10% CAPACITY AUGMENTATION IN THE CORUS IJMUIDEN PELLET PLANT[1]

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Abstract
Until 2006 the Corus IJmuiden pellet plant produced approximately 4.6 mln ton pellets per annum. To accommodate the increase of the iron production, the capacity of the pellet plant needed to be increased to 5.0 mln ton per annum. The productivity was increased by modifications to the plant layout, which were implemented during the 2006 cold maintenance stop.

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Introduction.

In the mid-sixties of the last century the decision was made, by Hoogovens (now Corus), to build a 2.4 Mtpa pelletizing plant at IJmuiden. At that time the steel plant at IJmuiden operated 6 Blast Furnaces with a seventh BF already on the drawing board. Also a sintering facility had been started at IJmuiden in the early sixties in order to improve control of the properties of the materials being fed to the blast furnaces.
At the time the strategy was, to make use of the abundance of cheap fine ores in the world. In doing so Corus acquired a position from which it was possible to develop a robust BF burden philosophy.
The pellet plant is a Lurgi design straight grate with a suction area of approximately 430 m2, three Polysius Ball mills for combined grinding and drying and seven Sala balling drums.
Today the two IJmuiden Blast Furnaces produce approximately 6.5 mln t HM at a very low coke rate (approx 270 kg/tHM) and high productivity (2.73-3.44 t/m3WV.24h), using a burden of which more than 90% is produced with a pellet- and a sinter plant next to the blast furnaces. The BF burden is approximately 50 % acid olivine pellets and 45 % high basicity sinter, while the remaining is made up by spot purchases of either lump ores or external pellets, see Table 1. To accommodate an increase of the iron production, the capacity of the pellet plant needed to be increased to 5.0 mln ton per annum.

Table 1 2005/2006 Average operational data Corus IJmuiden Blast Furnaces

Total BF production	BF productivity	Reductant		Burden			
	BF 6 -7	Coke Rate	PCI Rate	Sinter	Corus Pellet	Purchase pellet	Lump Ore
kt	t/m3WV/24h	Kg/tHM	Kg/tHM	Kg/tHM	Kg/tHM	Kg/tHM	Kg/tHM
11591	3.27-2.75	280	230	700	700	70	50

The pellet plant productivity was increased by modifications to the plant layout, which were implemented during the 2006 cold maintenance stop.
This paper will focus on the various actions which have been taken over the years to increase the output of the pellet plant without substantially modifying the pelletizing process and/or flow sheet of the plant. The development of the production figures are depicted in Figure 1.

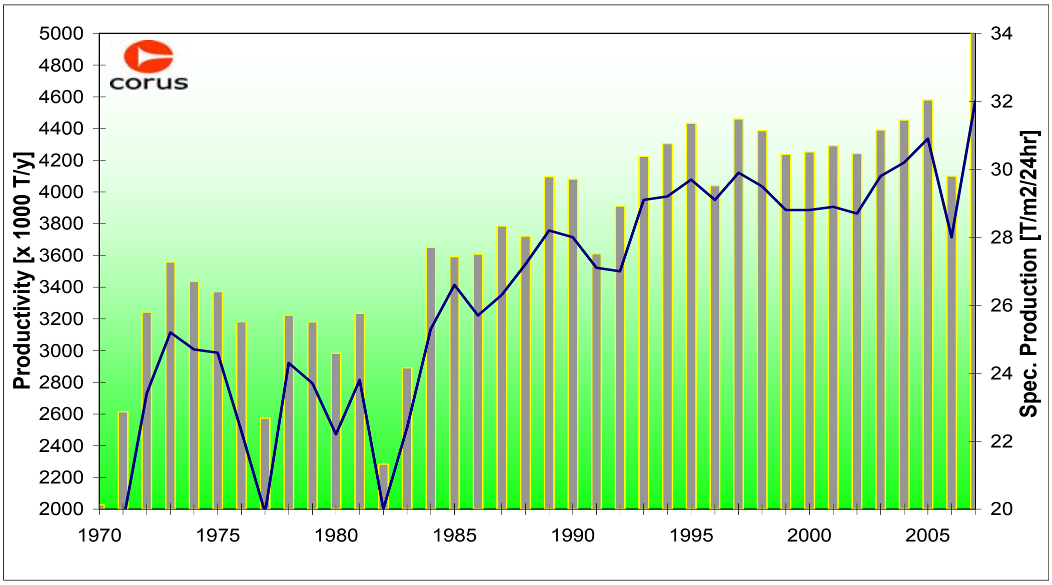

Figure 1: Bars: Annual productivity [T/y], Line: Specific Productivity [T/m2/24h]

2005/2006 Flow sheet IJmuiden Iron making.

The pellet plant produces an acid olivine-based pellet with very stable chemical properties, whereas the sinter plant produces a high basicity sinter. This arrangement ensures optimal productivity in the sinter- as well as the pellet plant, and in addition provides the BF-operators with a tool to very closely control the slag basicity in the blast furnace. See table 2 for the sinter and pellet chemistry and Table 3 for the pellet quality.

Table 2 2005/2006 sinter and pellet chemistry Corus IJmuiden

Chemistry agglomerate	IJmuiden	FeO	CaO	MgO	SiO_2	Al_2O_3	CaO/SiO_2
Sinter		13.85	11	1.5	3.6	1.35	3.05
Pellet		0.35	0.23	1.5	3.4	1.0	0.07

Table 3. Average IJmuiden Pellet Quality

Screening at pellet plant	ASTM	Screening at BF	Compression strength		IJSST		Free swelling	
-4 mm	-0.6 mm	- 4mm	- 60kg	Kg	dP [mm wc]	dR/dt 40%	30 min	90 min
3.5%	8%	2%	< 5%	199	4.4	0.7	15%	10%

Earlier Pellet plant developments before 2006

The pellet plant has a straight grate induration lay out, 7 balling drums and the ores are ground to the proper Blaine by 3 ball mills, which double as dryers to flash off the residual moisture in the ores and concentrates. Corus has found that dry grinding has the advantage of very intimate moisture control of the re-wetted ore mix, thus

enabling a high green pellet production. Basically the pellet plant capacity has predominantly been governed by the ability to grind the ores in sufficient amounts.
As the average moisture levels of the ores dropped in the early seventies, this opened up the opportunity to increase the grinding capacity at the expense of the drying chamber.
Later improvements included the use of coke breeze, which was ground along with the iron ore minerals thereby obtaining a very intimate mixing of breeze and ores. At the IJmuiden plant of Corus the pickling line produces approximately 30.000 tons/a of dry Rüttner-oxide, which until recently was worked into the sinter mix with considerable effort. The pellet plant has installed a separate silo, which now handles the oxide and feeds it into the pellet flow sheet after the grinding step, without any problem.
At a later stage the so-called ore by-pass was installed allowing the pellet plant to by pass the grinding- and mixing sections, with concentrates that already had sufficient Blaine.

Further increase towards 5 mln. t
By 2000 the capacity of the pellet plant had increased to 4.5 Mtpa by gradually removing the bottlenecks from the flow sheet. However the final leap to 5 Mtpa, still had to be made, since Corus was still purchasing foreign pellets to satisfy the BF's demand for agglomerates.
As it became apparent that the Blast Furnace requirement would continue to rise, the question as to whether the pellet plant was capable to follow this development became increasingly important.
As the maximal achievable annual production seemed to have found its zenith at 4,5 Mtpa, it was decided to have Corus Research and Development look into ways to predict the effects on productivity after adjustments - as described in the following paragraphs - would be carried through.
After careful appraisal of the flow sheet and the capacity of process fans, overall heat input, heat resources, etc. it became clear that after all the years of fine tuning there was still potential left in the pellet plant to improve production without drastic adjustments to the plant lay out.
Study revealed that by paying close attention to the process of balling and charging the green pellets onto the travelling grate, a substantial improvement in plant capacity could be achieved.
The additional improvements hinged on the concept of lowering the resistance to gas flow through the pellet bed to the maximum possible extent. This concept involved extra attention to the screening process of the green (unburned) pellets.
The freshly green balled pellets need to be screened right after balling and just before being charged onto the travelling grate, to an average pellet diameter of 12,5 mm.
This was achieved by decreasing the roll diameter of the roller screens in the balling section from 100 mm to 75 mm, hence increasing the active screening surface and removing even more undersized green pellets.
By achieving a very small standard deviation of the pellet diameter the maximum voidage in the bed is created (approximately 30 %) to allow maximum gas flow.
As the grain size distribution in the pellet bed shifts from only large pellets (12,5 mm) to smaller pellets (unscreened fines) the voids between the larger pellets are filled with smaller ones, thus blocking open area for gasses to pass through. In general it is accepted (and mathematically proven) that uniform populations of spheres have the

same voidage fraction , that can reach values of 44 % in extreme cases of very loosely packed populations [2] The voidage fraction drops off quickly as soon as the grain size distribution is spread out over a larger range of diameters, and is regained as a single pellet diameter becomes more pronounced in the population (Figure 2). In the case of relatively soft green pellets being charged to the bed of the induration machine Corus has found that the maximal achievable voidage fraction lies around 30 %.
This is why screening to a single pellet diameter is so important.

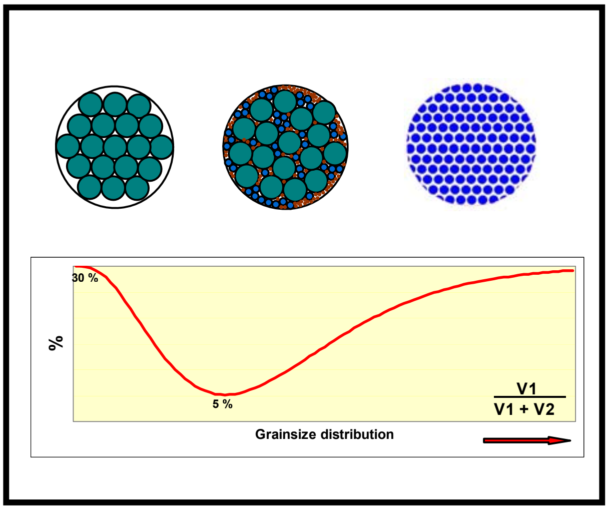

Figure 2 : Relationship between shifting grain size distribution and voidage between the grains.

Grate bars

The study also showed that the width of the slots between the grate bars could be increased. Consequently it was decided to increase the slot from 6 to 8 mm, thus increasing the suction area by 26 % and subsequently lowering the pressure drop of the process gasses as they pass through the induration machine. This was achieved by replacing all the existing grate bars by new ones, to ensure a larger gap between the bars proper.
As the ΔP was lowered more gasses could pass through the pellet bed, hence increasing production.
The principle was first checked by using the following equations:
$Q = v \cdot A$,
where Q is the gas flow rate, v the gas velocity, A is the surface area,
$\Delta P_{grate\ bar} = \xi \cdot \frac{1}{2} \rho v^2$,
where $\Delta P_{grate\ bar}$ is the pressure drop, ξ the friction factor and ρ is the gas density, the effect of the increment of the open area to 26% can be calculated.
In the following table the pressure drops are given for the original situation before the plant refurbishment and the calculated data as expected after the cold stop.

Table 3. Pressure drops over the grate bars before and after the revamp

[mbar]	First firing section	Sec. firing section	Cooling section
Before	9.4	5.5	7.1
After	5.8	3.4	4.4

Measurements

Using an instrumented pellet car the pressure difference over the grates was measured before and after the revision.

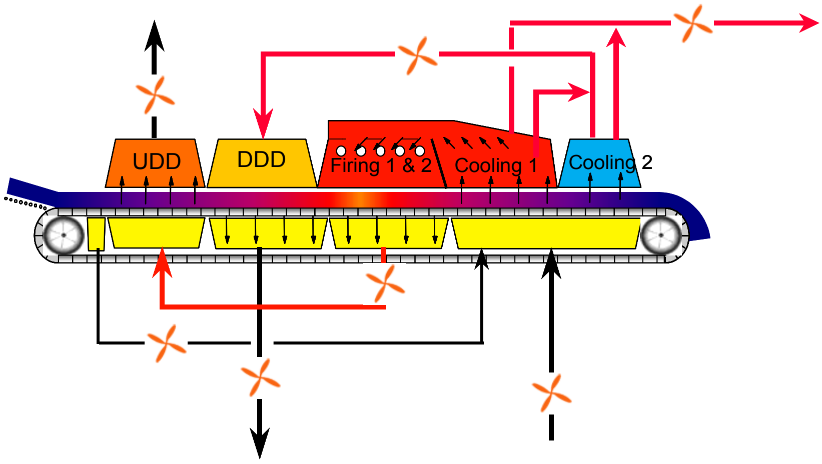

Figure 3: Schematic overview of flows through the induration machine

In Figure 4 a profile is given from two representative passes: one before and one after the revision. The transition from the different zones (Upwards Draft Drying, Downwards Draft Drying, Firing Zone 1 &2 Cooling Zone 1&2) is indicated by black dotted vertical lines. The zones correspond with the zones indicated in graph 3. As can been seen the pressure drop after the revision is smaller than before. With the decrease of the pressure difference over the grate bars, the pressure difference over the pellet bed could be increased, which results in a larger flow through the bed and a higher productivity.

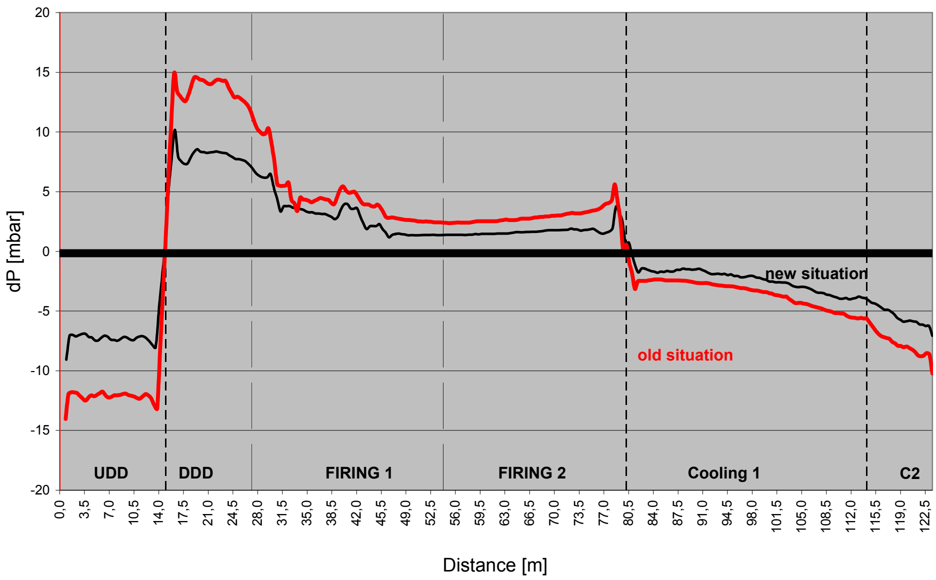

Figure 4: Pressure drop over grate bars during induration.

Charging of the green pellets

It was also decided to radically change the way the green pellets were charged to the travelling grate. Whereas in the 1960's the pellets were dropped on the last roller screen by a oscillating conveyor (Figure 5), in the new arrangement the pellets would

be first delivered onto a wide conveyor belt, with the same width as the induration machine (Figure 6).
In following this concept, Corus wanted to achieve a evenly charged induration machine. Basically the charging of the bed was placed outside the induration machine in an area where the charging could be monitored by the operators.
In the new configuration, the operators have 3 new parameters (instead of 2 in the old situation) with which to control the way the pellets are delivered to the induration machine. These parameters are: 1) Belt speed of the transversally oscillating conveyor, 2) the oscillation frequency and 3) the speed of the wide belt conveyor.

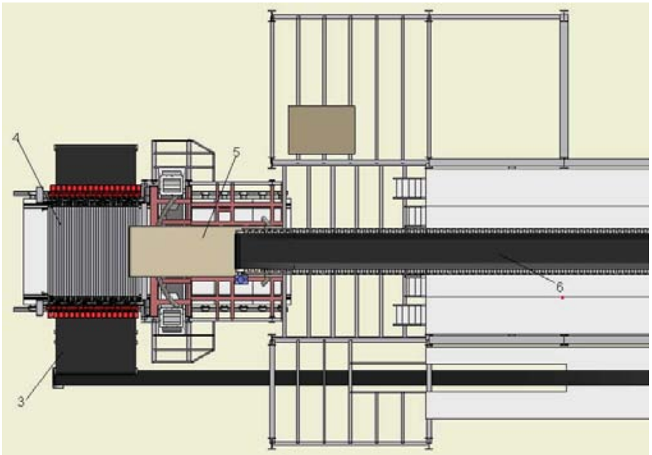

Figure 5: Original green ball feed mechanism. 3-Return fines, 4-roller screen, 5-oscillating conveyor; 6-conveyor from balling section

As a consequence to the above the efficiency of the last roller screen was drastically improved, resulting in a more efficient charging of the induration machine.

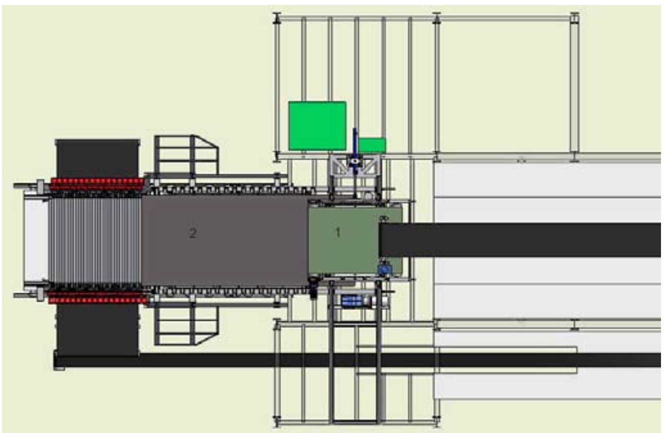

Figure 6: Upgraded green ball feed mechanism as installed in 2006. 1-tranversally oscillating conveyor; 2-wide belt conveyor

The big difference between the old and the new lay out is that the main roller screen can be evenly charged 100% of the time, whereas with the old swing conveyor the roller screen was fed with a sinusoidal curve that only partly covered the surface of the screen. This had adverse effects on the shape of the pellet bed in the induration machine, with hills and troughs that allowed preferential gas flows through the pellet bed. With an evenly stacked pellet bed the gasses passing through the bed are evenly distributed ensuring maximum gas efficiency and pellet quality.

By paying close attention to a much smaller standard deviation of the pellet diameter, the voidage fraction of the bed could be improved resulting in a lower pressure drop over the bed. This - in turn - meant that more process gasses could be forced through the bed. Without having to adjust various fan capacities.
However, one fan did get refurbished. To accommodate the induration machines ability to accept more gasses, it was decided to increase the capacity of the windbox recuperation fan by virtue of an improved impeller design. The shape of the impeller vanes was redesigned to come up with an additional 12 % flow, while not increasing the power consumption of the motor. The latter being restricted in power output because of power grid limitations.
A basic driver for installing a more efficient fan was that it was expected to pull more gasses through the firing zone and deliver more heat at the front end of the grate where the green pellets are dried. This way more process gasses could take part in the pelletizing process, ensuring higher productions, while at the same time increasing the drying capacity of the machine leaving more grate space for the induration and cooling. In other words the grate speed could then be increased in order to increase the productivity of the plant.

Actual results
The adaptation hinged on the concept that the amount of process gasses that pass through the induration machine have a positive linear relationship with the productivity. In other words, the more gasses that can be forced through the bed, the more pellets are produced.

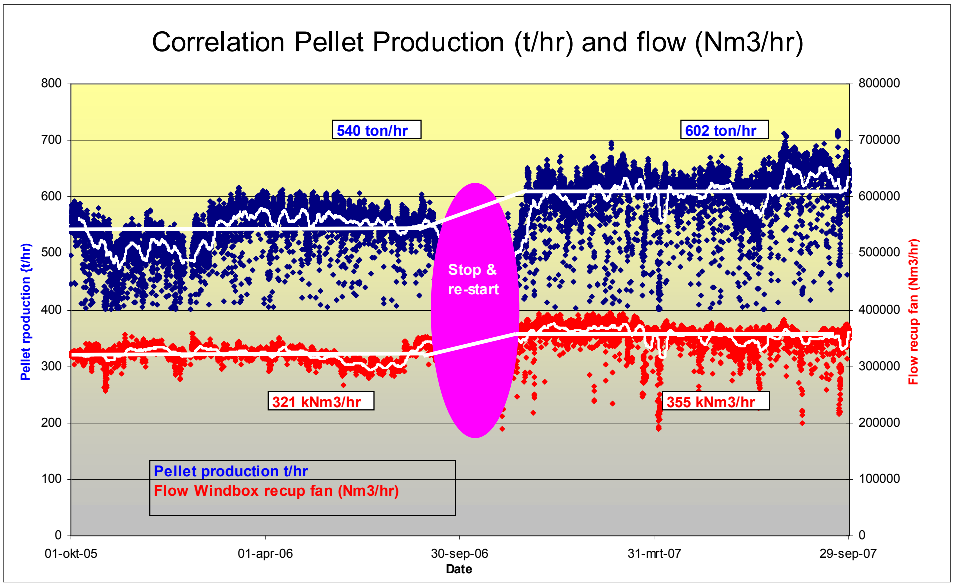

Figure 7 Productivity increases with higher gas flow through the pellet bed

As can be observed from fig. 7 this relationship has been confirmed. The increase in gas flow has been matched by almost similar increase in productivity
In the first month after the pellet plant was brought back into operation, the plant experienced a few teething troubles during which time the emphasis was focussed on removing any bottlenecks and readjusting the plants settings to the higher demands that were imposed on it.
In the seventh week after restarting the plant a record production was achieved by breaking the 100.000 ton/week level, specific production 33,6 t/m^2/24hr. The pellet plant

produced 100.544 tons and has since then passed the 100 kt level on a regular basis, without any compromises towards pellet quality (max 5% of the pellets Cold Compression Strength <60 kg/pellet), thus ensuring that the plant is well suited to achieve the 5 Mtpa. In total 4966 kt pellet were produced in 2007 (See Figure 8) compared with 4581 kt in 2005.

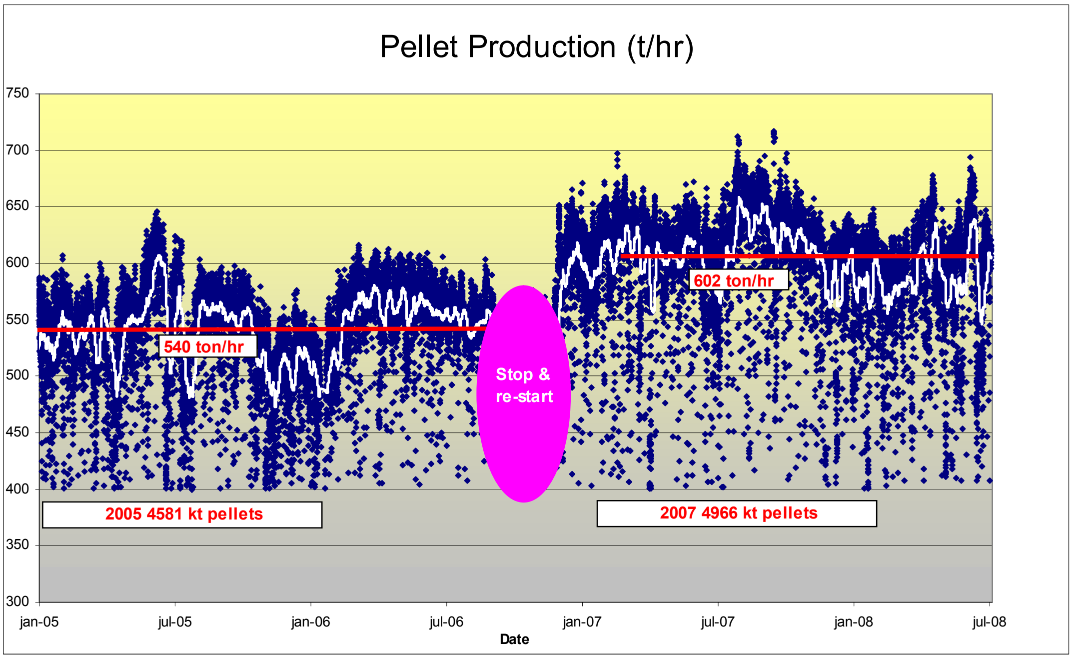

Figure 8 Production increase in the years before and after the last pellet plant revamp

Summary

Several steps have been taken in order to increase the pellet plant capacity.

1. Using the principle that more gasses through the bed result in higher productivity, various improvements can be made to enable such increase in gas flow.
2. Paying close attention to the uniformity of the pellet diameter,
3. Wider slots between the grate bars,
4. More efficient fan design,
5. By placing the charging of the induration machine outside the induration machine proper, better control is achieved of the shape of the pellet bed after it is deposited on the grate surface, thus enabling a well controlled gas flow through the bed.

Conclusion.

Increasing the capacity of a straight grate pellet plant can be done, even after years of continuous improvements, it is possible to make substantial steps in plant productivity. The IJmuiden pellet production increased with approximately 400 kt, facilitating, amongst others, the further increase of the BF productivity (see Table 4).

In the first full year of operation the targeted pellet production of 5 Mt was (almost) reached (Figure 8)

Table 4 2007 Average operational data Corus IJmuiden Blast Furnaces

Total BF production	BF productivity	Reductant		Burden			
	BF 6-7	Coke Rate	PCI Rate	Sinter	Corus Pellet	Purchase pellet	Lump Ore
Kt	t/m3WV/24h	Kg/tHM	Kg/tHM	Kg/tHM	Kg/tHM	Kg/tHM	Kg/tHM
6472	3.44-2.73	270	232	658	763	44	45

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