figure 2 – SOPRECO® concept description

Pressure probes are installed at the bottom of the ascension pipe and are continuously flushed with nitrogen in order to avoid possible clogging, pressure measurement point is configured in a particularly easy way for cleaning.
All control and supervision functions relevant to Sopreco® system are done through a PLC and supervision station (HMI).
The interface with the plant will be designed to receive all analogic signals from the pressure probe and to give the control signal to the Sopreco® valve positioner.
The most important function of PLC is the pressure control loop which shall keep constant at a given value the gas pressure in each single oven.
The PLC will be a part of the general control system configuration of the battery and will exchange some information to optimize the pressure control and to manage the pushing/charging sequence.
The HMI will be realized to allow operators and technicians to control in the best way the process as well as to inform about the status of the process, alarms, reports, plant overview, and detailed information for each single oven.
SOPRECO® valve is a special regulating valve essentially composed by a funnel which, thanks to a spherical gate can be partially opened or closed in order to change the gas flow free section and consequently control the oven pressure.
SOPRECO® valve is placed between the isolating valve and the elbow of the ascension pipe, thanks to the isolating valve the oven can be completely isolated from the collecting main as per traditional battery functioning.
SOPRECO® concept layout is shown in (Figure 3).

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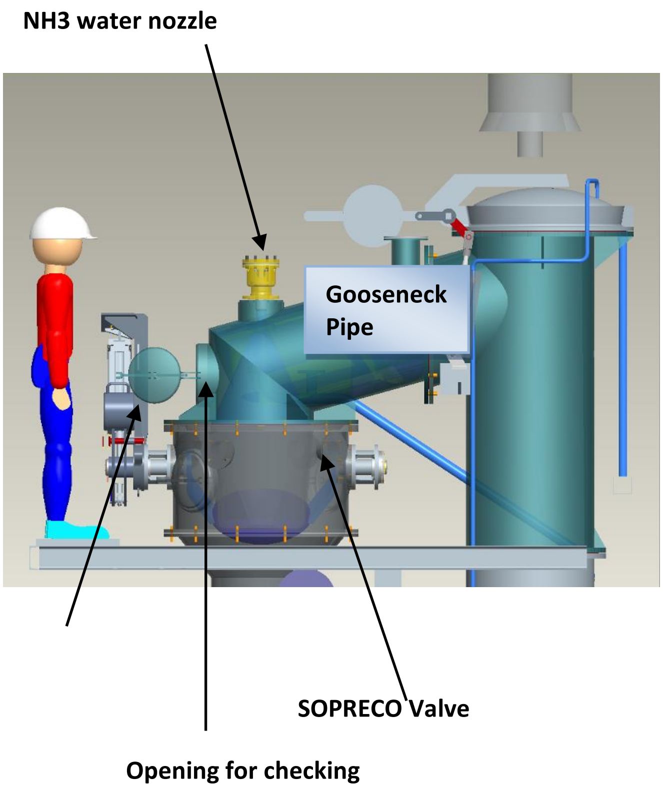

Figure 3 – SOPRECO® concept layout

3 STAMP CHARGING TECHNOLOGY

This technology was born in Silesia and Poland more than 100 years ago and then developed also in the South-West of Germany, in the Saar area, where local mines of low quality coal was present.
The most favorite reason to adopt stamp charging coke oven battery is the possibility to reduce cost utilizing low quality coal (cheaper coal with high volatile matter and low coking rate) that generally it is not utilized to produce blast furnace coke.
Considering the figure 4 the hot metal cost break-up at TATA Steel [1], it is clear that the coke cost makes up to 47% of the steel cost.
Therefore it is logical that availability, quality and price of coal are key concerns to reduce steel cost production.

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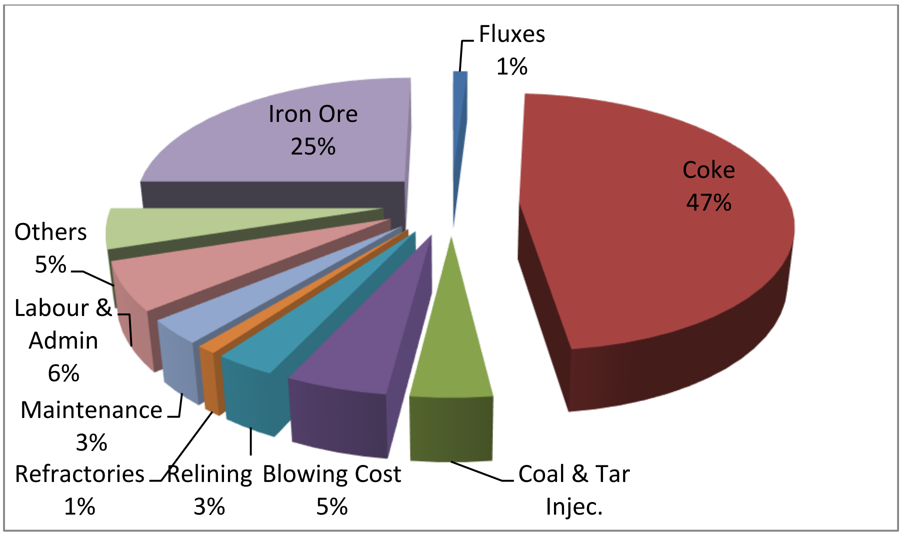

Figure 4. Hot metal cost break-up @ Tata Steel [1].

In the last years Paul Wurth (PW) has achieved brilliant results in the international coke making market becoming a global top player also in this technology.
The most remarkable projects that PW has already finalized are:

Table 3. ZKS Dillinger Hütte Plant (Germany) Main Figures

Item	Q.ty
Coke Production	1,240,000 [t/y]
Ovens Number (B1+B3)	90
Effective length of coking chamber	16,400 [mm]
Full height of coking chamber	6,250 [mm]
Average width of coking chamber	500 [mm]

All dimensions are given in hot conditions

- Ongoing Projects:

Table 4. Bhushan Power & Steel LTD Plant (India) Main Figures

Item	Q.ty
Coke Production	1,092,000 [t/y]
Ovens Number (B1+B2)	102
Effective length of coking chamber	16,400 [mm]
Full height of coking chamber	5,500 [mm]
Average width of coking chamber	500 [mm]

All dimensions are given in hot conditions

All of the above projects are characterized by state-of-the-art solutions as far as coke making technology and environmental measures are concerned.
This paper will outline the main technical data and solutions applied in these projects.
Basic and detail engineering, erection and start-up have been carrying out not only on the basis of the long lasting experience and know how available in PW, but also through the extensive utilization of advanced engineering and modelling tools recently developed in house.

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3.1 Paul Wurth Stamp Charging Technological Highlights

In stamp charging coke oven plants, the coal is compacted outside the oven chamber to form a coal cake with a density of about 1,1 t/m^3 and then introduced inside the oven from pusher side by the charging ram.
Such different charging process requests specific battery characteristics.

3.1.1 Strongest battery structure

In comparison with traditional top charging batteries, stamp charging design has to take into account higher stresses in the brickwork structure due to higher swelling pressure and due to the more severe pushing and charging operation.
For the above reason Paul Wurth batteries have a SUGA index higher than 12 kPa, strongest heating wall refractory design and optimized bracing system force distribution.
Such result is obtained utilizing an in house developed tool for the bracing System to verify the oven structure during the operation and pushing/charging.
The goal of the bracing system is to give suitable compression forces to the refractory in order to eliminate the tensile stresses in the heating walls and maintain close the joint between the refractory bricks.
The design of the system has been done on the following steps:

1. Definition of the bracing system basic dimension (wall protection plate, buckstay, door frame, heads of the heating wall) and preliminary force distribution. FEM Analysis of the heads of the battery (wall protection plate + door frame + heating wall heads) under thermal and mechanical forces (Figure 5).

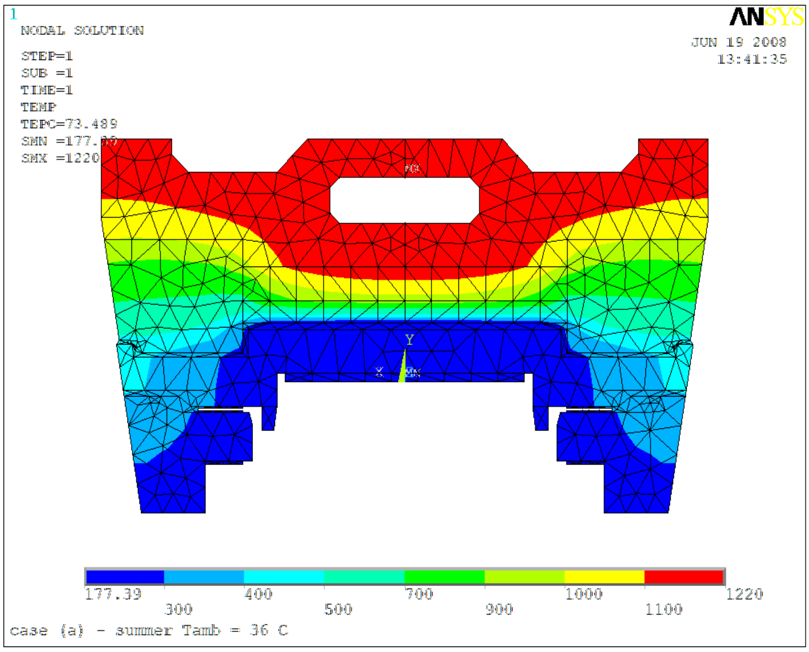

Figure 5. FEM simulation of battery head.

2. FEM Analysis of the heating wall (Figure 6) with the application of the bracing forces calculated under the following operating condition:

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- Tensile stresses generated by swelling pressure (coal distillation);
- Tensile stresses generated by oven pushing / charging.

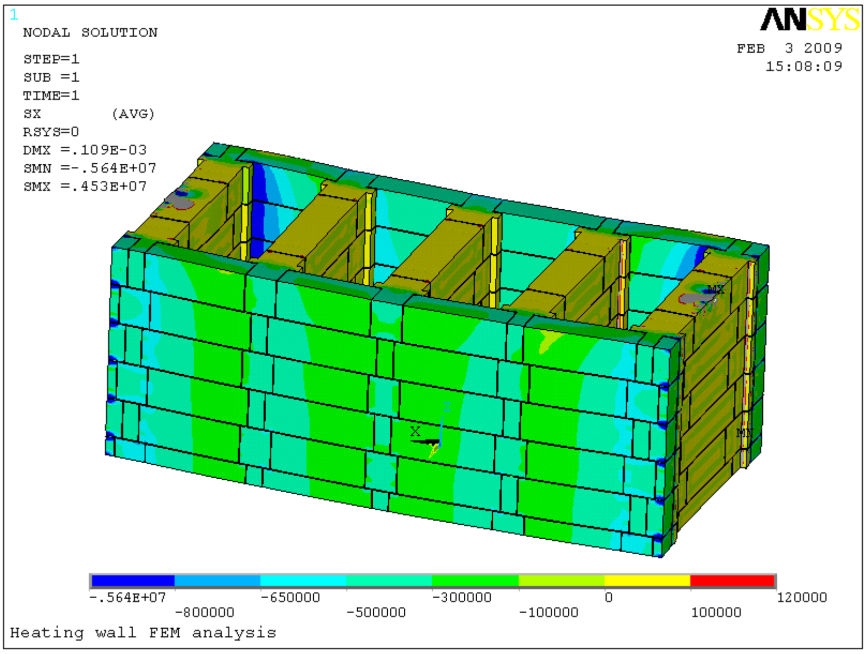

Figure 6. FEM simulation of heating wall brickwork.

Nevertheless such calculation is also useful to establish the best configuration in terms of liner / binder bricks joints configuration.
In order to give the calculated compression forces to the different heating walls portions the Wall Protection Plates have been designed as different individual pieces (Figure 7).
This special design solution ensures that the bracing system is always in contact with the refractory through the wall protection plate under normal operating thermal condition of the battery.

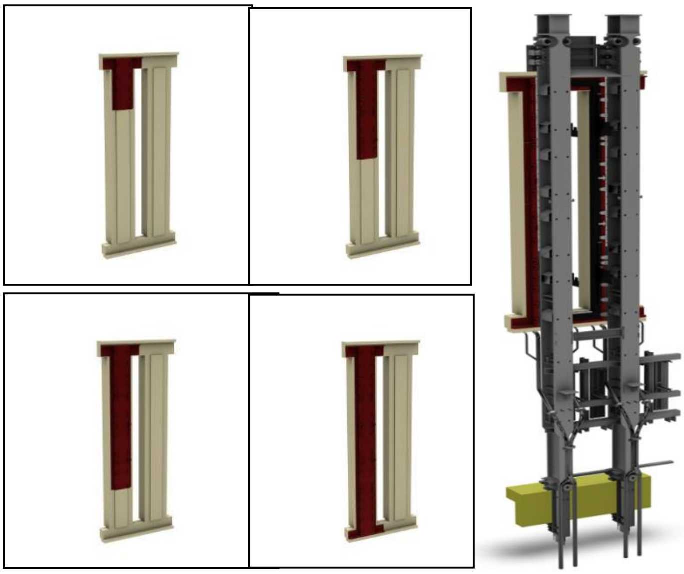

Figure 7. Wall Protection Plate and Bracing System.

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3.1.2 Optimized Combustion

Due to the higher and more uniform coal density of the coal cake, the stamp charging battery from under-firing point of view has higher specific consumption and requires a better vertical temperature distribution in the heating wall.
In order to achieve such targets and ensure the environmental requirements, a particular care has been put in the design of the combustion system making use of Flame Analysis (FAN): a 3D fluid-dynamic model which optimizes the design of the heating walls fluid circulation system.
This tool was decisive to define dimensions and positions of the staggered (2 levels) combustion air inlets (Figure 8) and waste gases partial recirculation.

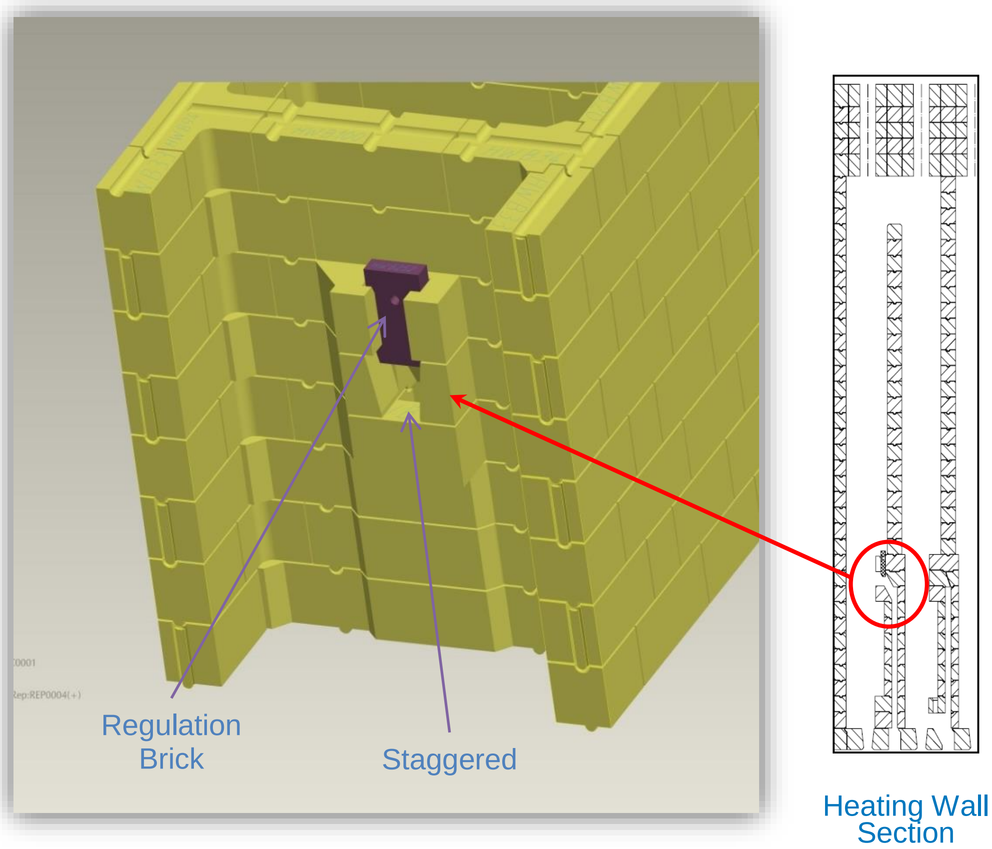

Figure 8. Heating wall – staggered 2^{nd} air inlet level.

3.1.3 Smokeless Charging System

In Stamp charging coke oven batteries, the oven remains open on pusher side for all the charging period and as consequence a huge amount of charging gas will be generated.
In order to avoid emission in atmosphere an appropriate smokeless charging system should be implemented.
The Smokeless Charging system adopted in the Paul Wurth coke oven batteries and proved in the ZKS coke oven batteries, is the combination of:

1. SOPRECO®
2. Charging Gas Transfer Car (CGT)
3. Pushing Sequence 2-1

The SOPRECO® is a special control valve placed between the isolating valve and the gooseneck of the ascension pipe (Figure 9). SOPRECO® is able to maintain positive pressure in the oven up to the end of distillation phase. SOPRECO® allows the

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collecting main to operate under negative pressure without affecting the oven life and guaranteeing more suction in the ovens during charging (also avoiding high pressure ammonia water installation) and during the first distillation phase with consequent and drastic emission reduction of the ovens in the atmosphere [2].

Figure 9. SOPRECO® valves installed in ZKS coke oven batteries.

The Charging Gas Transfer Car (CGT) is a machine located in the oven roof of the coke oven battery and equipped with two jumper pipes. During coal cake charging CGT connects the charged ovens "n" to the ovens "n+2" and "n+4", in a pushing sequence 2-1 (Figure 10).

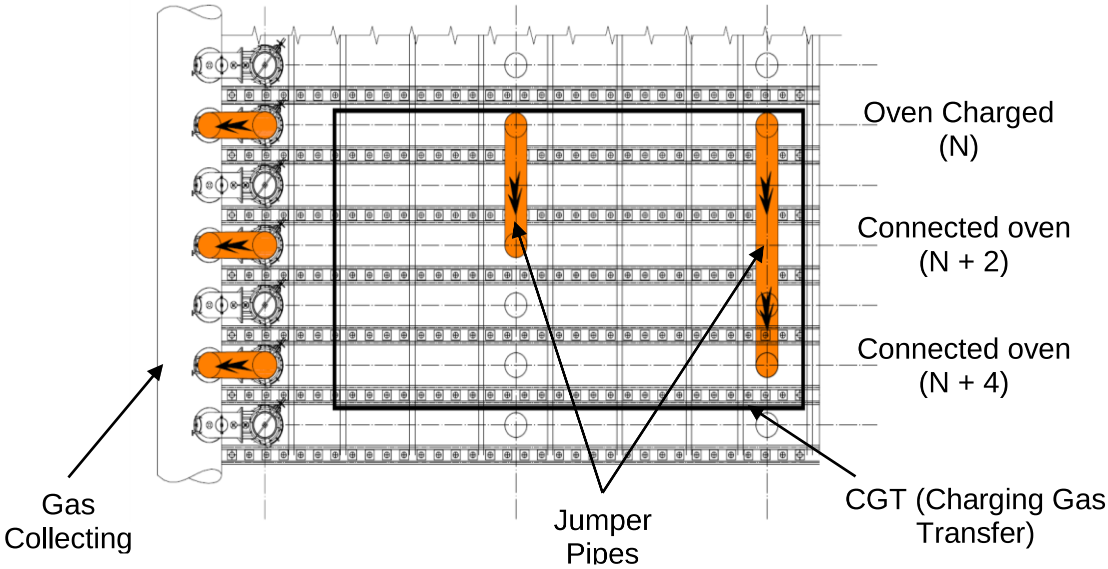

Figure 10. PW Smokeless charging system.

The smokeless charging system sequence is described in the below steps:

- The gas collecting main pressure is set to negative value.
- The charging oven "n" is connected with Jumper pipes with two ovens ("n+2" and "n+4") at the end of the distillation process.

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- The pressure in the oven not charged or not connected to the charged oven remains at positive value due to the SOPRECO®.
- Charging gas is drawn in the gas collecting main by the three stand pipes.

In this way is possible to charge stamp charging oven with no emissions in the atmosphere.

4 CONCLUSIONS

PW, thanks to the application of innovative calculation methods, has optimized the battery design for top and stamp charging, overcoming specific problematic issues, giving constancy to operational performances and, above all, achieving the most stringent environmental parameters complying with all international standards in force.

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