GLOBAL CHALLENGE ON EFFICIENT BLAST FURNACE OPERATION BY USE OF MODERN MEASURING TECHNOLOGY [1]
DIFFERENT DATA FOR DIFFERENT PHILOSOPHIES

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Abstract

Process understanding and optimisation requires the precise monitoring of relevant process parameters. Innovative measuring technology is giving the iron producers the ability to accurately monitor and operate the blast furnace by acting and foresight correction based on valuable data out of the operating furnace. Based on different operation philosophies, different hardware for the acquisition of relevant process data for expert systems exists on the market, to support the operators in bringing the blast furnace to its operation optimum. In an overview different methods of data acquisition will be highlighted and the most promising BF-measuring hardware will be introduced.

DESAFIO GLOBAL NA OPERAÇÃO EFICIENTE DO ALTO-FORNO PELO USO DE MODERNAS TECNOLOGIAS DE MEDIÇÃO
DADOS DIFERENTES PARA FILOSOFIAS DIFERENTES

Resumo

A compreensão e otimização do processo exigem o monitoramento preciso de parâmetros de processo relevantes. A inovadora tecnologia de medição oferece aos produtores de gusa um modo para monitorar e operar o alto-forno pela ação correta e previsível baseada em valiosos dados da operação do forno. Baseado em diferentes filosofias de operação, existem no mercado diferentes equipamentos para a aquisição de dados relevantes do processo para os sistemas especialistas, para dar suporte aos operadores e trazer o Alto-Forno a uma situação ótima de operação. De um modo geral os diferentes métodos de aquisição de dados serão destacados e os mais promissores equipamentos de medição em Altos-Fornos serão apresentados.

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INTRODUCTION

The global increase on steel production is driven mainly by the economic growth of the Asian market, accompanied by a strong price increase for base materials like iron ore, coke coal, coal and energy in general.
Estimations based on sources of the IISI and VDEH predict an increase in steel production of up to 1830Mtn´s for 2015 going along with higher prices for base materials and energy.
In addition to the global situation the European producers are facing local problems provoking the further optimization of the blast furnace process as a must.
Due to the strong environmental restrictions – amongst others the trading of emission-certificates - and the higher labour cost the European producers are continuously challenged to optimize their blast furnace operation in order to remain competitive to countries with less restrictions and labour costs.
The daily strive of reducing iron making cost includes therefore the search for higher production efficiency, optimal reduction agent utilization, best quality iron even with lower cost burden and a long furnace campaign life. Achieving these targets requires an intimate understanding of the blast furnace processes in view of optimizing them.
But not only the European furnace operators are challenged. Global warming, energy consumption coming along with problems in exhaustion of resources is calling on the industry to act environmentally responsible. Consolidation of the steel industry is going on and only the one who makes best use of all resources will be well positioned on the market.

GENERAL ASPECTS OF BF CONTROL SYSTEMS

In order to optimise the operation of a blast furnace various BF control systems with different strategies were developed by different companies.
Regardless of the various strategies and types of the control systems, the basic concept of all systems is similar: Bringing the blast furnace to its operation optimum under consideration of reliable real time data, mathematical models and historic data base. All these in a combination shall give the operator a safe guidance during operation and support in taking decisions.
Depending on the concept of the control system and user, the operators do have more or less freedom to follow the recommendations of the system or to just take them in consideration for actions they decide based on their own know-how.

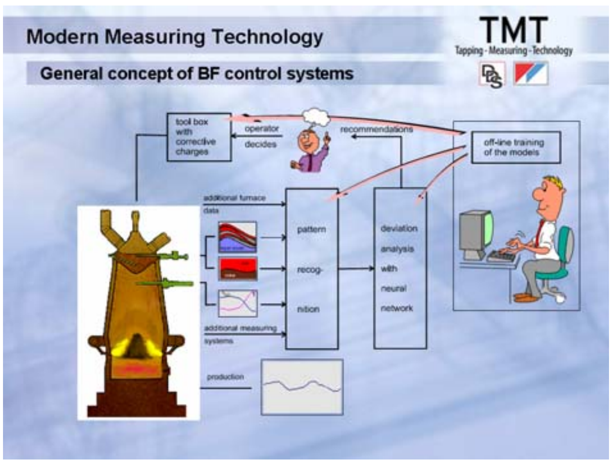


Figure 1: General concept of a BF control system

Probes at the blast furnace

Good process understanding and optimisation requires the precise monitoring of relevant process parameters as data base for the control system. Innovative measuring technology is giving the iron producers the ability to accurately monitor and operate the blast furnace by acting and not reacting based on valuable data out of the operating furnace.
Based on different operation philosophies, different hardware for the acquisition of relevant process data for expert systems exists on the market.

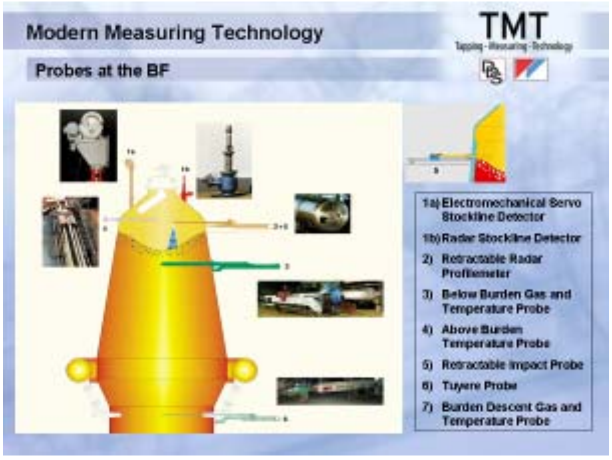


Figure 2: Probes at the BF

The described hardware supports the operators in bringing the blast furnace to its operation optimum with the following targets:
- Visualization of the blast furnace process
- Providing input data for mathematical models
- Control the burden distribution
- Optimize the energy usage
- Improving the hot metal quality
- Extend the blast furnace campaign life

The following equipment represents the most common used hardware installed at different blast furnaces in the world:

Servo-mechanical stockline probe

A commonly known and used measuring device is the servo-mechanical stockline probe. By use of a servo mechanical winch system the stockline probe is installed at the furnace top and gives information about the burden level and descent speed. These data give the input for the burden charging process and operation is always between the burden charging sequences. As nearly every installation worldwide is does have stockline probes, they do not need any further explanation.

Radar stockline probe

Instead of working with the mechanical winch system only many operators added the radar solution due to the advantage that a continuous measuring of the burden level and burden descend speed is possible. That means no loss of charging time during the measuring process, resulting in a smoother charging process.

The very compact installation makes it easy to install it even at a later stage and as the connecting tube is flexible in length it fits into every BF-top situation. On the other hand the radar might not give reliable signals in case of a high concentration of particles in the gas zone above the burden level and therefore a back-up winch system should be considered.

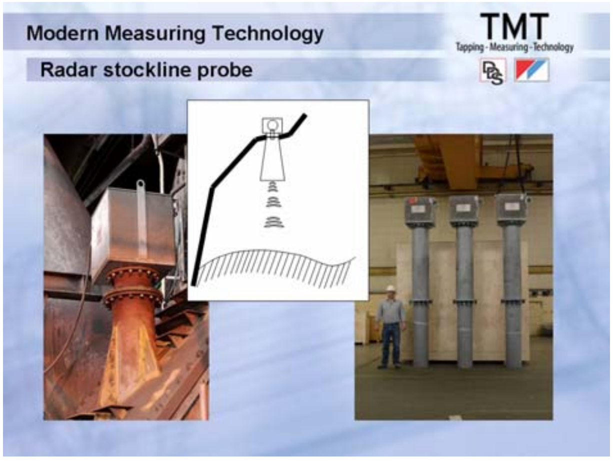
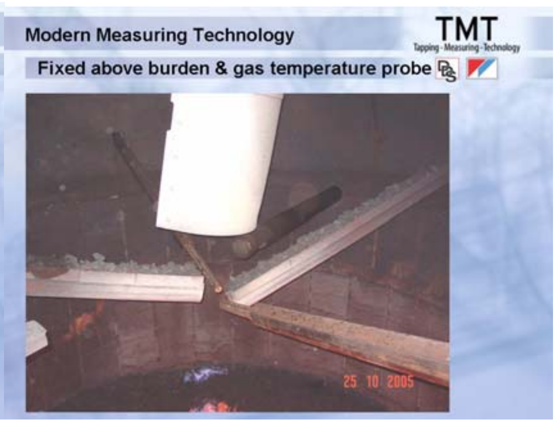


Figure 3: Radar stockline probe

Especially in Japan, but also newer installations in the Russian Federation at JSC Magnitogorsk and Novolipetsk and for example CST in Brazil are considering the radar technology within their control systems. Also at TKS-CSA the new furnaces will be equipped with 2 radar stockline probes besides the mechanical probes. Due to the possibility of observing the stockline at three different points, burden brake downs at certain can be detected much earlier.

Fixed above burden gas & temperature probe

The above burden temperature probe is a commonly used instrument. It measures the temperature in the gas area above the burden as a function of the furnace radius. Either one, two, three or four of these probes are arranged over the burden. This type of probe is a standard method to get a temperature-over-the-radius function to assess the gas velocities what can be taken as an image of the reducing gas utilization. By installation of three or four probes it can also be evaluated if the furnace is symmetrically. Picture 5 shows the installation of 2 temperature and gas probes, as well as an impact probe and ignition lance.



Figures 4 and 5: Fixed above burden probe for temperature and gas

A mayor disadvantage of this type of probe is that the temperature information is not very accurate. The measurement is influenced by the following effects:
- gas turbulence
- cold material that is charged in the furnace generates measuring mistakes
- the burden surface changes the gas flow direction, so that the correlation between gas temperature and radius gets disturbed.
- the exhaust pipes generate an additional effect on the gas flow direction, thus disturbing the relation between temperature and radius.

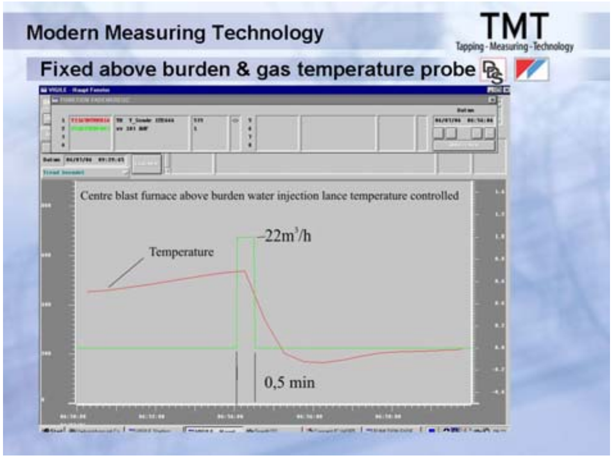


Figure 6: Temperature curve before and after water injection

In addition to the temperature measuring many of these probes are equipped as well with gas analysis. This additional information helps the operator to evaluate even better where the gas is passing the burden and connected to an analyzer cabinet the content of the gas can be determined.

Impact probe

The impact probe is utilized to confirm the burden charging curve while charging. Installed above the stockline and equipped with several sensors on the upper side, the impact of the charged material on the lance is measured and gives a clear picture of the real trajectory to compare it to the model. Especially damages at the feeding chute can be detected as the real impact deviates from the model.

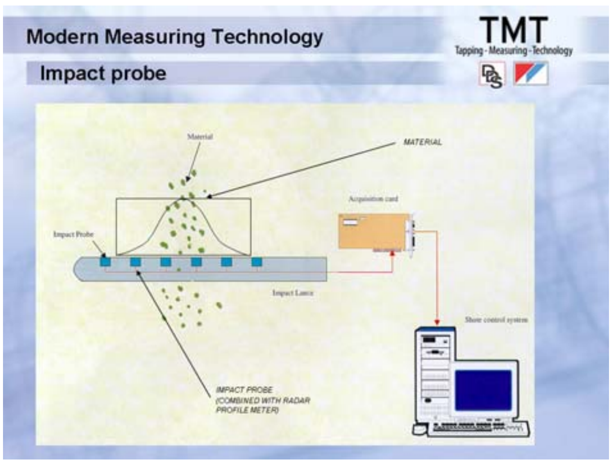


Figure 7: Function of impact probe

Profilmeter

The Profilmeter belongs to the key instruments with regards to the goal to optimize the furnace operation. It is arranged in the gas area over the burden. The profilmeter is equipped with a radar electronic outside the furnace. The radar waves are deflected by a mirror-type plate towards the stockline. Similar to the principal of the echo dept sounder the distance to the burden is measured. With the lance moving over the furnace surface the profile of the burden can be measured.

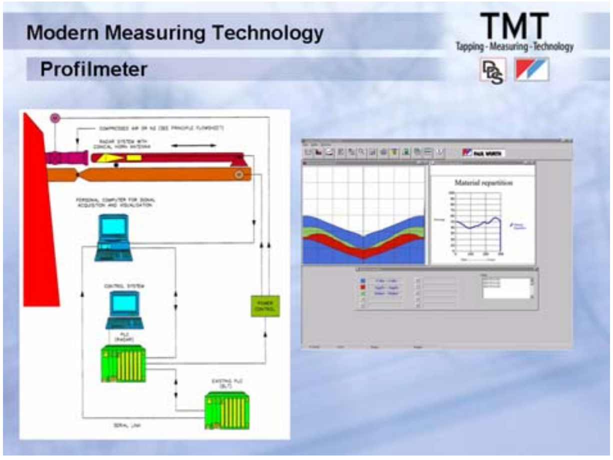


Figure 8: Profilmeter principle and data evaluation

If a measurement of the profile is performed after each charging, a complete charging cycle can be sampled. With the information about type and amount of the material charged, the different profile measurements can be formed to al layer model of the burden in the furnace. Figure 9 shows a layer model as a result of several profile measurements. The material is classified in different groups for mineral and coke.

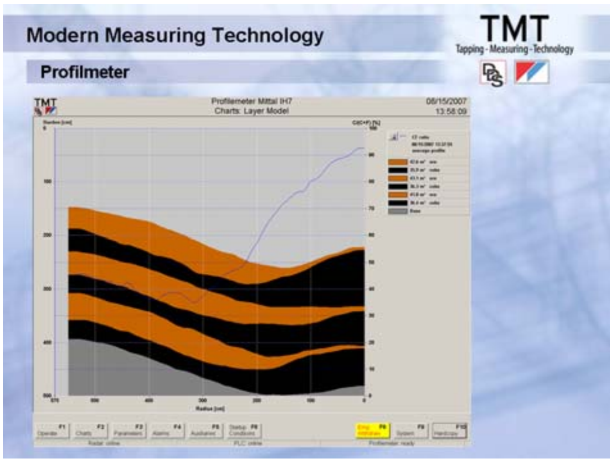


Figure 9: Layer model measured with Profilmeter

If the components of the different groups are integrated up, the relation between coke and mineral burden can be evaluated as a function of the furnace radius.

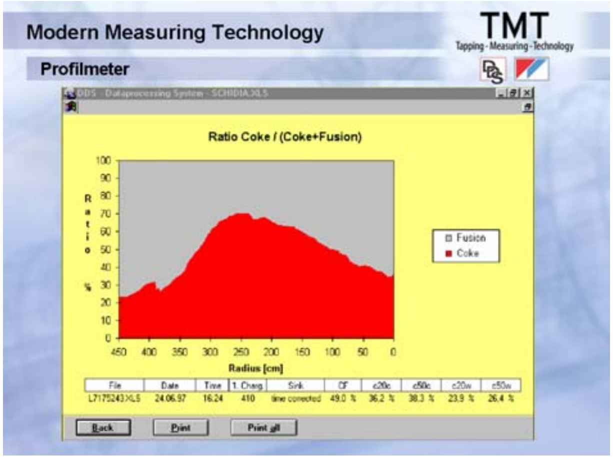


Figure 10: Coke/Mineral ration

The Profilmeter results give very important intermediate information of the process. As there are so many possibilities to vary the charging program, it is a very important knowledge, how the material is really arranged in the furnace as a result of the actual charging program.

The profilmeter is utilized at many of the worldwide installed modern blast furnaces and proofed to give a reliable data base. Amongst others it is installed at POSCO´s furnaces in Korea, Salzgitter in Germany, Aceralia in Spain or at CST in Brazil.

In-Burden probe

The in burden probe is arranged about 3 to 4 meter below the burden surface. It is capable to take reliable temperature measurements and also take gas samples for online analysis. The in burden probe has the following advantages:

- most reliable information about temperature as a function of furnace radius
- measurement not disturbed by gas turbulence
- measurement not disturbed by cold material
- temperature and gas measurement is possible
- the probe is retractable, therefore it is better maintainable and more reliable.

Figure 11: In-burden probe

For all these reason the in burden probe really proves to be a key instrument for the optimisation of the furnace operation. If such a probe is not available, it is highly recommended to invest in an instrument like this, because the resulting furnace optimisation will ensure a quick pay back.

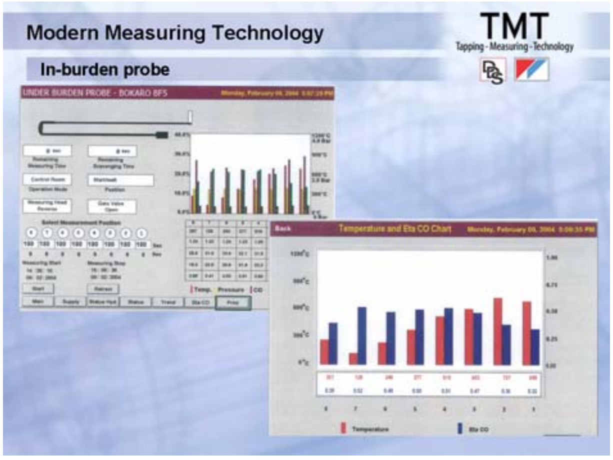


Figure 12: Measurement by In-burden probe and η_{CO}-visualization

The conventional data treatment ensures already, that the original measurement values which are sampled as a function of the time are converted to functions of the furnace radius. This applies for the temperature as well as for the measured gas portions CO, CO_2, H_2. Additionally to the measured values the N_2 portion can be calculated. Also the gas efficiency value η_{CO} can be calculated from the CO and CO_2 gas portions. As there is a high correlation between the temperature function and the function of η_{CO}, for further use in optimization models either one of the tow functions can be used.
More than 70 in-burden probes installed around the world confirm the advantage of having reliable data measured below the stockline. For Thyssen-Krupp in Germany it can be considered as one of the key-probes within their control system, but amongst others also Arcelor-Mittals Dillinger Hütte in Germany or CST in Brazil trust this innovative and proven measuring technology within their operations.

Wall measurement

The wall temperature measurement is also a useful help for furnace optimization. The measurement can either be performed with thermocouples in the furnace wall or by evaluating the temperature increase of the cooling water. Both methods generate a temperature function over the height of the furnace shaft. This is useful additional information. But as there is no information from the inner part of the furnace this measurement cannot substitute the in-burden measurement.

Scanning probe

The intention for this measurement is comparable to the one of the profilmeter. The main difference is that this measurement is performed on the same level as the in-burden probe thus having the advantage that intermixing of material and rolling effects of the material cannot influence the direct layer measurement.
The principle of the Scanning probe is based on the continuous movement of a horizontal measuring probe in the blast furnace. At the front end of the movable lance a measuring head is installed. This measuring head serves to detect the electric

resistance of the micro volume (grains) of the charging material passing along the head.

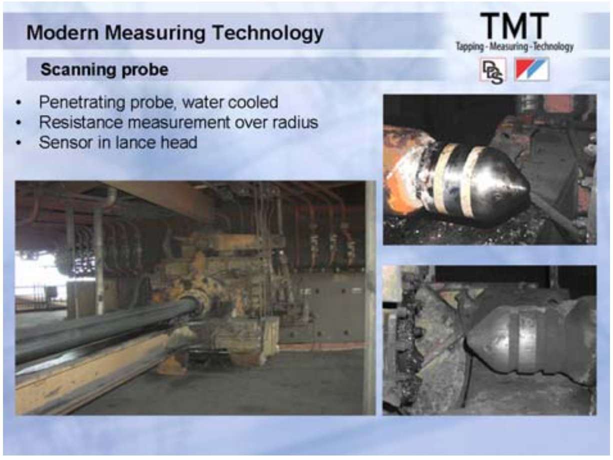


Figure 13: Scanning probe

Using the principle of measuring electrical conducting capacity of the charging material in the furnace to get information about the material distribution has a long history. Benefit is taken from the big difference in the electrical resistance of coke and burden grains (micro volume). With temperatures up to 600°C the electrical resistance of coke pieces is in the range of 0-4Ω, whereas the resistance of burden particles is in the MΩ-range.

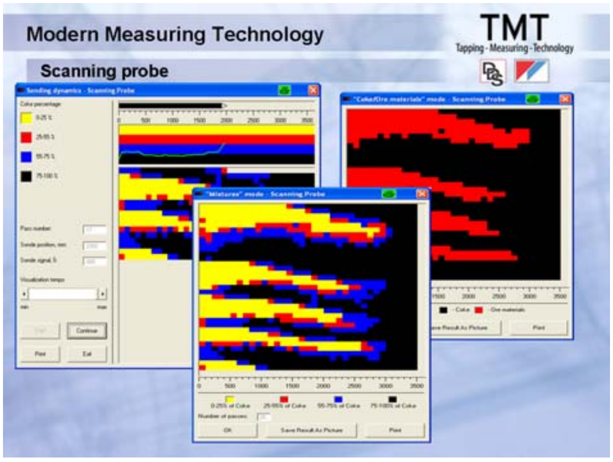


Figure 14: Layer model based on scanning probe data

With the target to build up a complete and informative layer model of the burden, the probe has to perform a sequence of probe operations (30-60 operations per cycle). Within each operation the probe is moving in- and out the furnace and measures continuously the conductivity of the burden. Between each operation a certain time has to pass allowing the burden to descend about 100-120mm before starting the next movement. Best method to control the descent rate is by use of the signals coming from various radar stockline probes or by use of a profilmeter to eliminate the radial differences of the burden descent. This complete operation sequence assures that always a new section of burden will be measured and a matrix of reliable data is taken. Based on this matrix a model of the real burden situation below the scanning probe can be done by use of special developed software (Figure 14) and be used to proof and fin-tune the charging model, as this is based on mathematics and physics only and not considering real operation deviations and charging mistakes (Figure 15).

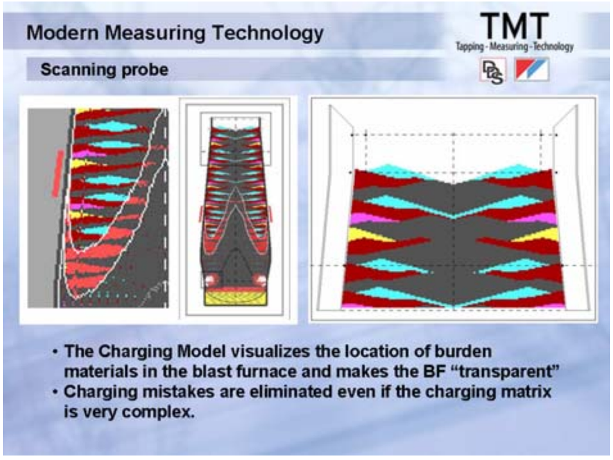


Figure 15: Mathematical charging model

The latest version of the scanning-probe program gives as well information about porosity of the burden and helps to understand more about the gas dynamics within the furnace.
The scanning probe is installed and operational at BF5 of JSC Novolipetsk in Russia and EKO-Stahl in Germany.

CONCLUSION

The described measuring probes give a picture about the possibilities of modern measuring technologies and benefits for the blast furnace operator to even better understand and optimize the process. Although many more than the mentioned probes are installed at world wide blast furnaces and listing all installations by type of probe would be to complex, there are different trends and opinions among the experts, on what probe is giving the more reliable information.
Nevertheless the targets are similar:
- Smooth burden descent
- High reduction efficiency
- Heat loss limitation
- Low pressure drop
- Low hearth wear

Therefore it is important to control the gas distribution to achieve a centre chimney with low activities near the walls. The gas distribution on the other hand can be controlled by the burden distribution; means controlled charging of the different raw materials. Respectively the following conclusion can be made:
- the more reliable data about the current gas and temperature distribution can be collected, the better the information on gas distribution is.
- the more data about the real burden profile and composition can be taken, the better the possibility to proof the charging model and develop the best charging matrix is.
- the earlier deviations of the theoretical charging curves can be detected, the sooner the reasons can be determined to adopt the system accordingly.

Different automation systems and different charging modelling tools with more or less complexity are used to support the operator in the interpretation of the data, to determine the right charging matrix and action while operating the blast furnace. The more data are collected, the more important is the use of a sophisticated system to process the received data in a fast and reliable way.
Based on mathematical models, historic data, actual measured data and knowledge input out of various different operation situations, expert systems are designed to guide the operator through this complex accumulation of information. Data are evaluated and processed with forecasted information and recommendations of actions. Based on these prepared information the experienced operator is able to decide even better and faster the necessary action to bring the blast furnace to its operation optimum.
Due to the fact that the iron producers are forced to maximize the efficiency of their operations even within the last percentages the significance on control systems is rising and respectively the relevancy of reliable measuring equipment.
The mentioned installations can only taken as a small sample about who is using which type of probe, but it shows that the mayor iron producers around the world realized that the relevancy and need of optimising the blast furnace operation based on valuable date is stronger than ever. The decision to rely on modern measuring technology for the process optimization is a strategy clearly approved by their good operating results and market positions and a demand to every blast furnace operator with the interest of a beneficial operation - regardless of its size or location.