THE NEWEST GENERATION OF PAUL WURTH BELL-LESS TOP® BLAST FURNACE CHARGING SYSTEMS[1]

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Abstract:
The Paul Wurth Bell-Less Top® (BLT) is the industrial standard for iron blast furnace charging systems. Since Paul Wurth's invention of the BLT in the early 1970s the system has evolved with the changes in iron-making technologies and market conditions. With the latest demands for high charging equipment availability and maintainability – new developments have been recently implemented. The paper will cover the evolution of the Bell-Less Top®, the latest operational requirements and the latest new developments and solutions.
Key words: Blast furnace; Charging system; Furnace top; Burden distribution; Bell-less top, Paul Wurth Top. BLT.

A NOVA GERAÇÃO DO SISTEMA DE CARREGAMENTO DE ALTO FORNO TOPO SEM CONE DA PAUL WURTH

Resumo
O Topo sem Cone (Bell-Less Top® -BLT -) é um sistema de carregamento para altos fornos. Desde a sua criação no início dos anos 70 este sistema tem evoluído muito para atender novas tecnologias de fabricação de gusa e condições do mercado. Com as últimas demandas de alta disponibilidade e taxas de utilização cada vez maiores dos equipamentos de carregamento do topo, novos desenvolvimentos foram implementados. Este trabalho apresentará a evolução do Topo sem Cone (Bell-Less Top®), desde o seu primórdio os últimos desenvolvimentos e soluções técnicas.
Palavras chave: Alto forno; Sistema de carregamento; Topo do forno; Distribuição de carga; Topo sem cone.

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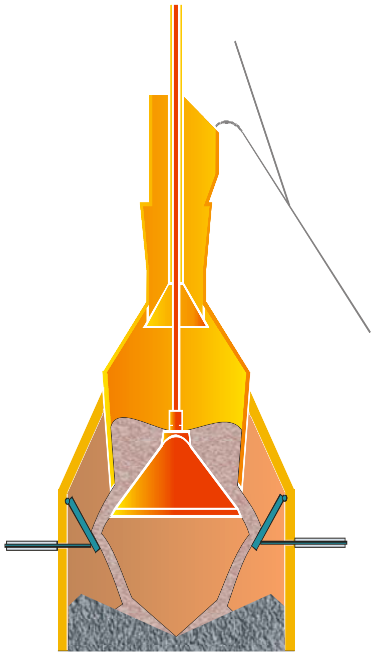
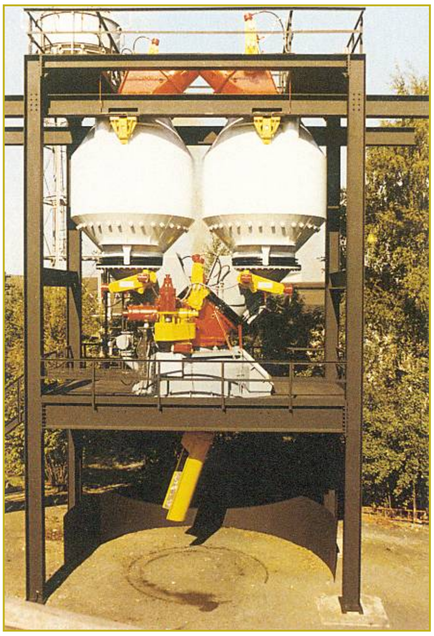
INTRODUCTION

As an industrial process with thousands of years of history - the iron blast furnace continues its evolution and development.
Changes in product market demand, environmental regulations, available raw materials, process know-how and available materials and components and technologies of furnace construction have encouraged changes in the 'current' blast furnace technology.
The latest, major surge in blast furnace process awareness came in the 1960s and 1970s. The influence of burden distribution control on the furnace process, its design and lifetime were finally realised and quantified.
The traditional use of bells (apparently introduced in about 1870) for pressure lock feed of raw materials at ambient pressure into the pressurised and dirty atmosphere of the furnace top had reached its service limits with the evolved furnace process. Addition of moveable armour to influence or improve burden distribution did not meet all the required objectives of charging system improvement.
To meet the demands of the time – to have reliable burden distribution control, to maintain high top pressure and to have a reliable and easily maintainable charging and burden distribution system was invented the Bell-Less Top® (BLT).The BLT was invented by Paul Wurth and the first unit was installed on Thyssen AG Hamborn BF4 in 1971. Blow-in of the furnace and successful operation of the first BLT started in 1972



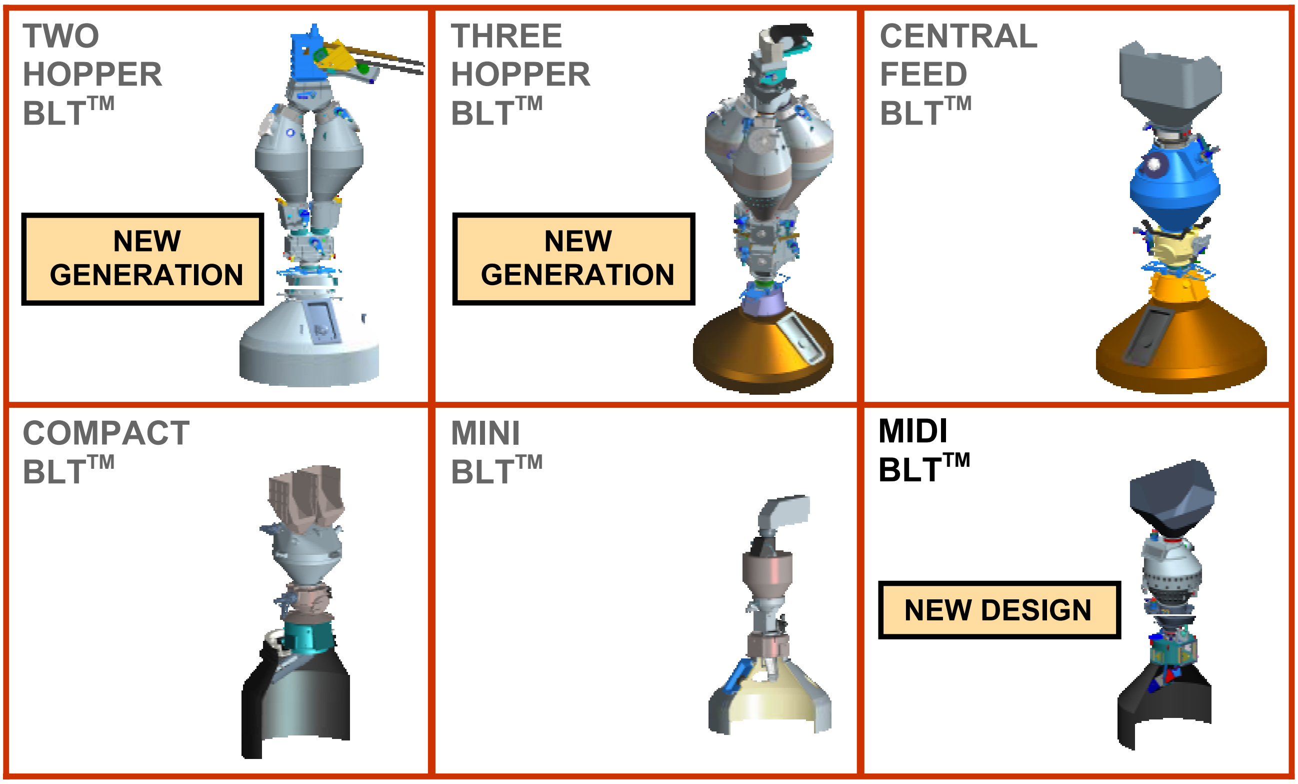
Double Bell and Movable Armour Top



The first BLT on its Test Stand

Many benefits were realised with the installation of the Two Hopper Top (PH-BLT) system. Improved burden distribution led to a reduction in fuel consumption, wall heat load and wears and provided increased productivity, daily production and stability of furnace operation.
The BLT became the industrial standard for BF charging systems. With a decade of improvements the Two Hopper BLT style of top became a strengthened, mature technology.

In the early 1980's further optimisation of the blast furnace process had shown the need for further optimization of charging technology. With decades of improvements of the raw material (leading to higher standards for coke, sinter, pellets and other feed material) it was felt that the top design or layout could influence material size segregation. The Central Feed Bell-Less Top – with several variations – was developed in order to maximise the opportunity for segregation control and optimised furnace burdening.
Other BLT configurations have been developed to suit other plant requirements such as very small or mid-size furnaces, limited space or for upgrading poor performing bell type or competitors' non-bell charging systems.



Different Styles of the BLT Technology

1.1 Raw Material Requirements

Continuing furnace process development led to very strict control on the raw material qualities. Modern stockhouses incorporate screening for almost every feed material to the furnace as the stockhouse is the last viable location to remove fines.
Unfortunately, as the stockhouse has become significantly more complicated, the screening process captures large quantities of fines and small pieces of feed material. These secondary materials have to be recycled in the sinter plant or have to be sold as by-products.
Market demand for raw materials is such that the furnaces often have to cope with changing availability of material with differing chemical and physical characteristics. Sometimes only poor grades of some raw materials are available. These issues further complicate the quantities and variety of secondary materials to be handled in the plant.

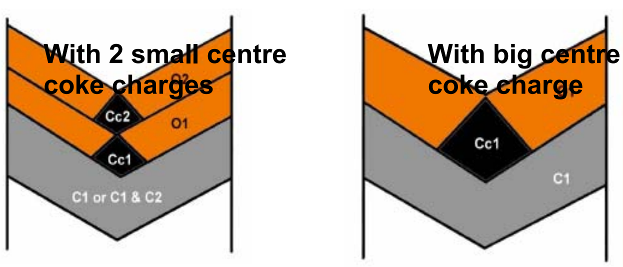
So the latest challenges for furnaces of all sizes are the handling of numerous raw materials – some of poor quality - and handling large quantities of secondary materials.
The blast furnace itself is recognized at the best means to use much of the generated secondary charge material. Small size (nut) coke (say 10 to 34 mm)) and small size sinter (say 4 to 8 mm) can be charged to the furnace – to optimise the gas aero-dynamics within the furnace. Use of this material – puts it to its originally intended service and reduces plant costs. With the know-how available to use the material within the furnace comes the problem of how to feed these materials along with the main feed material into the furnace,

1.2 Centre Charged Coke

The approach of centre-charging of coke to the furnace has been found to be highly beneficial to furnace operation. Specially separated large size coke (say larger than 60 mm) can be charged to the centre of the furnace. This develops a central chimney which greatly improves central gas flow and promotes the elimination of zinc from the furnace. The coarse coke will descend to the dead man without much size loss, thus improving dead man permeability and improving hearth drainage. The special coke is one more material that has to be sequenced through the top charging equipment.
However, few furnaces which are operating at high productivity have the flexibility in their existing charging equipment to introduce one more material.

1.3 Centre Coke Charging Chute

With market demand for iron – most operators are pushing their furnaces to maximize production. Rated or nominal capacity is often surpassed such that many furnaces are now operated at their design or peak production. Some furnaces have been able to use their over-filling or forced filling capacity (the ability of the stockhouse and charging system to feed raw material into the furnace at a rate faster than the furnace was designed to operate – intended for 'topping' up the furnace in case of abnormal operation – i.e. after 'slips') to support even 'above peak' operation. This type of operation does not normally lend itself to feeding additional types of material through the charging system (even if there are spare bins in the stockhouse).
Plant requirements have led to the need for charging equipment incorporating more flexibility in handling multiple raw materials and the specially developed center coke charging chute illustrated here below.



Requirement for New Charging Equipment

2.0 A Practical Example

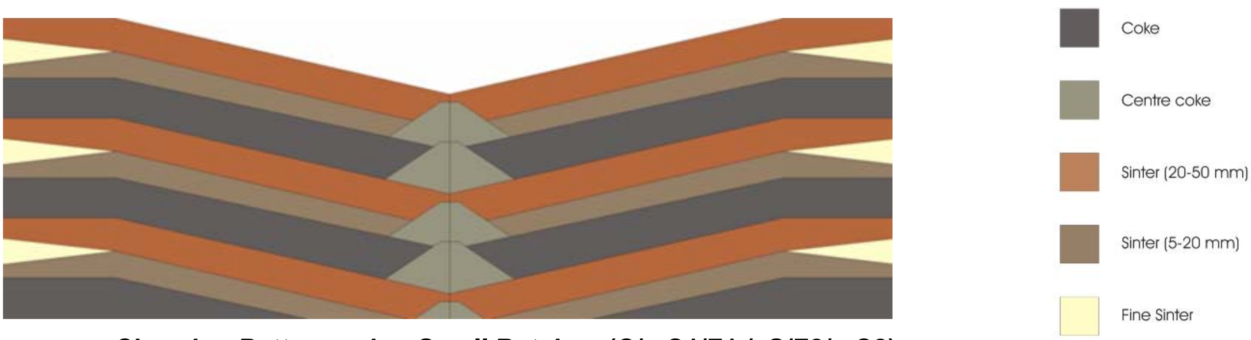
Rather than using the third hopper as a spare or solely to increase component longevity it can be used to achieve special charging patterns to further improve furnace operation.

Traditionally charging patterns have tended to use 'relatively' thick layers of ferrous burden – in part – to evenly distribute a homogenous raw material granulometry across the burden surface. However, distribution of smaller size raw material particles in the voids between the larger raw material particles – severely restricts the bed permeability and ascending gas flow.

With a Paul Wurth Three Hopper Top – it is possible to distribute two sized layers of raw materials – rather than one thick layer – thus ensuring superior bed permeability and controlled gas flow.

Thus - it is possible to use a sophisticated charging pattern with 2 types of coke (coarse coke for the centre small - centre coke batches (cC1, cC2)) and normal coke (C) for the rest of the furnace), 2 sinter batches with different particle sizes can be charged in two independent layers (F1, F2) and a layer (sS) of a mixture of small sinter with nut coke to be charged to the wall to reduce local wall gas flow.

This gives a charging pattern: (C/ cC1/F1 /sS/F2/ cC2).



Charging Pattern using Small Batches (C/ cC1/F1 /sS/F2/ cC2)

Thus, for new and existing furnaces the requirement has been identified to provide even more flexibility and performance in the charging equipment.

Paul Wurth has risen to the challenge again and has developed the latest generation of charging equipment – the New Three Hopper Bell-Less Top (3H-BLT).

The Three Hopper Bell-Less Tops were installed in the U.S.A. in 1977 and later in Japan – starting in 1990.

Table 1 – Earlier Style Three Hopper BLTs

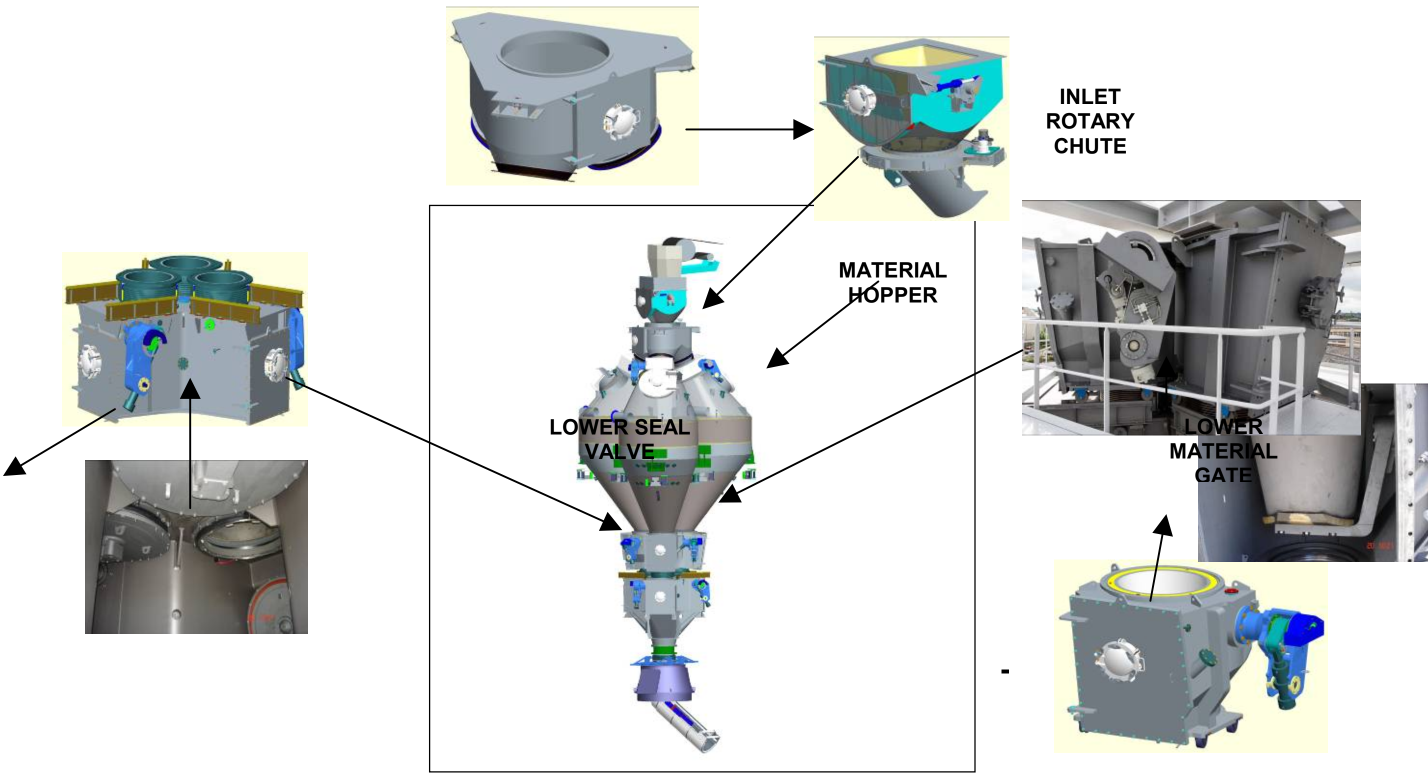
Works & Furnace	Hearth diameter [m]	BF Inner Volume [m^3]	Daily production [tHMpd]	BLT Type	Year of blow in
Sparrows Point - BF L	**13.5**	**3 763**	**8 330**	**3 Hopper**	**1977**
Mizushima – BF 3	**14**	**4 359**	**9 100**	**3 Hopper**	**1990**
Chiba – BF 6	**15**	**5 153**	**11 500**	**3 Hopper**	**1998**
Mizushima – BF 4	**14.4**	**4 826**	**10 000**	**3 Hopper**	**2001**
Mizushima – BF 2	**13.5**	**4 100**	**8 700**	**3 Hopper**	**2003**
Fukuyama – BF 5	**14.4**	**4 664**	**10 000**	**3 Hopper**	**2005**

The original reason for implementing this style was to maximise charging system availability. The concept was to have the third hopper available as a spare so that in the event of a problem with one of the two operating hoppers – the third hopper could be brought into operation and thus maintain design charging capacity. In real operation the three hoppers were all put in operation together.
Thus the charging for a 2 hopper operation was made using all three – no hopper was kept idle. If one hopper went out of service – the top operated as a conventional Two Hopper BLT until the third hopper was repaired. It was noted that the sequencing through all 3 hoppers of a Three Hopper BLT resulted in reduced valve operation frequency – thus increasing the lifetime of all the valves and hoppers.
The Japanese Three Hopper Top users recognised the ability of the Three Hopper Top configuration to support higher charging levels and to provide greater flexibility in charging multiple materials.

3.0 THE NEW THREE HOPPER BELL-LESS TOP® SOLUTION

The previous style of three hopper top was reviewed to see how it could be improved to suit the most recent operational requirements. The following changes were implemented:

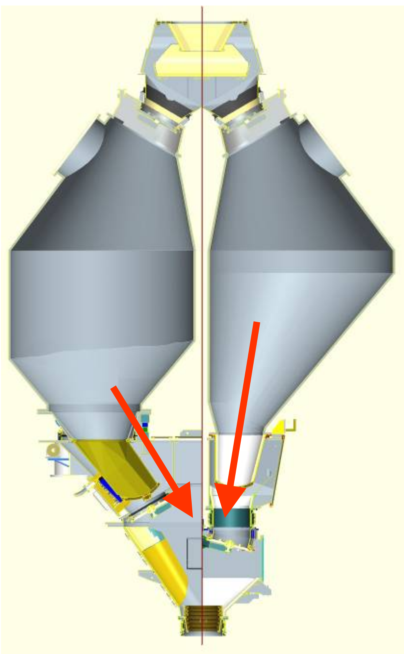
- Simplified rotary chute for feeding the material hoppers.
- Material hoppers adapted to minimize material segregation
- Reliable material hopper weighing systems.
- Individual lower material gate units
- Improved seal valve actuation unit to permit more centralized hopper discharge.

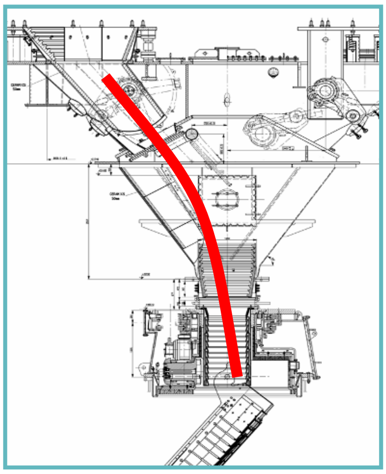


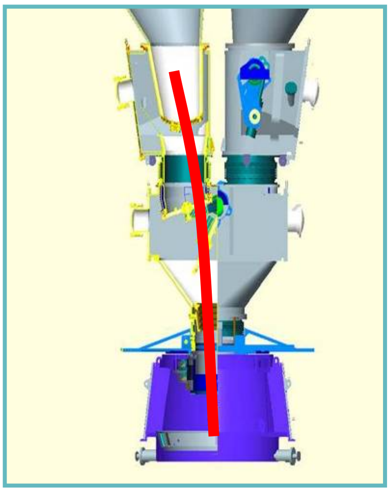
New Three Hopper Bell-Less Top –

3.1 The New Three Hopper Top Solution Gives the Following Operational Improvements

- The furnace charging capacity is increased. Depending on the complexity of the charging program, a 3 Hopper Bell-Less Top may be the only charging system solution to achieve the foreseen daily production.
- Small batches of raw material can be burdened - the accuracy and the capacity of the charging equipment will not be reduced.
- Two materials can be burdened simultaneously enabling the mixing of 2 materials of different sizes - without segregation.
- Several batches of centre coke (or any other material for that matter) can be stored in one hopper: The batches are released one after the other and no intermediate equalising is required.
- Full production can still be reached with 1 hopper out of service so the recovery rate is high.
- Due to more central charging and the new type of distribution chute - coke centre charging can be employed.
- Six different materials and layers can be charged in the furnace in a flexible way, still keeping a maximum charging capacity of more than 150%. See the images below:







Previous and New Material Hopper Arrangements

3.2 The New Three Hopper Top Solution gives the following maintenance improvements -

- The new BLT configuration uses many proven components of the previous Paul Wurth BLT designs.
- There will be less wear in the feeder spout due to more central material discharge.

- The less severe angles in the lower part of the hoppers will reduce wear.
- The separate lower material gate casings can be easily dismantled & rolled out for maintenance or replacement.
- There is improved access to the bellow arrangements, centring & wear device and feeder spout – for inspection, maintenance or replacement.
- There are large access doors in the lower seal valve casing & material gate casings to facilitate maintenance activities.
- The upper & lower seal valves and drives are interchangeable.
- Weighing beams eliminate the mechanical guides and spring assemblies required with the previous load cells.

4.0 The newest BLT solution with 02 Parallel Hoppers –

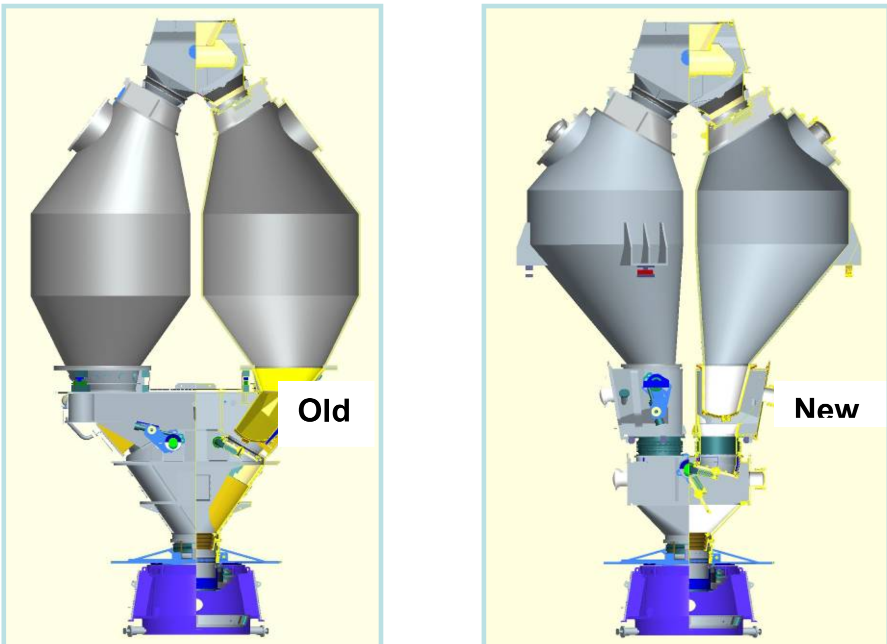
The main advantages of the Paul Wurth New Generation 2 Hoppers Bell Less Top Charging System can be classified in three main categories:

1- Improvement under metallurgical aspects;
2- Improvement under BF operational aspects;
3- Improvement under BLT maintenance aspects.

This charging system is characterized by

- a modular construction of three separate units, two Lower material gate Units and one Seal Valve Actuation Unit.
- Improved hopper geometry with weighing beam system

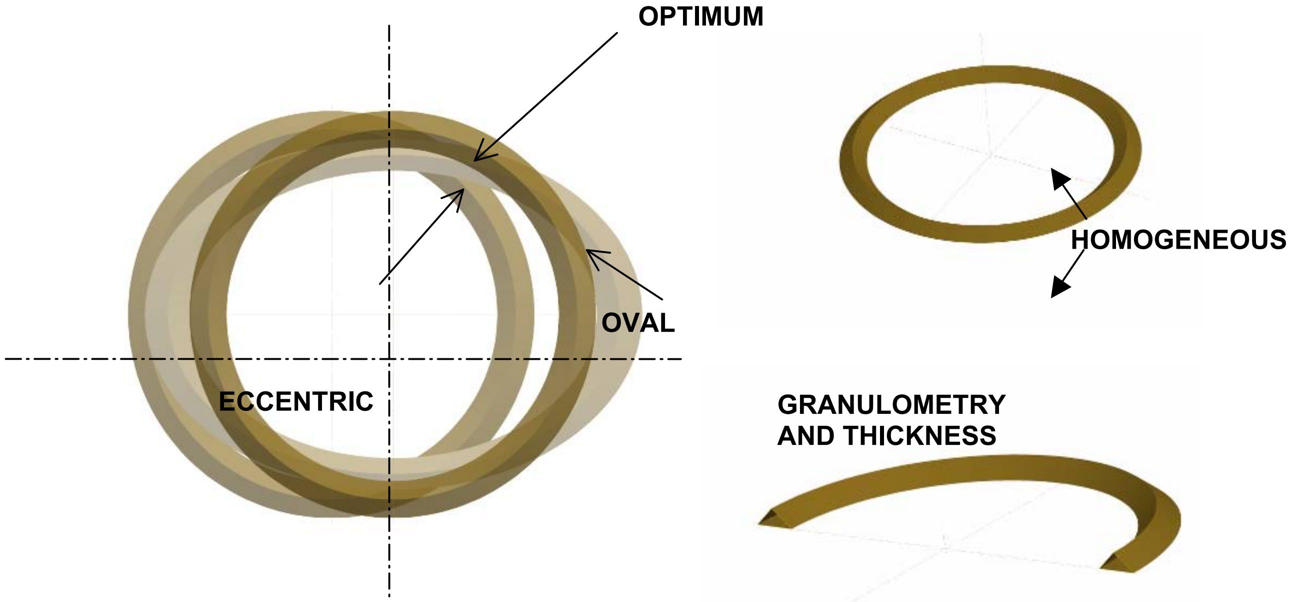
Each of the three separate units has been designed in order to improve the performance of the blast furnace operation, to improve the reliability as well as to reduce the time loss for maintenance works on the BLT equipment.
All these improvements are introduced without increasing the total height of BLT charging system.



The objectives of the new parallel hopper are:

- Centric discharge flow on distribution chute;
- New weighing system with integrated and online tarring features with load beams without springs, tie rods and torsion links and

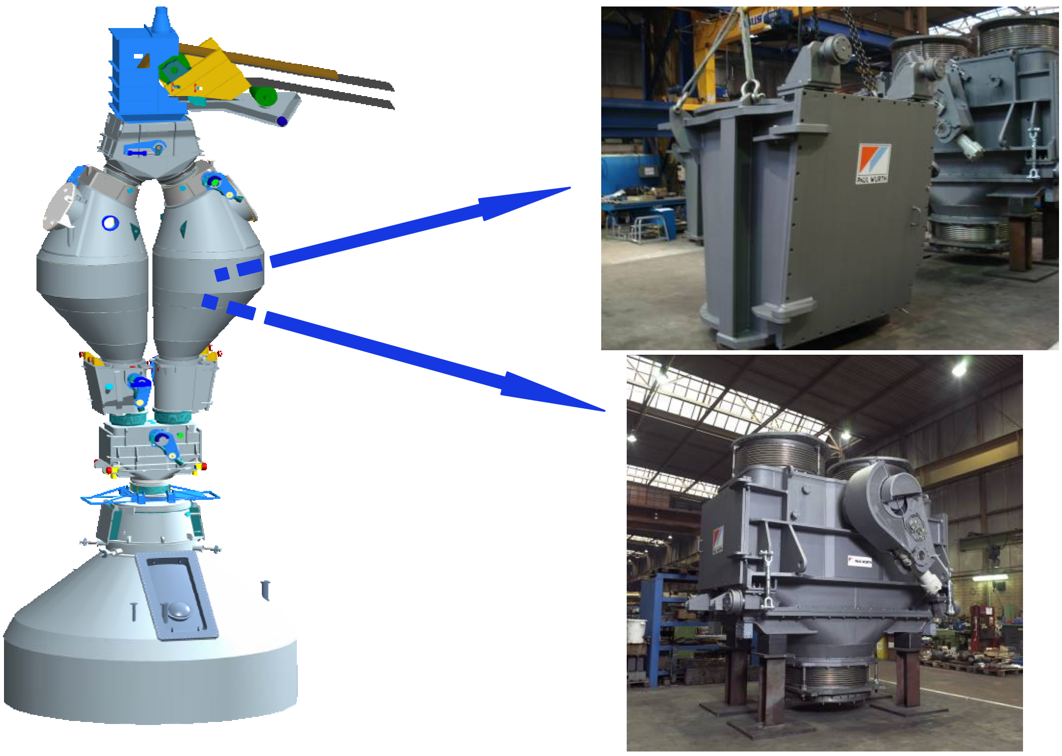
relocation eliminating the connection with the valve actuation unit;
- Easy maintenance and accessibility
- Less sharp angle in the lower part of the hopper will reduce segregation during charging in the furnace;



Raw Material is Positioned in Perfect, Even Rings Concentric with the Centerline of the BF

Old Concept – 1978 -
Load cell / spring / tie rods and torsion links

Latest Concept since 2003 -
Loading beams
Improved weighing accuracy.



In summary, the new design of parallel and 3 hopper BLT permit coke center charging while providing higher flexibility and greater availability and serviceability compared to other charging system technologies. Furthermore the new Three Hopper BLT meets the needs to charge a wider range of fractions of raw material (i.e. small sinter and nut coke), simultaneous and separated feed of different materials,

The New Three Hopper Top is an excellent solution for modern middle and large capacity blast furnaces or for furnaces with challenging raw material conditions.

5.0 Future developments

Paul Wurth is continuously reviewing all of its Bell-Less Top® charging equipment designs to ensure that it offers its clients the most up-to-date technologies and best configurations to suit the specific plant and operational requirements.

CONCLUSION:

The paper has illustrated the new developments of the Bell-Less Top® charging system on the traditional parallel hoppers and the latest developments of the new Three Hopper Bell-Less Top®. Frequent changing of raw material supplies and quality, change to centre coke operation, need for cost reduction using raw material secondaries in the BF and need for flexibility in BF operation and charging/burden distribution control have provided challenges to blast furnace process-based engineering and equipment companies to ‘meet these challenges’. The paper has emphasized how vital blast furnace charging equipment has been invented, developed and optimised by Paul Wurth to suit changing requirements

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