EFFECT OF RAW MATERIAL ON BLAST FURNACE PERFORMANCE: THE USE OF AN EXPERIMENTAL BLAST FURNACE

Anna Dahlstedt *
Mats Hallin* 
Jan-Olov Wikström **

*LKAB Luleå, Sweden
**MEFOS, Luleå, Sweden

SUMMARY

LKAB’s experimental blast furnace in Luleå was built and commissioned in late 1997, primarily for product development of iron ore pellets. During 1998 and 1999 five campaigns were conducted to evaluate different types of iron ore pellets. This paper describes the experimental blast furnace, the methodology used for tests and the results from the test campaigns. The experimental blast furnace, with a daily production of 30-40 t/day, is designed to give a realistic reductant rate. It is equipped with systems for PCI, oil injection, injection of slag formers and state of the art control/monitoring system including three burden probes. About twenty different iron ore pellet composition have been tested in the campaigns, both as a 100 % pellet burden and in combination with sinter. During operation, sampling of burden materials from different levels has been done. At the end of each campaign the blast furnace has been quenched and dissected. The results show that small changes in the composition of iron ore pellets sometimes have a big impact on process results in terms of process stability and amount of reductants consumed. The experimental blast furnace has proven to be a very efficient tool for product development and has generated a lot of knowledge about the blast furnace process.

KEYWORDS

Blast Furnace, Raw Materials, Iron ore pellet

1. INTRODUCTION

The experimental blast furnace in Luleå is a strategic investment that enables faster, assured product development. The furnace is a cornerstone of LKAB’s research and development effort. By building an experimental blast furnace to use in the process of product development, LKAB expects to strengthen its position as a leading supplier of blast furnace pellets, in terms of product quality and performance. The goal is to design and produce pellets that, when used, creates added value in the customer’s process, compared to other burden materials.

The blast furnace is still the dominating process for reduction of iron ore, and will continue to be so for the foreseeable future. Thanks to important developments in the blast furnace process, the challenges from new reduction processes are met. Therefore, we expect that blast furnace pellet will remain the most important product at the company. Higher productivity and process developments puts new demands on the raw materials used. The research efforts made by LKAB in the future will focus on pellet development to meet these demands.

1.1 Pellet development in LKAB

The present blast furnace pellet was first introduced in 1982. It is produced from magnetite ores, mined in Kiruna or Malmberget. The concentrate has a very low gangue content. Bentonite is added as a binder and olivine to adjust the composition before pellets are formed and fired. During almost twenty years, outstanding operational results have been achieved in Nordic blast furnaces, using 100% olivine pellets and the product has been modified to meet customer demands.

1.2 The need for an experimental blast furnace

The need for a step in between laboratory scale metallurgical testing and full-scale tests of new blast furnace pellets has been more and more evident during the last 10 – 15 years. It is a way to reduce the risks before full-scale tests are performed. The possibilities for operating the experimental blast furnace in a broad range of process concepts can also allow for faster progress in pellet development and for testing concepts to risky to test directly in a full-scale blast furnace.

A feasibility study was initiated in 1994 to evaluate the possibilities to build an experimental blast furnace and to do the basic design. This was done by MEFOS and LKAB in co-operation and discussions were made with experts from all over the world. In October of 1996 the LKAB board of directors decided to build the furnace and also to run five campaigns in 1997-1999. Hot commissioning started in 1997 and in 1997-1999 five test
campaigns to try out new pellets were carried out.

2. THE EXPERIMENTAL BLAST FURNACE

The experimental blast furnace was fully financed by LKAB, who also owns the furnace. It is situated at the MEFOS premises, next to the Luleå plant of SSAB. It is built inside a building used for coal gasification trials in the eighties, thus having raw material handling system, electrical supply and so on. During operation SSAB supplies raw materials, including gases, carries out analyses on hot metal and slag, etc. This has had an instrumental influence on the costs of building and operating the experimental blast furnace. LKAB and MEFOS are operating the blast furnace in co-operation. MEFOS in-depth knowledge of blast furnace operation has been invaluable in planning and conducting trials.

2.1 Description of the furnace

The experimental blast furnace is shown in Fig. 1. It has a working volume of 8.2 m$^3$ and a diameter of 1.2 m at tuyere level. From tuyere level to stock line, the height is 6 m, there are three tuyeres placed with 120 degrees separation. The tuyeres have a diameter of 54 mm, resulting in a blast velocity of 150 m/s at normal blast volume. The furnace is equipped with systems for injecting pulverised coal, oil and other injection materials.

Great effort has been taken to keep heat losses to a minimum and therefore insulating refractories were chosen. Only the bosh and tuyeres are water-cooled. The blast is normally preheated to 1170°C - 1250°C in pebble bed heaters. There are two pebble bed heaters, working in cycles. One is on blast while the other is on gas (propane). Small alumina balls are used for heat storage.

The raw materials system consists of four bins for pellets or sinter, one bin for coke and two small bins for slag formers. Each material is weighed separately according to the actual recipe. The material is transported to the furnace top by a skip and to a receiving hopper. Below the receiving hopper, there is a pressure equalising lock hopper. Furnace top pressure can be controlled up to 150 kPa overpressure.

The experimental blast furnace is equipped with a bell top. There is a movable armour for burden distribution control. Two mechanical stock rods are used to monitor the burden descent and to control the charging into the furnace. The top gas is transported through the uptakes and downcomer to a dust catcher. The gas is further cleaned in a venturi scrubber and a wet electrostatic precipitator. Finally, the top gas is flared in a torch.

The furnace has one tap hole. It is opened with a pneumatic drill. After each tap, the tap hole is closed with a hydraulic mud gun. The hot metal and the slag are tapped into a ladle, transported to the SSAB steel plant, and charged as scrap to the BOF.

Burden probes are installed at three different levels. There are two horizontal probes, one at tuyere level and one in the shaft, and one inclined probe to sample in the bosh. The shaft...
probe and the inclined probe at the bosh parallel are equipped with two different heads. One is used to collect material samples from the furnace. The other is used to collect furnace gas for analysis and to measure the temperature. The tuyere probe is equipped with a gas collecting and temperature-measuring head.

To make dissection and repair easy the hearth is detachable and can be separated from the furnace in one to two hours.

2.2 Raw Material preparation and dust treatment

The raw materials for the experimental blast furnace are normally produced before each campaign. The test pellets are produced either in the Steel Belt Plant located in Malmberget or in one of the grate kiln plants located in the Kiruna area. Pellets are made using normal pellet feed concentrate. Binder and additives are blended to the concentrate using the normal production lines. The balling and induration is done at standard plant practise, which means that the test pellets have normal size distribution. A normal test quantity for the experimental blast furnace is around 1000 tonnes. During production sampling is done at regular intervals and tested for chemical composition, mechanical and metallurgical properties.

Test pellets are transported to the experimental blast furnace and stored in a stock house. During the campaigns, the pellets are transported to the blast furnace by a front loader. The pellets are screened at 6 mm and sampled before they are stored in day bins.

Sinter is transported from the actual steel plant to the stock house at the experimental furnace, it is normally standard sinter as produced at the steel plant. Top size is 40 mm and the sinter is screened at 6 mm, before being used in the blast furnace. The sinter is sampled and tested in the same way as for the pellets.

Coke is produced at SSAB coke plant in Luleå, close to the blast furnace. Before each campaign a batch of about 900 tonnes is prepared by screening production coke in the fraction 15 – 30 mm. The batch is sampled and transported to the experimental blast furnace for storage in the stock house. During campaigns, coke is transported to the experimental blast furnace with a front loader, screened at 6 mm and sampled before storing in the day bin for coke.

Fluxes are screened to the fraction 10 – 20 mm and stored in big-bags. The big-bags are transported to the day bins, no additional screening of fines is done.

The dry flue dust is collected in a storage container, sampled twice a day and analysed for the chemical composition. The wet flue dust (sludge) is collected in a thickener and sampled when the thickener is emptied by a suction truck. Sampling of the water phase and the wet dust is done.

2.3 Operating the experimental blast furnace

The operation of the blast furnace is very similar to a commercial blast furnace. At blow in a small amount of charcoal is used as start up burden in front of the tuyeres. Within the first hour, full wind is reached and the blast temperature is in the range of 800°C - 850°C. The blast temperature is increased to the desired set point in the first 24 hours of operation. The amount of reducing agents is slowly decreased during the first 72 hours, to a level corresponding to about 110%, compared to normal operation. After this period injection of coal or oil is started. Operation is stabilised during the next 48 to 72 hours. The furnace is operated at productivity ranging from 3.4 to 4.0 t/m³/day. Hot metal and slag composition is kept at set points decided before the campaign. Normal tap-to-tap time is 60-80 minutes, depending on actual production rate and normal tap duration is five to fifteen minutes. Drill diameter varies between 25 and 28 mm, depending on tapping conditions in previous tap. The hot metal temperature is measured with a temperature probe. Hot metal and slag are sampled at every tap and analysed by SSAB. Normal analyse response time is 20 minutes.

The test periods normally starts with a transition period where the test material is charged to the furnace for a period of 24-36 hours, corresponding to six to nine throughputs. After that period the actual test starts. The test time depends on what objectives that are to be met for the test. A typical test period range from two days up to six days. During this time operational data is logged and monitored closely. Sampling of burden materials, using the burden probes, is done once or twice every shift.

Reference material is charged to the furnace at regular intervals to check if there has been any
change in the furnace or auxiliary equipment that influence the operation.

From dissections, it is known that there are rather large difference between the material in the centre of the furnace and material closer to the wall. The material retrieved by the probe is divided into samples representing different positions on the radius of the furnace. All material taken out of the furnace is screened and the fraction >6,3 mm is sorted, so that pellets, coke and slag formers are separated. Breakdown and strength of materials are tested and samples are prepared for microscopy investigations. Chemical analysis is also done, primarily to determine the overall reduction degree.

Process data are logged every second and stored in a database, as ten-second and minute averages. These data are transferred at regular intervals to another database where process data calculations are carried out. Data in this database is used for reports, trend charts and mass- and heat balance calculations. Chemical analyses for raw materials, hot metal and slag are also stored in this database.

As to now the experience is that the experimental blast furnace is a very sensitive tool for detecting differences in properties for different pellets. The response time is much shorter for the experimental furnace compared to a commercial furnace. One example is the time for the blast furnace to go from normal heat levels to cold conditions, it could take less than six hours. On the other hand, the blast furnace also recovers quickly to normal conditions, after corrective actions are made.

3. RESULTS FROM EXPERIMENTAL BLAST FURNACE OPERATION

During the campaigns performed so far, many different process concepts have been tested in the experimental blast furnace. Examples are:

100 % pellets as ferrous burden with injection of PCI in the range of 0 – 150 kg/tHM,
Simultaneous injection of PCI slag formers and oil injection up to 65 kg/tHM. The slag rate has varied between 85kg/tHM and 190 kg/tHM.

Sinter/pellets as ferrous burden with pellet ratio from 20 % to 60 %. Oil injection up to 65 kg/tHM. Slag rates between 170 kg/tHM to 220 kg/tHM.

These various operation modes have given different results not only in consumption figures but also in process characteristics. For example, it is interesting to see the difference between 100 % pellet operation and operation with high amounts of sinter. The big difference is in the rate of change in operating condition, meaning that when operating with high amounts of sinter a slower response in the operational parameters can be seen, when changes are made. This is probably due to the lesser moveability for the gas.

3.1 Comparison with full scale blast furnaces

The experimental blast furnace has proved to have the similar behaviour as full-scale blast furnaces. Among the important areas are formation of different zones inside the blast furnace, the composition of the reducing gas and gas distribution over the radius.

One concern regarding small blast furnaces is if the zones that normally are present in full-scale blast furnaces also exist in the experimental blast furnace. This is important from many different aspects, but mostly for correct simulation. If there are drying, reserve, cohesive and dripping zones present in the experimental blast furnace, the reduction of
the ferrous burden will hence proceed in the same manner as in a full-scale furnace.

The five different dissections that have been made so far show the presence of a cohesive zone, located about 1 - 1.5 meters above tuyere level. In all dissections, there has been a distinct cohesive zone although different in shape, width and position.

Another example is the results from vertical temperature probing that are made during campaigns.

As Fig. 2 indicates there are three different zones by judging from temperature gradient in the blast furnace. The profile is measured at a vertical line about 1/3 of the radius from the furnace wall.

Zone 1: Temperature range from about 350°C to 815°C, retention time is 23 min in this zone and the temperature gradient is 20°C/min.

Zone 2: Temperature range from about 815°C to 1098°C, retention time is 2 h 26 min and the temperature gradient is 2°C/min.

Zone 3: Temperature range from 1100°C to 1200°C, retention time is 17 min (exact retention time is difficult to predict because the thermocouple was lost at 1200°C). The temperature gradient is 5°C/min.

The presence of these zones makes clear that the same zones exist in the experimental blast furnace as are normally found in full-size blast furnaces.

The gas distribution is measured by an above burden cross probe and the shaft probe located about 1.2 m below stock-line. Most of the time there is a marked central gas flow in the furnace. The gas temperature at the wall is about 120°C and about 350°C at the centre. Gas composition at the top is typically 21% CO, 22% CO₂ and 3% - 5% H₂, depending on injection rates.

The sampling of materials during operation gives good possibilities to learn how material properties and process status relates. It is also possible to use information from material taken out of the experimental blast furnace to design improved laboratory tests for pellet testing in the future.

3.2 Comparison of metallurgical test data and blast furnace operation

One very important issue is the meaning of metallurgical laboratory test results of pellets and the corresponding effects on blast furnace operation. As all pellets are sampled and tested before charging to the experimental blast furnace, one can judge if certain levels of test results have a significant impact on the blast furnace operation. Two different metallurgical tests has been chosen for comparison:

Low Temperature Disintegration ISO 13930 at 500°C, reduction for 60 min during tumbling in drum with diameter 150 mm, equipped with lifters and a reduction gas composition of, 20%CO, 20% CO₂, 2% H₂, and 58% N₂. Gas flow is 20 l/min. Fractions +6.3 mm, +3.15 mm and −0.5 mm are reported.

Reduction test ISO 4695 at 950°C up to 65% reduction degree with reduction gas 40% CO
and 60% N₂. Time and reduction gradient between 30 – 60% reduction degree is reported. Material is tumbled after test and fractions +6.3, +3.15 and −0.5 mm are reported.

For the comparison, 53 normal "test days" have been chosen, from campaign three and four. The pellets were sampled with intervals of about 6 hours, each sample was split, combined with other samples from the same day, to form a day sample. The pellets used for this comparison are listed in table 1.

**TABLE 1: Composition for test pellets**

<table>
<thead>
<tr>
<th>Pellet</th>
<th>Type</th>
<th>Fe (%)</th>
<th>SiO₂ %</th>
<th>CaO %</th>
<th>Mg O%</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPBO</td>
<td>Olivine</td>
<td>66.8</td>
<td>2,0</td>
<td>0,4</td>
<td>1,5</td>
</tr>
<tr>
<td>KPBO-L</td>
<td>Olivine</td>
<td>66.8</td>
<td>1,9</td>
<td>0,6</td>
<td>1,3</td>
</tr>
<tr>
<td>FP05</td>
<td>Olivine</td>
<td>67.2</td>
<td>2,0</td>
<td>0,2</td>
<td>1,1</td>
</tr>
<tr>
<td>FP14</td>
<td>Fluxed</td>
<td>66.9</td>
<td>1,25</td>
<td>1,25</td>
<td>0,8</td>
</tr>
<tr>
<td>FP 20</td>
<td>Fluxed</td>
<td>66.9</td>
<td>1,6</td>
<td>1,6</td>
<td>0,3</td>
</tr>
<tr>
<td>FP 21</td>
<td>Acid</td>
<td>66.9</td>
<td>2,4</td>
<td>0,6</td>
<td>0,5</td>
</tr>
<tr>
<td>FP 22</td>
<td>Olivine</td>
<td>66.6</td>
<td>2,3</td>
<td>0,5</td>
<td>1,0</td>
</tr>
</tbody>
</table>

The day sample was used for metallurgical testing and then compared with operational results. The operation results used are, gas utilisation index (CO) and Burden Resistance Index (BRI), which gives information about burden permeability. The higher the CO is, the higher utilisation of the reducing gas. The lower the BRI is, the lower is the burden resistance to gas flow.

The data from metallurgical testing was compared with the operation data and an evaluation was done.

For most of these test data we could not find any correlation to the operation results, this was true for:

- LTD ISO 13930 + 6.3 mm
- LTD ISO 13930 + 3.15 mm
- LTD ISO 13930 − 0.5 mm
- Reduction test ISO 4695
- Reduction test ISO 4695 R40

**FIG. 3. ITH + 6.3 mm vs. Burden Resistance index**

There was, however, a relationship between the strength after reduction, measured as the amount of pellets reporting to the +6.3 mm fraction after tumbling, ITH +6.3mm.

Fig. 3 shows the scatter plot for ITH + 6.3 mm and BRI. It is shown that the higher the strength of the pellets after reduction, the lower is the burden resistance to gas flow. This relationship seems to be reasonable and the regression is significant on the 95% confidence level. The explained variance for the regression, the r-square value is 0.3.

### 3.3 Evaluation of iron ore products

The blast furnace process is, as well known complex. Although the fundamentals are the same for all operations, even two different blast furnaces at the same plant behave differently. This means that the evaluation of actual operation data with the goal to rank different raw materials and their associated properties is difficult. In general, there is an agreement of the paramount importance of raw materials quality to blast furnace operation results. Some estimates have been made that 80% of the overall result is dependent of the raw materials used. This is true, not only for the quality of the ferrous burden components, but also for coke, fluxes and injection materials such as pulverised coal.

The issue about ranking different pellets, e.g. what are the characteristics of a good pellet, have been under discussion during many years. When it comes to judge and discriminate between different pellets tested in the experimental blast furnace, the following criteria are used.

1. The overall permeability and its variation during operation, measured as the Burden Resistance Index (BRI). This is calculated as the pressure drop from tuyere level to top and divided by the bosh gas volume.
2. The gas utilisation and its stability, measured as CO, calculated from top gas analysis.
3. The burden descent rate and its stability calculated from stock rod information.

### 3.4 Example of pellets tested in the experimental blast furnace

The composition of some of the pellets tested so far is listed in table 1. MPBO is the standard LKAB olivine pellet, produced in Malmberget. KPBO-L, FP05 and FP22 are olivine pellets with various amounts of quartzite and lime. FP 14 is a fluxed pellet with high MgO content and FP20 is a fluxed pellet without addition of MgO. Both FP14 and FP20 have a CaO/SiO₂ ratio of 1,0. The pellet FP21 is an acid pellet
with a CaO/SiO₂ ratio of 0.25. This pellet is produced with both quartzite and limestone addition.

The operational results for the pellets were compared with special attention to the parameters BRI, CO₂ and variation in the burden descent rate expressed as the Standard Deviation (σ). Operating conditions for the test periods are listed in Table 2. Normally a 36 hour period of operation has been used for evaluation of the data.

### TABLE 2: Operating conditions

<table>
<thead>
<tr>
<th>Pellet</th>
<th>Blast vol. (Nm³/h)</th>
<th>Blast temp. (°C)</th>
<th>Oxygen in blast (%)</th>
<th>PCI (kg/t HM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPBO</td>
<td>1600</td>
<td>1165</td>
<td>23</td>
<td>88</td>
</tr>
<tr>
<td>KPBO-L</td>
<td>1620</td>
<td>1177</td>
<td>23</td>
<td>86</td>
</tr>
<tr>
<td>FP05</td>
<td>1620</td>
<td>1168</td>
<td>23</td>
<td>86</td>
</tr>
<tr>
<td>FP14</td>
<td>1610</td>
<td>1181</td>
<td>23</td>
<td>94</td>
</tr>
<tr>
<td>FP 20</td>
<td>1600</td>
<td>1179</td>
<td>23.5</td>
<td>85</td>
</tr>
<tr>
<td>FP 21</td>
<td>1600</td>
<td>1178</td>
<td>23.5</td>
<td>85</td>
</tr>
<tr>
<td>FP 22</td>
<td>1600</td>
<td>1179</td>
<td>23.5</td>
<td>81</td>
</tr>
</tbody>
</table>

Results from the operation with respect to BRI, CO₂, σ for burden descent rate and amount of reducing agents used from the test periods with these pellets are given in Table 3.

### TABLE 3: Results from test periods.

<table>
<thead>
<tr>
<th>Pellet</th>
<th>BRI (-)</th>
<th>CO₂ (%)</th>
<th>σ BDR</th>
<th>Coke, Coal (kg/tHM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPBO</td>
<td>5.73</td>
<td>48.3</td>
<td>0.7</td>
<td>525</td>
</tr>
<tr>
<td>KPBO-L</td>
<td>6.43</td>
<td>50.1</td>
<td>0.6</td>
<td>515</td>
</tr>
<tr>
<td>FP05</td>
<td>6.01</td>
<td>48.6</td>
<td>0.5</td>
<td>512</td>
</tr>
<tr>
<td>FP14</td>
<td>7.09</td>
<td>46.1</td>
<td>0.9</td>
<td>540</td>
</tr>
<tr>
<td>FP 20</td>
<td>6.26</td>
<td>47.0</td>
<td>0.5</td>
<td>532</td>
</tr>
<tr>
<td>FP 21</td>
<td>5.91</td>
<td>48.9</td>
<td>0.5</td>
<td>515</td>
</tr>
<tr>
<td>FP 22</td>
<td>6.34</td>
<td>48.8</td>
<td>0.5</td>
<td>524</td>
</tr>
</tbody>
</table>

The pellet MPBO is used as the reference pellet. Compared with the other pellets one can see that MPBO has the lowest burden resistance, average CO₂ and higher standard deviation for burden descent rate. The average coke and coal consumption for MPBO was 525 kg/tHM.

For the modified olivine pellets KPBO-L, FP05 and FP22 they show average burden resistance, high CO₂ and lower σ for burden descent rate than MPBO. Coke and coal rates for these pellets were in the range of 512 kg/tHM to 524 kg/tHM.

The fluxed pellet FP14 has a high BRI, low CO₂ and high σ for burden descent rate and combined coke and coal rate was 540 kg/tHM.

The second fluxed pellet FP20 has average values of BRI and σ of burden descent rate. The average CO₂ is rather high and σ for the burden descent rate is low. The amount of coke and coal consumed was 515 kg/tHM.

Finally for the acid pellet FP 21 the BRI is low, CO₂ is rather high and σ for the burden descent rate is low. The amount of coke and coal consumed was 515 kg/tHM.

From these tests, it can be concluded that all three types of pellets have good results when compared to MPBO. There are however some doubt about the fluxed pellet FP14 because of the relative high BRI, the low CO₂ and large S.D. for burden descent rate. This pellet has almost the same composition, as FP20.

The difference is primarily a higher MgO content in FP14. In order to further examine the exact cause for the poorer results material from burden sampling and dissection was examined. The detailed analysis is reported in another paper (1) and it was found that swelling had occurred rather high up in the furnace.

**FIG. 4: CO₂ FP14 during the test period**

In Fig. 4 and 5 a comparison is made between CO₂ for FP14 and FP20, during the 36 hour evaluation periods. From these figures, it can be seen that the stability for FP14 is low, with a high variation in CO₂ compared to FP20.

**FIG. 5: CO₂ FP20 during the test period**

### 3.5 Pellet properties effects on blast furnace performance

Based on the experience so far, some conclusions can be drawn from the different campaigns.

The most important factor for pellet behaviour in the blast furnace is the composition of the slag phase in the pellet. It is not only the “normal” slag compounds like silicates, but also the ferrite formed during firing that influence the properties of the pellet during reduction.

The slag phase has a strong interaction with the iron oxides in the pellet during reduction and several slag phases containing iron are
formed (2). The strength of the slag phase and the melting point determines much of the pellet strength during reduction.

The reducibility of the pellet is linked to the type of phases of the slag. Depending on the type the slag can promote or act as barrier for the reducing gas. Many of the problems associated with low reducibility are in fact caused by the presence of a phase with “free” silicates than can form a slag with low melting point in the pellet. There is also some evidence that thin slag films are formed at grain boundaries that can form an internal coating of the iron oxides, creating a barrier for the reducing gas.

4 CONCLUSIONS

The experimental blast furnace is a unique test facility for blast furnace burden materials. It gives big opportunities for product development and process research. Many of the risks involved in full-scale production trials can be avoided. The furnace was primarily built for the purpose of product development, but it is also used in other blast furnace related research projects.

The efforts to keep heat losses to a minimum have proven sufficient. Because of this the consumption of reducing agents are similar to many full-scale blast furnaces. The chemical and thermal treatment the pellets undergo in the experimental blast furnace can therefore be said to simulate a full-scale blast furnace. The example from operation with FP14 also proves the furnace to be sensitive to inferior pellet strength during reduction. This effect is more pronounced in the experimental furnace compared to when the same pellet was tested in a full-scale blast furnace.

As burden material can be sampled from the furnace during operation or after quenching, investigation of reduction mechanisms for various materials and process conditions can be done. This will aid future design of blast furnace pellets.

Used to its full potential, the experimental blast furnace will serve as a valuable tool for blast furnace development and to improve process efficiency. Challenges from alternative reduction processes for iron ores and increased environmental demands will necessitate further process research and technical development. The small blast furnace can prove very important in this work. Two campaigns to test new pellets will be run by LKAB in 2000. There will also be possibilities for others to use it. The experimental blast furnace strengthens Luleå’s position as an internationally significant centre of metallurgical development.

Symbols

- MPBO Standard LKAB olivine pellet, produced in Malmberget.
- KPBO Standard LKAB olivine pellet, produced from Kiruna ore.
- LTD 13930 Low temperature disintegration test. (reduction to magnetite at 500°C)
- ISO 4695 Reducibility test, at 950°C to 65% reduction.
- ITH Tumbling test on reduced material from ISO4695.

**co** Gas utilisation [%CO / (%CO + %CO₂)]

**BRI** Burden Resistance Index \([\text{Blast Pressure}^2 - \text{Top pressure}^2]/\text{(bosh gas volume)}^{1/3}\) * k₁

Reference
