DECREASING BLAST FURNACE PROCESS COSTS AT ISCOR LONG PRODUCTS

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SUMMARY

Since 1995, various improvements in blast furnace practice have been made at Iscor Long Products. Coke quality was improved dramatically, which allowed many improvements in fuel rate, charging practice and a reduction in hot metal production cost. These improvements include an increase in hot blast temperature and pitch injection, charging of sinter fines, and increased charging of small coke.

Further advances to reduce cost include reduced drill and taphole clay consumption, and the installation of second and third liquid fuels injection systems to handle incompatible products.

These improvements allowed Iscor Long Products to remain competitive during a very demanding period in the steel industry.

KEY WORDS
Cost reduction, coke quality, deadman control, taphole practice.

1. INTRODUCTION

At Iscor Long Products we operate a 10.1m stave cooled blast furnace, with 2017 m3 working volume. The traditional approach was to operate at a blast temperature of 950 ^{o}C. This, together with a relatively inferior coke quality (CSR=43, Ash=15%), resulted in a fuel rate of 560 kg/thm. This paper indicates the improvements made in operating practice and cost reduction since 1995, as well as the philosophies used to achieve the results.

2. DECREASING ENERGY LOSSES

In 1992 all the factors influencing our high fuel rate were not known, but the coke quality stood out from the rest. It was realised that the coke quality was not sufficient for a medium-sized blast furnace, as a high degree of energy loss occurred through the top gas as high top gas temperature. By decreasing coke reactivity from 36 to 30, the energy loss was greatly reduced.

Laboratory work performed by the authors showed that coke with a high reactivity usually also starts to react at a lower temperature. One of the main functions of coke in the blast furnace is to maintain enough structural integrity in the lower part of the furnace to support the burden. If the coke starts to react too high in the shaft, the resulting coke degradation leads to a very low average sizing of the coke reaching tuyere level. At Iscor Long Products the only effective way to counteract this was to increase the total coke rate, and to decrease the pitch injection rate accordingly. This was however a very inefficient and expensive iron making route.

The big breakthrough came in 1996, when a trial was performed on the charging of low reactivity Chinese beehive coke(1).

Table 1 shows the qualities of our 1996 metallurgical coke, the Chinese coke, as well as the current coke quality.

Table 1: Different coke qualities as used at Iscor Long Products.

	CSR	CRI	Ash
1996	45	36	14.7
Chinese	70	20	10.0
1998 Best practice	56	28	11.9
Current	53	29	12.0

Because Chinese coke has such a low reactivity, care must be taken to avoid using too much. The philosophy we applied was to obtain an average reactivity of 28% to 30%. Our charging pattern is CCOO, with the ability to have a maximum of 12 steps per sequence. By replacing one of the coke steps with Chinese coke, in either an 8 or 12 step sequence, the Chinese coke could be varied between 17 and 30%.

We have not explored higher percentages, because it has not been necessary, and of course coke needs to have some reactivity for the regenerative reactions in the blast furnace shaft.

The effect of the lower coke ash, and the coke ash composition is not discussed in this paper. When this work was started, the effect of low ash was not known as it is today.

At the start of the first trial, the arrival of the low reactivity coke at tuyere level was dramatic. It resulted in an immediate decrease in blast pressure standard deviation, and a marked improvement in dead man quality as the trial progressed.

The working zones in the blast furnace moved downwards as expected, and the reduced energy loss was accompanied by a substantial decrease in fuel rate. This is shown in Table 2.

With this knowledge, the local coke quality was aggressively tackled, as is explained in section 5.

Table 2: Summarised results from the 1995 Chinese coke trial.

	Metallurgical coke (kg/thm)	Chinese coke (kg/thm)	Total coke (kg/ thm)	Pitch (kg/ thm)	Total fuel (kg/ thm)
Base period	475	0	500	53	552
18%	376	85	487	49	534
27%	338	120	484	49	531

3. INCREASING HOT BLAST TEMPERATURE AND PITCH INJECTION RATE

As mentioned before, the traditional approach was to operate at 950 °C blast temperature. One of the reasons was the inferior coke quality, and the resultant damage inflicted on the coke at tuyere level.

To compensate for the low blast temperature, a high oxygen enrichment practice (3% enrichment) was used.

Since 1991 the pitch injection rate could not be increased above 45 kg/thm. Each attempt to increase injection rate would result in unstable furnace conditions, tuyere losses, and damage to the stack refractory system.

In hindsight, this was due to lack of knowledge with respect to burden distribution control and tuyere parameter control, particularly tuyere velocity.

The breakthrough came in 1996, with the attendance of the last European Ironmaking Congress in Belgium. When Mr. Kadoguchi (2) presented his paper, it was mentioned that the coal injection rate was no longer 201 kg/thm, but 202 kg/thm. This was the key to the successful increase of blast temperature and pitch injection at Iscor Long Products.

The problem of increasing blast temperature and pitch injection rate was solved by taking very small steps upwards. Since July 1997, blast temperature was increased by 10 °C per month, and pitch by 1 kg/thm. At the same time the coke rate was adjusted accordingly, thus forcing the furnace to accept the changes, and not waste the extra energy into the top gas.

During the rest of the month, the hot blast system, burden distribution parameters and deadman condition were monitored. Adjustments to burden distribution were made to maintain a permeable deadman, and control reduction characteristics in the shaft.

Each step brought new challenges, as none of the operating staff had any experience at these high blast temperatures and associated low coke rates. The results are shown in Fig.'s 1 and 2. Fig. 1 shows the blast temperature from 1988 in year averages, and month averages from January 1997.

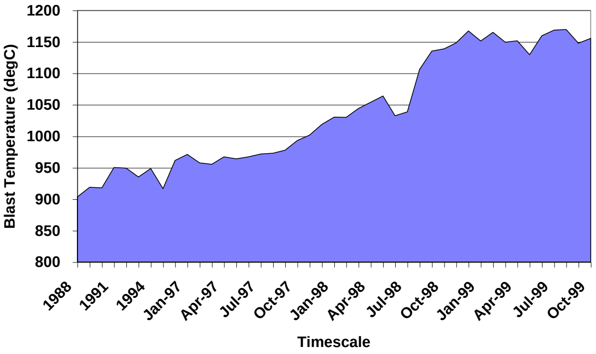

FIG. 1. Blast temperature

Mild steel lances were used for pitch injection. With the increased blast temperature, and the high-sulpher oil used in the second injection system (explained later), the lances succumbed to pitting corrosion, causing oil to run down the inside of the blowpipe. The resulting flame temperature of the burning oil was far above the limits of the blowpipe refractory system(3).

When this temporary setback was eliminated, blast temperature could be increased with ease, and much less associated stress!

Fig. 2 shows the increase in pitch injection rate. We currently operate three injection systems, the first for a coal-based pitch, the second for a high-sulpher refinery based bottoms product, and the third for light fuels.

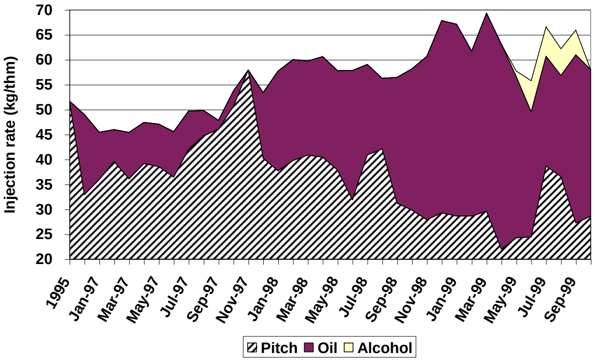

FIG. 2. Liquid fuel injection rate

The light fuels are available sporadically, as refinery streams are sometimes unbalanced. The product is supplied at a very low cost, and contains zero impurities.

The end result is that blast temperature increased to 1150 °C (month average, setpoint = 1173 °C), and pitch to 65 kg/thm. This resulted in a substantial decrease in coke rate and associated energy costs per ton of hot metal.

4. DEADMAN CONTROL

With the decreasing coke rate, control of deadman permeability became ever more critical. A simple model was developed describing coke flow below the cohesive zone. Fig. 3 shows our concept of coke flow below the cohesive zone. It should be noted that the deadman is fed mostly from coke charged in the middle of the furnace.

A piece of coke in the middle of the furnace will descend to the top of the deadman, and if a space is available, it will enter the deadman. If no space is available, it will progress to the flame front to be consumed by the blast.

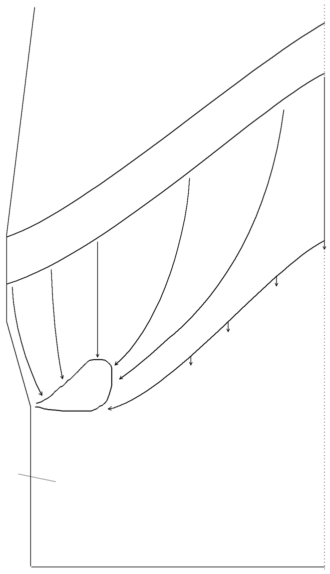

FIG. 3. Coke flow pattern below the cohesive zone.

Sidewall drainage is influenced by more factors, including tuyere velocity, and direct reduction rate.

Small coke radial charging position, as well as coke rate is manipulated to control direct reduction rate. When sinter is reclaimed from stockpile, the fines loading increases, and coke rate is increased by 2 kg/thm during such periods.

It has been found that increased small coke charging, or the radial position of small coke is not effective enough to maintain sufficient indirect reduction during reclaiming of sinter. During normal operation small coke charging is however the preferred route.

Burden distribution and coke rate is used to control the state of the deadman. Care is taken to maintain a high degree of material segregation to the middle of the furnace, ensuring a temperature peak of 600 °C above the burden. This ensures a rich gas in the middle, and that the coke in the middle is relatively free from alkali deposition. As the coke in the middle does not work as hard in the shaft as the rest of the coke, it is in a better mechanical condition when it reaches the deadman.

When the underhearth temperatures start to decrease, operating parameters are verified, and small increases in coke rate are applied. Although this increases the fuel rate in the short term, the long term benefits exceed the short term cost implications by far.

Titanium-rich pellets are charged as part of the normal burden to counter side-wall wear. The pellets contain 12% Titania, and 56% Fe. Pellets are charged to a maximum of 40 kg/thm, and apart from effective hearth sidewall protection, also results in a decrease in hot metal costs.

5. INCREASING COKE QUALITY

With the experience gained from using low reactivity coke, the Newcastle coke quality was improved, using selected imported coals to enhance the coking blend. Traditionally Iscor Long Products relied totally on locally mined coals, and this was a major shift in company thinking.

A spreadsheet model was developed(4), using coal properties to predict pushability, coke properties, blast furnace performance and hot metal reductant costs.

To predict hot metal reductant costs, various factors are influenced by the predicted coke quality. These factors include the amount of pitch that can be injected, the amount of small coke that can be charged, and blast temperature that can be used. With the knowledge gained, blast temperature is now fixed in the model at 1170 °C.

The model has been modified in 1998 to incorporate different blast furnace productivities. As the end result is hot metal reductant costs, it came in very handy during the economic crisis of last year. Blast furnace productivity was decreased from 2.6 thm/m^3/24h to 1.8 thm/m^3/24h, and the coke quality was decreased accordingly.

This was by far not technical excellence, but it was a pure financial decision. As a long products producer, the Works benefited substantially from this decision in that it could remain competitive in the market.

The increase in local coke quality of course gave the opportunity to increase blast temperature and pitch, but also resulted in other advantages. The amount of small coke (10 – 30mm) has been increased from 20 kg/thm to 40 kg/thm.

The small coke is charged in two fractions, a nut fraction (25-30mm), and peas of 10-25mm. Peas have been charged since March 1998, as more value could be added by charging it than by selling it to the ferro-alloy industry.

Another advantage was the opportunity to charge fine sinter (-5mm) to the blast furnace. This practice was followed successfully until production levels decreased, as the expected lower gas flow rates in the furnace shaft did not allow this.

6. METALLURGICAL MODELS AND BURDEN DISTRIBUTION MODEL

In 1993 a set of CRM metallurgical models were purchased, together with a burden distribution model developed by Sidmar. For this paper, only the burden distribution model is discussed.

After gaining operational experience in the use of this model, it has proved invaluable to daily furnace operation.

With the inferior coke quality, the aim was to achieve maximum gas-solid interaction, but as coke quality improved and pitch injection rate increased, the coke inflection point was moved away from the wall. The actions taken are the same as for increased coal injection rate.

A good example of this is the technique developed for centre-charging coke. Fig. 4 shows a schematic output of the model, with the top half being a normal discharge, and the lower half including a centre-charged coke.

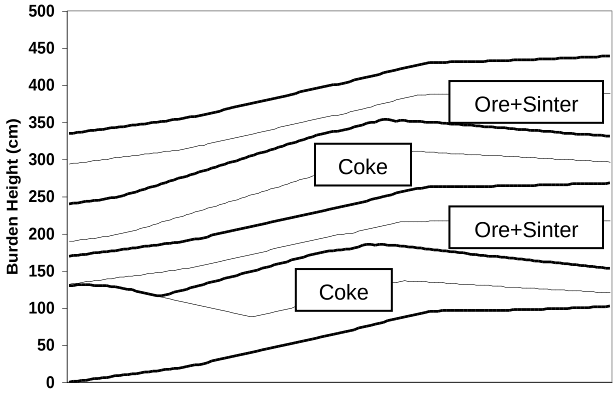

FIG. 4. Schematic output of burden distribution model showing coke centre-charging technique.

Centre-charging of coke has been found to be very effective, but also quite an extreme measure to take.

The charging system offers a lot of flexibility, in that additives can be charged on the main charging conveyor anywhere in the ore-sinter sandwich. Peas and nuts, for example, are not charged directly to the wall, as it gives too much permeability against the wall. Scrap is charged in the middle of the furnace, to prevent tuyere losses.

In 1997 the charging of sinter fines was commenced, again not against the furnace sidewall, this time to ensure proper indirect reduction directly above the tuyeres.

With the amount of scrap materials charged, the burden distribution model was upgraded to Version 2, which takes material size distribution into account.

Our furnace operating philosophy is very similar to Sidmar's, thus the model could be applied with few changes to the rules.

7. DISTRIBUTION CHUTE DESIGN

One of the cost reduction exercises taken was to change the design of the distribution chute. In 1978 the chute length was increased from 3.0m to 3.5m, to achieve the desired trajectories. The chute employed was of smooth liner plate design, and was used with great success.

As the chute wore through its campaign, more resistance to flow was created, and the exit velocity of the material stream decreased.

The trajectories for both a new and an old chute were measured during the 1993 reline, and on a scheduled shutdown the burden profile was used to select the correct trajectory for the operation at the time, and thus fine-tune the model to accurately predict actual charging profiles.

This chute (design) lasted about nine months in the furnace, before it had to be changed again. In 1998 a stonebox chute was fitted, which is supposed to last four years. It was of great concern that the exit velocity would decrease, but from lessons learned at Iscor Flat Products, and BHP, Australia, the installed design gave a trajectory very close to that of a new chute.

The advantage is that the trajectories do not change over time. Based on the last inspection in February 1999, the new design should give a lifetime of 4 years. After 20 months in the furnace, the chute showed very little wear.

8. TAPHOLE CLAY AND DRILL CONSUMPTION

The installed taphole length is 2.0m, and in operation it is maintained at 2.2 to 2.3m with a tar-bonded taphole clay. A dry hearth practice is followed in order to avoid drainage problems.

Through meticulous management of clay consumption, it has been reduced from 780 g/thm to 350 g/thm. As an example, the clay that falls out when the claygun is primed, is collected and re-used.

Another breakthrough in reducing clay consumption was to reduce the number of notches injected from five to three. Measurement of taphole length was upgraded, to ensure that taphole integrity did not suffer as a result. When the desired taphole length is not achieved, drill size is temporarily increased from 40mm to 55mm. This has the advantage that more clay can be injected before sintering starts, and thus taphole length can be restored to the desired level.

Concerning the drills, a hexagonal bar was used, with laser-cut flights welded on as the drill tip. The scavenging medium was 5bar compressed air.

Drill consumption averaged 0.6 casts per drill.

Various drillbits were tested, without any significant improvement in drill consumption. The first step was to upgrade the flow and pressure of the scavenging medium to nitrogen at 14bar pressure. Although the results were better, the general consensus was that better results were achievable.

The problem was that although the scavenging air pressure was increased, the amount of air was still not enough to displace the generated dust to a satisfactory degree. This was due to the throttling effect of the relatively small hole through the drill rod. Calculations also showed that the nitrogen had virtually no cooling effect on the outer diameter of the bar due to the thick wall thickness.

The design was changed to a thick-walled pipe, with the same flights. The resulting higher nitrogen flow to the drill tip cools the tip with much better efficiency. The idea was to develop an inexpensive drill, able to open only one taphole. However, drill consumption decreased to 2.2 casts per drill, using the same practice of drilling through into the hot metal. At the same time, the cost per drill bit was halved.

Drills are also reconditioned, with the damaged part cut off, and a new tip welded on. Reconditioned drills do not last as long as new drills, yielding lives of 1.8 casts per drill. New drills frequently yield lives above 4 casts per drill.

9. PRODUCTIVITY IMPROVEMENTS

The effort put into fuel rate reductions of course gave rise to productivity improvements. Fig. 5 shows the furnace productivity since 1995. The peak was reached in 1997, and could have been maintained was it not for the steel crisis that ensued the next year.

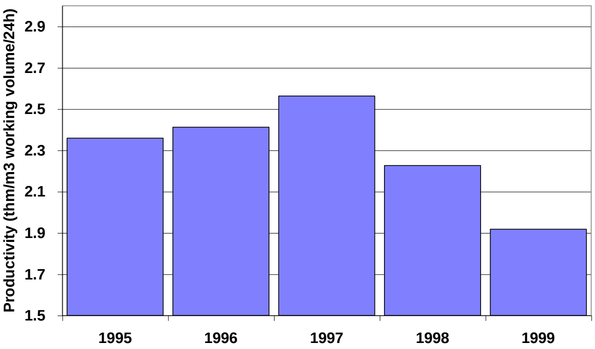

FIG. 5. Productivity since 1995

Current productivity is 2.1 thm/m^3/24h, or 4200 thm/day.

Of particular mention are the advances made in maintenance availability. Scheduled shutdowns used to occur at eight week intervals. By analysing what equipment was determining, and solving the relevant technical challenges, shutdown intervals are currently 18 weeks.

After the reline in 1993 a project was started to identify the equipment determining the scheduled shutdown frequency of 8 weeks.

9.1 Top Temperature Probe

The top temperature probe is manufactured from stainless steel, with good wear resistance, resistance to chloride and sulpher attack, and high temperature strength. The design includes flat bar stiffeners, and the probe is hinged in the middle of the furnace.

Two failure mechanisms existed: thermocouples failing prematurely, and the hinging mechanism failing. The probe had to be changed every 8 weeks.

Investigation showed that the material of the stiffeners differed from the rest of the probe. As the thermal expansion coefficients of the two materials differed, the probe bent upwards, until mechanical failure of the hinge occurred.

After the material specification was rectified, the thermocouples were shielded from direct attack by the ascending gas stream. The protective housings were specifically designed to not affect the temperature readings too much. A shielding plate was attached to the hinge, to further protect the nitrogen-cooled hinge from high temperatures in the middle of the furnace..

The last probe was changed after 18 months, due to mechanical wear.

9.2 Steam Heated Seats

The steam heated lower seals on the Paul Wurth top frequently leaked, due to pinching of material, build-up of wet material on the seat, and the seal elastomer bursting. The seals had to be changed every 8 weeks.

By modifying the bifurcated chute to allow for more space between the seal flap and the bifurcated chute, the last outflowing material is not pinched anymore. The control of the steam heated seats were upgraded, and temperature alarms were installed. Various elastomers were also tested to give extended lifetime.

Currently the seals are changed every 18 weeks, mostly out of a precautionary basis.

9.3 Radar Burden Level Probes

Stockline probes in use since 1993 were mechanical probes, with servo motors. These probes lasted only 12 weeks due to lost weights and cables. 3 out of the 6 probes were replaced with locally manufactured radar units, with the control software written in-house.

The installation has the facility to remove the source in operation, and calibration can also be performed in operation. The first radar probe was removed after 12 months, to clean the pick-up cone.

The remaining three mechanical probes are operated once a week, and are used when the burden depth is too low for accurate operation of the radar probes.

Currently the constraint exists that we do not have enough manpower for the scheduled shutdowns. Geographically we are quite far from experienced labour, and we are busy developing/training local contractors for selected jobs on shutdowns.

The goal is to progress to two stops per year, each with a duration of 16 hours.

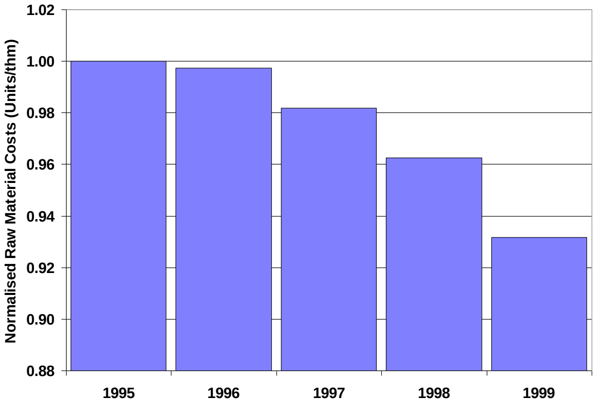

FIG. 6. Normalised raw material costs since 1995.

10. RESULTS ACHIEVED

Fig. 6 shows the raw material costs since 1995. The largest advantage was obtained in 1999, due to the cheaper coal blend used for coke manufacture.

Fig. 7 show the total cost per ton of hot metal, also normalised to indicate the reduction achieved since 1995.

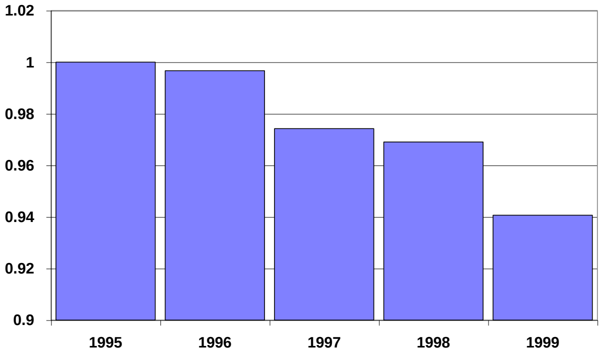

FIG. 7. Normalised total costs since 1995.

11. CONCLUSION

In the blast furnace, more than 90% of the total cost/thm is invested in the raw material feedstock. Again, a substantial amount is the cost of energy. Advances in technology have been around to allow the energy input to be optimised, through coal selection, coke quality, fuel injection and high blast temperatures.

Iscor Long Products has managed to apply these technological advances, through sound engineering principles, to significantly improve fuel rate, and thereby markedly decrease process costs.

The application of advanced burden distribution models, plus the dramatic reduction in plant outage time has further improved furnace stability, resulting in subsequent increased productivity, and refinement of fuel rate.

The results achieved over the last three years in particular have enabled the Works to remain competitive during probably the most demanding period experienced in the steel industry.

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