FIRST SUCCESSFUL PULVERIZED COAL INJECTION START-UP IN RUSSIA AT EVRAZ NTMK[1]

Alexey Kushnarev[2]
Philipp Bermes[3]
Pierre Mahowald[4]
Georges Stamatakis[5]
Stephan Becker[6]
André Oliveira[7]
Jean-Paul Simões[8]

Abstract

EVRAZ is a large vertically-integrated steel and mining company with operations in the Russian Federation, Ukraine, Europe, USA, Canada and South Africa and employs approximately 110 000 people. EVRAZ is among the top 20 largest steel producers in the world. EVRAZ NTMK located in Nizhny Tagil, Russia is an integrated steel production plant, which in 2010 produced 4.3 million tons of hot metal with two modern blast furnaces. Having made good experience with Paul Wurth installations such as copper staves and their compatibility with the high productivity operation of NTMK, Paul Wurth was awarded with the installation of grinding and drying as well as pulverized coal plant. On 19.12.2012 EVRAZ Nizhny Tagil Metallurgical Plant started successfully the injection of pulverized coal into their blast furnace Nr. 5. As scheduled, blast furnace No. 6 followed approximately 1 month later. Initially operated at natural gas injection rates of 90 kg/tHM, both blast furnaces are now operated at combined natural gas and pulverized coal injection rates above 180 kg/tHM. The ramp-up to nominal injection rates was achieved in less than 2 months after PCI start-up. In order to realize this ambitious target and to avoid any negative impact on the production rates, Paul Wurth actively assisted NTMK in the PCI ramp-up process. Production rates of 3.9 t/d/m³ have been reached in average.

Keywords: Pulverized coal injection; Commissioning; Operational results; Ramp-up; Co-injection.

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2 *Managing director, EVRAZ NTMK, Nizhniy Tagil, Russia*
3 *Process engineer, Paul Wurth S.A., Luxembourg, Luxembourg*
4 *Head of injection technologies, Paul Wurth S.A., Luxembourg, Luxembourg*
5 *Head of process, Paul Wurth S.A., Luxembourg, Luxembourg*
6 *Project manager, Paul Wurth S.A., Luxembourg, Luxembourg*
7 *Metallurgy Process Analyst, Paul Wurth Do Brasil*
8 *Head of BF Plant & Process, Paul Wurth S.A., Luxembourg, Luxembourg*

1 INTRODUCTION

Among the main advantages of PCI technology are the improvements of blast furnace process efficiency an increased productivity and thus a high level of performance and competitiveness in the global market. From an economical point of view the benefit is that a significant amount of metallurgical coke is saved. This is a result of the much higher possible injection rates with PCI compared to natural gas and the substitution of natural gas by cheaper coal in a market with constantly increasing gas prices. Currently the cost saving effect is expected to be approximately $ 10 per ton of crude steel and is estimated to increase significantly in future.

Paul Wurth's contractual scope of supply comprised all key components required for the grinding and drying cycle including the grinding mills, the injection plants with static distribution of pulverized coal as well as the complete automation system of all involved plant units. The latter is also including the raw coal handling area.

The new technology was realized at first in the steel works of NTMK. EVRAZ NTMK located in Nizhny Tagil, Russia is an integrated steel production plant, which in 2010 produced 4.3 million tons of hot metal with two modern blast furnaces. The PCI project for NTMK considers a split up of all equipment parts of the PCI system into two batches, to be procured, installed and commissioned in two different stages. Stage no. 1 includes the PCI at the existing blast furnaces 5 and 6 whereas PCI for the future blast furnace no. 7 will be realized in stage 2.

Blast furnaces no. 5 and 6 at NTMK, now equipped with PCI, share the following characteristics:

Table 1 – Characteristics no 5 and no 6 Blast Furnace

Hearth diameter	9,7 m
Useful Volume	2.200 m³
Daily production with PCI	6900 t/d according to contract 7200 t/d actual
Number of hot blast tuyeres	22
Number of tapholes	2
Hot blast temperature	1.250 °C
Hot blast pressure	≤ 4,0 bar g
Top pressure	≤ 2,5 bar g
Cooling	Copper staves in bosh belly & lower shaft; convection cooling

In the following the main characteristics for GAD and PCI plant in stage 1 are given. Figures for stage 2 are indicated in brackets.

Table 2 – Key figures at of the PCI plant at NTMK

GAD plant	
Mill nominal grinding capacity	80 t/h
Number of mills	1 (+ 1)
Total grinding capacity	80 (+ 80) t/h
Loesche mill type	LM 35.3 D
Raw coal bin capacity	2 x 480 m3
PCI plant	
Pulverised coal storage capacity	3 x 1000 m3
Global flow to BF	BF 5 51,8 t/h – 180 kg/tHM
Global flow to BF	BF 6 51,8 t/h – 180 kg/tHM

Being specialized in complex PCI processes with high requirements regarding flexibility and operational availability, Paul Wurth provided the suitable solution to each task. Paul Wurth took charge from the concept engineering to the realization up to the start-up of the plant. The project scope and the included services covered:

- Concept evaluation (also raw coal processing)
- Evaluation of optimal process technology
- Basic engineering
- Selection and supply of core components
- Design and supply of the automation system (MCC's, RIO's, PLC's and software)
- Advisory services for erection of the plant
- Start-up and commissioning
- Performance Test
- Documentation
- Training of customer´s staff
- Metallurgical assistance

Figure 1 – NTMK site.

Besides the supply of all technological equipment a highly automated control system was realized by Paul Wurth for the complete plant including the control of the raw coal handling area. Optimal process adaptations following the requirements of the blast furnaces and the properties of the raw coals are realized with an intelligent program code. The process visualization system includes the collection, evaluation and storage of process and production data, equipment diagnostics and generating informative process trends.
The project was realized in close cooperation between the project team of NTMK, the engineering Russian company METPROM and Paul Wurth. The NTMK project team was supported throughout all stages of the project by providing appropriate management tools (planning, erection & commissioning assignments), documentation and manuals. Building and pipeline engineering as well as piping line construction was mutually developed by focusing on the technological demands and following the Russian standards and safety requirements.
Less than 3 years passed between signing of contract and achievement of nominal injection capacity. In the following the project milestones are detailed:

Project Milestones

Contract signing:	April	2010
Ground breaking:	Dec.	2010
Start delivery:	Mai	2011
Start mech. erection:	June	2011
Commissioning start:	August	2012
Start-up of PCI BF 5:	December	2012
Start-up of PCI BF 6:	January	2013
Nominal injection rates	February	2013

During mechanical and electrical installation phase the supervision of equipment installation was controlled by the supervisors from the main contractor

Co. MOSTINGSSTROY and Paul Wurth. Practical installation experience and close cooperation with the Russian erection companies was the base for a professional processing of all installation activities.

Site Responsibilities:

MOSTINGSTROY	Main Contractor
METALKONSTRUKT	Plate work and steel structure
PROKATMONTASCH	Installation of technological equipment, large size piping
URALDOMNOREMOND	Installation of small size piping Distribution towers
SERVICEAUTOMATIKA	Installation of EIC
TES	Small size piping,

Process Support for BF operation

To facilitate the adaptation of the new PCI technology NTMK and Paul Wurth have agreed on a close collaboration in terms of blast furnace process during the ramping-up phase of PCI.

It has been especially demanded by NTMK that Paul Wurth delivers metallurgical assistance not only in the commissioning of PCI and GAD but also in the following operation of the blast furnaces with PCI.

This approach of NTMK and Paul Wurth has proven its effectiveness as can be seen from the operational results. Highly qualified operational skills combined with the right support delivered top class performance and an adaptation to a new technology in shortest time.

2 SUPPLIED TECHNOLOGY

2.1Raw Coal Handling

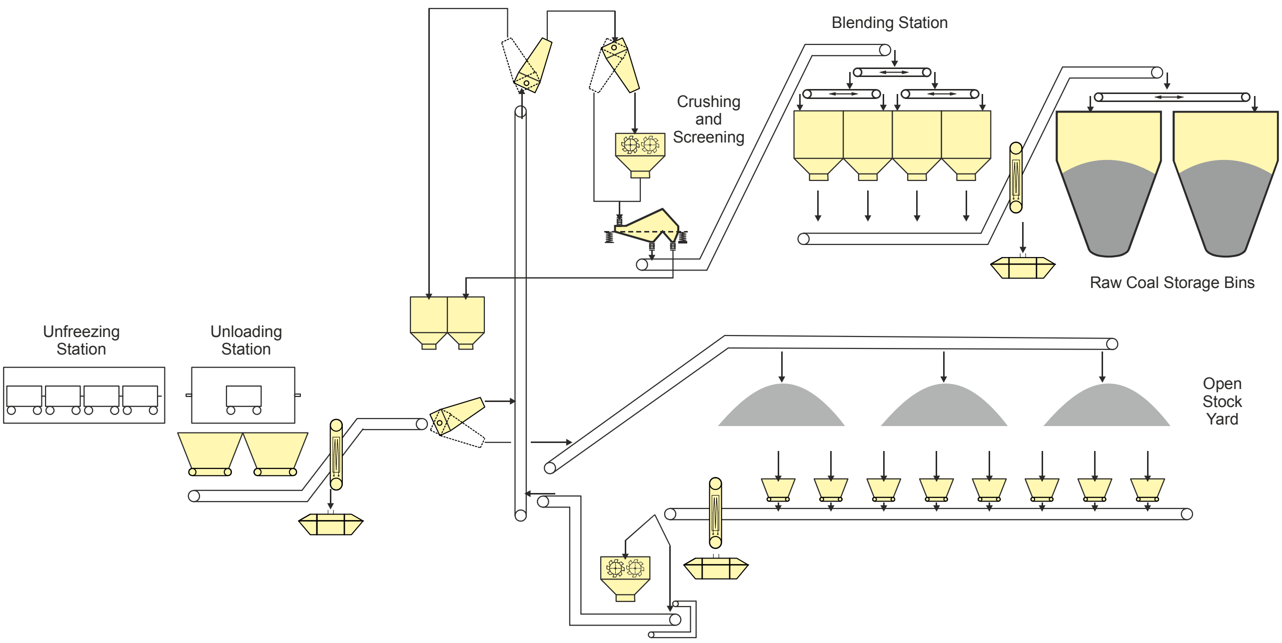

Figure 2 – Raw coal storage plant - general overview.

Raw coal is delivered to the site by train. Due to the harsh climate conditions an unfreezing station before the unloading was foreseen. From the unloading station the raw coal can be forwarded either directly to the crushing and screening station or to

an open field yard. To protect the installations from metallic particles transported with the raw coal a system of metallic detector, deviation chute and several magnetic separators is installed.
In the crushing and screening station the raw coal is further threated to minimise the input of tramp material that may either damage the pulverising equipment or be turned into fibrous material which is difficult to remove from the pulverised coal. In the blending station several qualities of raw coal can be mixed together to achieve a constant raw coal quality. Finally the raw coal is delivered to the raw coal storage bins.

2.2 Grinding and Drying Plant

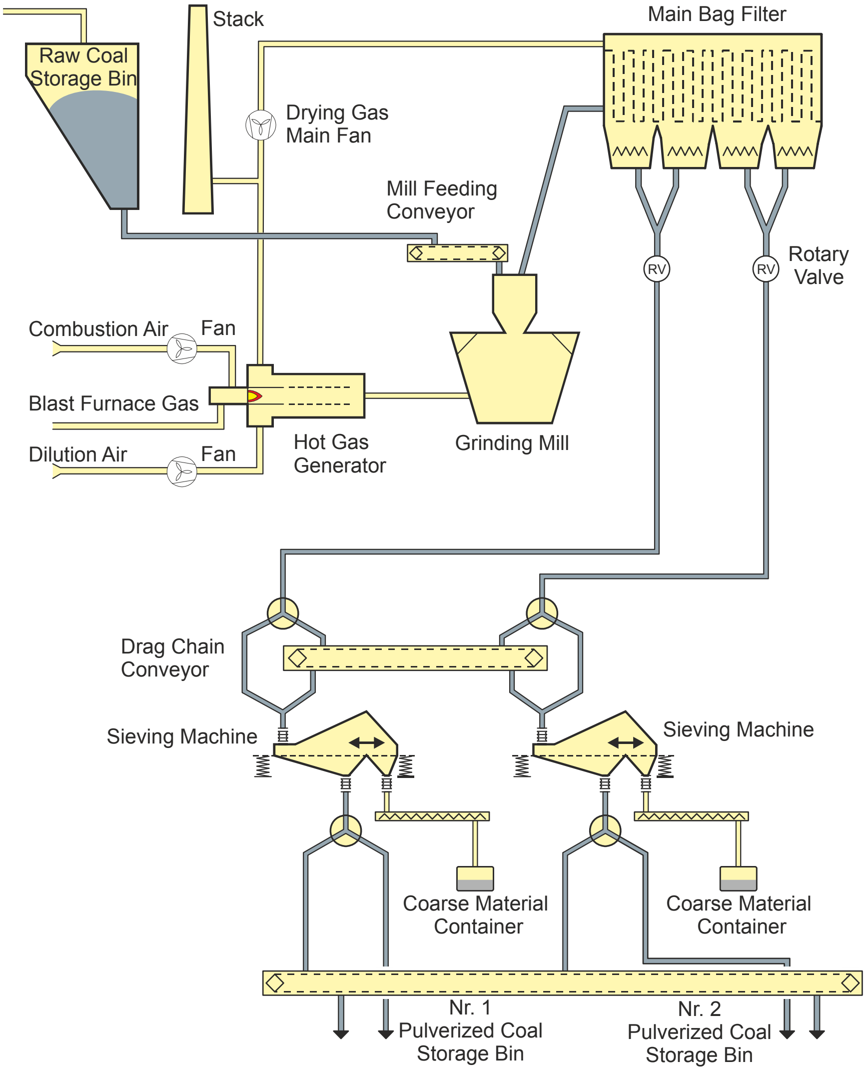

Figure 3 – Grinding and Drying Plant - General Overview - Stage I

The mill dosing conveyor is feeding a constant raw coal mass flow from the raw coal storage bin to the vertical roller mill. The mill throughput is regulated with the conveying speed of the mill feeding conveyor. Inside the mill, the raw coal is grinded to fine pulverised coal, classified and dried with drying gas. The drying gas stream is produced by the drying gas main fan and heated up in the hot gas generator by burning blast furnace gas. In the main bag filter the pulverised coal discharged from the mill by the drying gas and the dynamic classifier is separated from the drying gas.

The sieving machines separate the remaining coarse material from the pulverised coal. The pulverised coal with the required granularity falls from screening machines into the pulverised coal storage bins which are connected below the screening machines. For full flexibility the pulverized coal may be optional discharged via a reversible drag chain conveyor to Bin 1 or bin 2.

Table 3 – Key data for Grinding and Drying Plant

Raw coal storage bin	480 m^3 (~ 4 h at nominal pulverised coal output)
Mill type	Loesche LM 35.3D Vertical roller mill with integrated dynamic classifier
Mill nominal throughput	80 t/h
Hot gas generator	Loesche LF22 / MLB13
Fuel	Blast furnace gas
Main burner nominal output	13,000 kW
Main filter filtering surface	3500 m^2
Main filter - number of sleeves	1512
Main fan nominal power	1120 kW
Sieving machines nominal throughput	96 t/h
Sieving machines scalping size	90 µm
Drag chain conveyor nominal conveying capacity	96 t/h

2.3 Pulverised Coal Injection Plant for BF5 and BF6

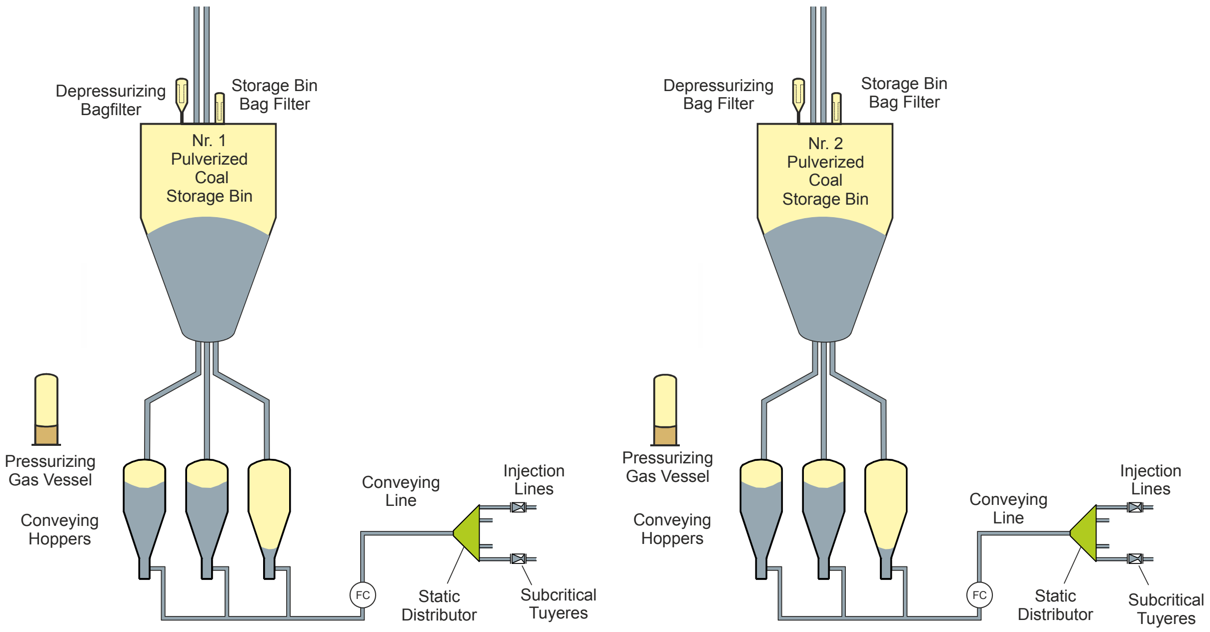

Figure 4 – Pulverised Coal Injection Plant - General Overview.

The two pulverised coal injection plants are identical in layout and size. The pulverised coal from the grinding and drying systems is buffered in the pulverised coal storage bins. The conveying hoppers are charged by gravity from the pulverised coal storage bins. The conveying system is based on a 3 hopper system with nitrogen recovery. The global flow rate in the conveying line is controlled with a Gritzko® Flow Rate Control Valve in combination with a Cabloc® flow measurement device. In the static distributor the pulverised coal flow is split-up to the individual injection lines. The injection lines are equipped with sub-critical tuyeres and line length equilibration to enhance the equal distribution to the individual injection lances.

Table 4 – Key data for Pulverised Coal Injection Plant

Pulverised coal storage bin volume	2x 1.000 m^3
PCI System	2 + 1 hopper design
Special features	Nitrogen recovery
Conveying hopper volume	28 m^3
Global Injection Flow Rate Control	Control is performed by means of Cabloc flow meter and a GRITZKO® flow control valve
Accuracy of Global Injection Flow Rate Control in the PCI Plant	± 2,0 %
Distribution Principle	Static Splitter with coal tuyeres: Equal Distribution is obtained by means of sub-critical tuyeres and length balanced lines
Accuracy of Equal Distribution of Global Injection Flow Rate onto the Injection Lines	± 5,0 %
Nominal injection rate per Blast Furnace	2x 51,8 t/h

3 RAMP-UP

For the ramp-up and its precedent planning it was important to consider the specific operation conditions of blast furnaces 5 and 6. NTMK has trimmed their blast furnace process very specifically to their requirements. Among these requirements are the processing of vanadium ores with high titanium content and an extremely high productivity operation in the magnitude of 4 t/m³/d on the working volume.
For the processing of titanium vanadium containing ores special attention needs to be paid to the thermal regulation to avoid hearth clogging by slag at cold temperatures and titanium compounds in case hot metal temperature reaches an upper limit. Furthermore the operation at high productivity makes it absolutely necessary to monitor closely the raw material characteristics and to control the blast and injection conditions. As a result to these preconditions it is of utmost importance to operate the blast furnace in a very rigid regime as the operation window is very narrow and the tolerance for errors close to zero.
PCI was ultimately introduced to make use of its capabilities of decreasing coke rate, increasing productivity and improving the thermal regulation of the blast furnace. Yet, during the ramp-up period of the PCI the blast furnace process is undergoing changes.
Coke rate decreases, the charging needs to be adapted and the blast furnace needs to be stabilized under the influence of the changing conditions in the raceway and the resulting changes in the gas distribution. Therefore the PCI rates are gradually increased up to target levels during the ramp-upand the premise for this period was to avoid as much as possible any impact of the injection on the operation results of the blast furnace, to keep the productivity in the same range as before PCI and finally to do so as fast as possible to profit quickly from the full capacity of the PCI installation.

Already before the hot commissioning of the PCI, Paul Wurth provided NTMK with a detailed study on PCI operation. Main target of this study was to support the operation people in their preparation of the start-up and to support the management in the operation planning.
In addition for the study provided a first production estimation, evaluation of different coals and evaluation of the necessary utilities.
Key elements of this study were:

- Calculation of individual operation points during the ramp-up period
- Evaluation of different operation conditions
- Evaluation of impact of different injection coals
- Detailed operational set-points
- Flame temperature calculation
- Replacement ratio calculation
- Exact timing
- Go/no-go/step-back criteria
- Reaction in case of PCI stoppage
- Production estimation

3.1 Assistance During Ramp-Up

Paul Wurth process support was present during the entire ramp-up period. A team of blast furnace process experts arrived prior to the hot commissioning to discuss the main operation conditions and the critical points with NTMK operation people. Their presence lasted till stable PCI rates of 150 kg/t were achieved.
During the ramp-up the main tasks included:

- Coordinate commissioning PCI/GAD with BF operation
- Continuous adaptation of program
- Supervision of operation
- Review of operation

3.2 Coordinate Commissioning PCI/GAD with BF Operation

During the ramp-up of PCI the specific requirements of PCI plant, GAD and blast furnace need to be coordinated. This is especially important at the beginning when PCI rates are low. During this phase GAD needs to be operated in start-stop mode. Operation time of the PCI in regard to blast furnace acceptance of coal and capacity of coal in storage bin needs to be coordinated.
It is important to have specialists knowing GAD, PCI as well as the blast furnace process in order to coordinate the ramp-up.

3.3 Continuous Adaptation of Program

The initial planning is always based on certain assumptions of the raw materials in use and the operation conditions. It is therefore necessary to adapt the initial planning during the ramp-up accordingly.
In order to establish smooth operation conditions and to keep the operation as stable as possible during the transition from NG to PCI Paul Wurth specialists adapted the planning constantly to the reactions of the blast furnace and extended it by the by new information arriving such as changing coal or raw material characteristics.

3.4 Supervision of Operation

During the critical phases, mainly directly after the start-up and at each transition step, the supervision was 24 h around the clock. During this time the training of the operators continued. Whenever needed recommendations regarding new blast furnace set-points and charging were given. Due to the very high operational skills of the NTMK personal this type of recommendation shortly became obsolete for the everyday operations such as start and stop of PCI or hot metal temperature control with PCI.
After this the supervision concentrated on monitoring the operation to avoid troubles from unforeseen situations, and to provide general recommendation on the target set-points for the ramp-up curve.
The blast furnace conditions allowing for an increase of the PCI rate at every step of the ramp-up were mutually discussed and observed.

3.5 Subsequent Analysis and Recommendations for Improvement

In a later analysis the past days were analysed in detail and points of improvement were highlighted.

4 OPERATIONAL RESULTS

After the start up, the grinding and drying system was fine-tuned and tested with different raw coal qualities. The contractual requirements concerning the properties of the pulverised coal (granularity 80% < 90 μm, moisture < 1.5%), could be fulfilled with different supplied coal qualities, actually the installation could be operated at 10% above the nominal output of the grinding and drying system.
In the pulverised coal injection plant all the contractual requirements could be fulfilled. The global injection flow rate showed a very stable behaviour over the complete control range of the global flow rate, even during the switch-over from one conveying hopper to another. The results concerning the important values for the equal distribution in the injection lines were very satisfying (contractual requirement: <5% deviation), this to avoid negative influences on the blast furnace operation.
After 43 days of operation of the installation, a total injection rate of 190 kg/t consisting of 150 kg/t coal and 40 kg/t natural gas was achieved. Except for the very first days of operation the production rates of the blast furnace and the hot metal characteristics were at the same level or above their characteristics before the PCI start.

5 CONCLUSION

The EVRAZ NTMK site is now operating the first pulverized coal injection system in Russia. Even on those highly efficient and thereby also very sensitive blast furnaces the ramp-up in PCI rate could be performed in very short time with almost no noticeable impact on production rates or hot metal temperatures and silicon contents. It led to a significant reduction in coke rate and provides the possibility for future increases in blast furnace productivity and operation stability.