Experience of new BOF operations at Třinecké železárny

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Abstract

The paper gives an account of the results obtained for new technologies recently introduced at the BOF converters at Třinecké železárny. Since 1998, scrap pre-heating technologies as well as those using the so-called steelmaking sinter have been introduced and optimised. The converter vessels have been replaced and the associated converter and bottom blowing nozzle linings have been renewed. The technologies of nitrogenisation of the converter steel, slag splashing, phosphorus content prediction, the so-called direct tapping and slag-free tapping technologies are currently under development. The application of these technologies seeks to allow for production cost savings and provision of the required parameters of the steel.

Key words: BOF, scrap preheating, lining, slag splashing, direct tapping, nitrogenising

Introduction

At the BOF steelplant, the steel is produced in two 185 tonne BOF LD-type converters with bottom Ar or N_2 blowing. Two inert gas homogenisation stations serving the function of homogenising the as-tapped steel are available for the secondary treatment of the steel. Two ladle furnaces are used to heat the steel as well as a chemical heating facility. Moreover, steel vacuum degassing is available in an RH-type device while the erection of a second RH-OB vacuum degassing station was launched sooner this year. The steel is cast using a bloom caster (5 strands) into 250 x 320 mm, 300 x 350 mm, ø 320 mm, ø 410 mm, and ø 525 mm formats. The output of the bloom CCM is 900 kt/y. The billet CCM (8 strands) may cast 1400 kt a year, solely into the 150 x 150 mm format. The annual output is approx. 2400 kt of steel including 2250 kt of continuously cast steel. The rest is cast into ingots.

Třinecké železárny, as the producer of long products, have their steelmaking based on iron ore foundations. Therefore, a lot of attention is devoted to the converters and the technologies they operate. The present paper gives a rounded-off overview of the procedures and changes introduced during the recent years.

1. Replacement of Converter Vessels

The extensive modernisation involving the replacement of the two converters took place in two stages in the steelplant department where the original converters (of Soviet design) were replaced, after 21 years of service, with SMS DEMAG-system converters. The K2 converter including the drive was replaced during September and October 2004, whereas the K1 replacement occurred in September and October 2005.

Modernisation Highlights:

- the new converter vessels are of slenderer, “unweighted” structure compared to the original ones;
- the volume of the vessel was increased by 28 m^3 (total volume of 167 m^3);
- the vessel is seated in the bearing ring using 8 bars;
- the bottom inert gas blowing through the converter bottom was changed from 4 to 8 blowing nozzles;
- the tilting drive has been provided with inverter-controlled asynchronous electric motors.

The scope of the modernisation investment also included the revamping of the drive of the facility initiating the oxygen lances for the converter, the measuring probe, the bottom blowing control station, total replacement of the steel structure of the protective walls (doghouse) and impact walls under the converter. At the same time, the converter tilting drive electric facility was totally modernised. The total modernisation investment was completed within 32 days with the adjacent converter operated at full capacity.

2. Trends in Converter Lining Life

The global trends in using refractory converter materials have gone from resin bonded dolomite materials, magnesite-dolomite and magnesite materials, via burnt magnesite vacuum saturated materials up to magnesite-carbon (MgO-C) materials. The trends at Třinecké železárny took an identical course. The development in converter lining materials leading up to the presently used MgO-C type materials was a response to the ever growing demands, operational requirements and conditions to which the refractories were exposed. The service life of the linings was gradually changing as a function of the availability of high-quality refractories, the steel grades produced, the type of secondary treatment applied and the casting method. **Figure 1** shows a graphical representation of the gradual rise in increasing the life of converter linings at TŽ.

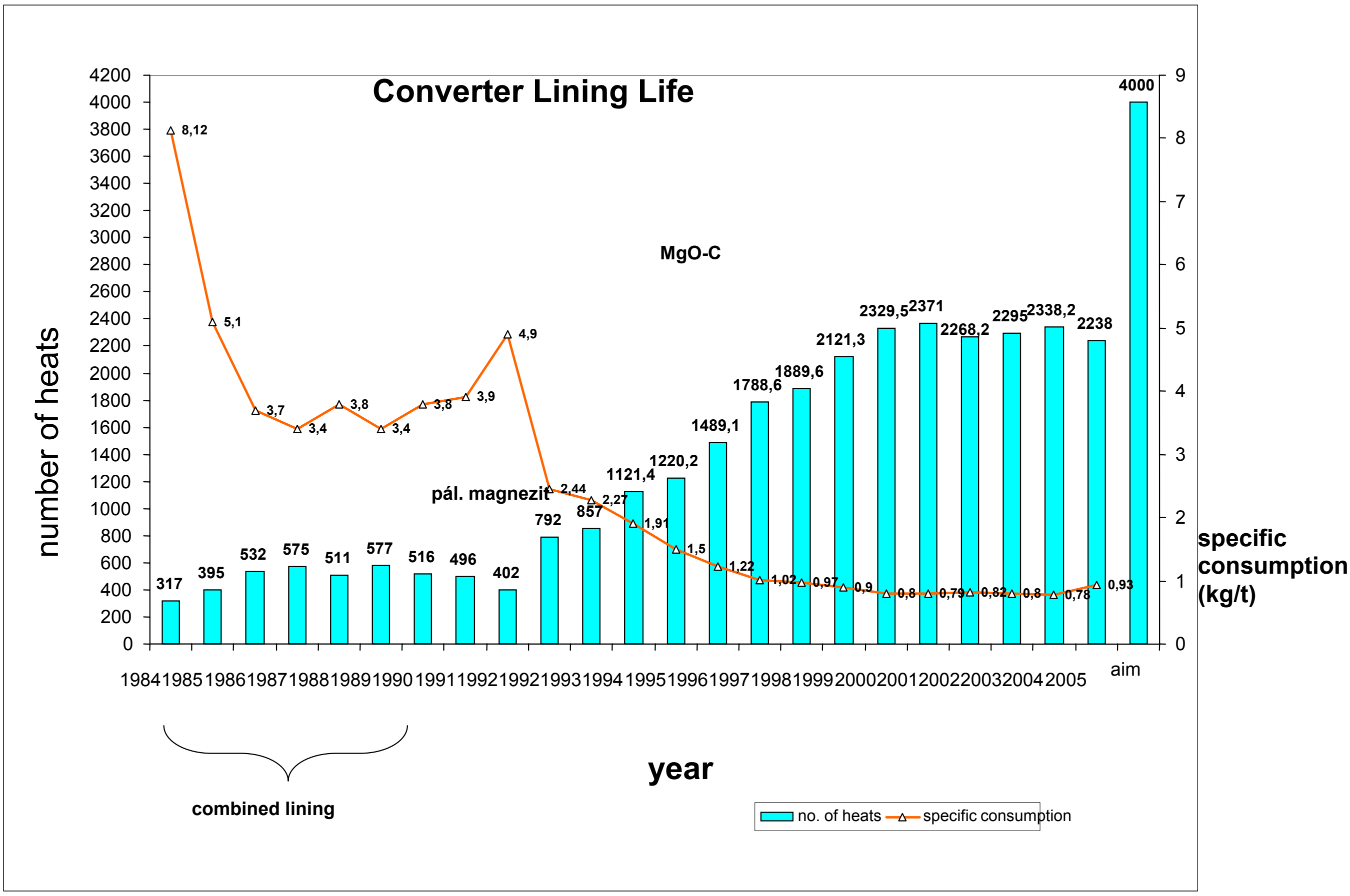

Figure 1 – Trends in Converter Lining Life at Třinecké železárny

The increases in the lining life were achieved:

a) through changes in the production technology:
- increasing MgO in slag
- adjusting the doses of dolomite lime
- reducing the consumption of fluorspar
- changing to six-hole nozzles
- reducing the average tapping temperature from 1660 °C to 1645 °C.

b) through adjustments in the construction of the linings, maintenance of the linings during the service life:
- introduction of zonal linings
- use of ever increasing volume of heavy duty shaped bricks in the linings
- development and introduction of shot-creting and redressing substances at ever increasing quality.

The effect of quality parameters of refractory materials is substantial due to the purity and MgO crystal size, the fused grain ratio, the quality of bonding applied and the content of carbon in the shaped bricks.
Thanks to the two methods described above, the specific consumption of the shaped bricks was reduced from 8.12 kg/t of steel at the onset of the operation to the current 0.78 kg/t of steel. The increase in the specific consumption in 2005 was brought about by a change in the shape of the converter vessels thus increasing the total mass of the converter linings. The record-breaking life amounted to 2620 heats, yet two converters had to be shut down prematurely in 2005 due to organisational issues, not due to the lining wear; the total life with these campaigns could have reached up to 2850 heats.
The thinnest location in the structure of the lining is the bottom/wall radius of the converter. Various types of traditional linings up to semi-spherical linings were tested. **Figure 2** shows the examples of the various types of linings used. At the time being, spherical lining is being operated at the K2 converter (see Figure 2). The practical use of the lining will be subjected to an evaluation of the costs as well as operating safety and reliability.

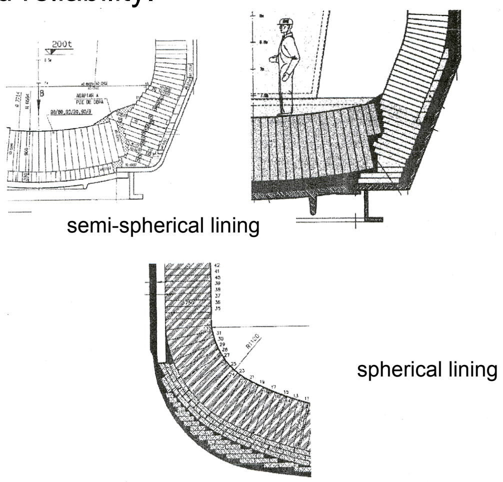

Figure 2 – Examples of various type sof linings

3. Trends in the Life of Converter Bottom Blowing

Bottom converter blowing was launched in 1994 at TŽ. Since then, the bottom blowing system has undergone a number of changes. Various types of blowing nozzles have been used, ranging from metallic slotted nozzles, via ceramic tube blowing nozzles, steel U – tube systems with the achieved lives ranging from 400 to 700 heats, up to the presently used MHP (**M**ulti**H**ole**P**lugs) nozzles. 18-, 24- and 32-tube nozzles have gradually been used. The shaped bricks with pressed-in tubes manufactured out of MgO-C material are being made of resin bonding with 100 % fused grain – long crystals. The residual C content is 14 %.

The previous vessels held 4 MHP-type blowing nozzles arranged along the circumference. The lifetime of the MHP nozzles was 1200 heats.

With the new converter vessels, the layout of the nozzles is different as well as the shape of the vessel. Eight MHP-type blowing nozzles are arranged in the bottom along an elliptic orbit. The layout of the nozzles with the new vessels is shown in **Figure 3**. In order to meet the technological production conditions, it is essential that as long service life of the bottom blowing system as possible be provided. The target is to extend the bottom blowing system life to the entire life of the converter lining. The trends in the lifetime of the bottom blowing system are shown in **Figure 4**.

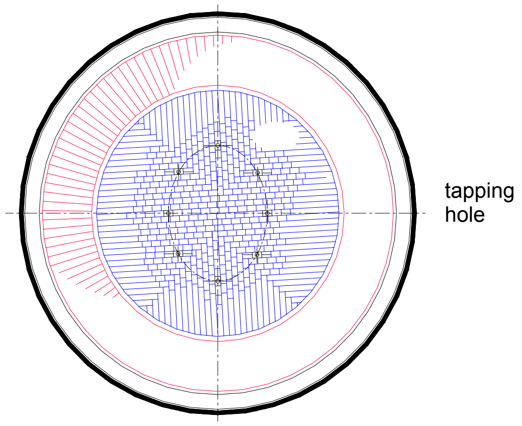

Figure 3 – Layout of nozzles with new vessels

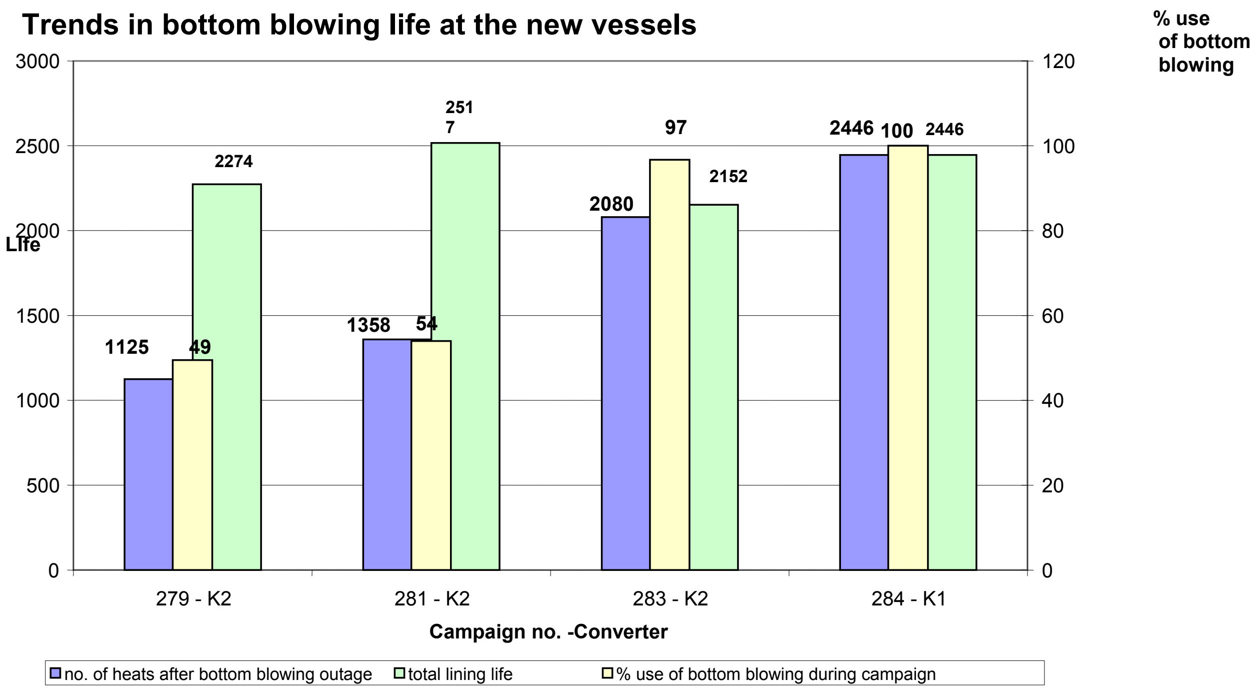

Figure 4 – Trends in bottom blowing nozzle lining at the new vessels

4. Slag Splashing Technology

The converter linings are zonal structures, which make it possible to achieve uniform wear of the entire converter. At TŽ, however, they do not allow further step increases to be achieved in their life and, inherently, specific costs to be reduced. One of the options available to achieve further increases in the life figures involves the introduction of the slag splashing technology in practical operation.

At TŽ, optimal conditions have already been yielded to introduce the technology (bottom blowing introduced with the new vessels, which allows achieving the same life as is the case with converter lining) and at the time being, operation tests are underway at the BOF steelplant, which make use of slag splashing.

Fundamental slag splashing parameters:
- nozzle used: existing six-hole oxygen nozzle;
- nozzle position above the bath: 600 – 1200 mm;
- Nitrogen flow rate: 600 Nm^3/min;
- Nitrogen blow time: 4 min;
- raw materials used for optimising the chemical composition of slag: raw dolomite and raw magnesite;
- average chemical composition of slags before the slag splashing application (see **tab. 1**).

Tab. 1: Average chemical composition of slags before slag splashing application [%]

Fe_{total}	CaO	MgO	SiO_2	MnO	Al_2O_3	Basicity
25.12	36.73	10.16	10.79	4.48	1.54	3.55

Presently the technology is being verified at the two converters where partial success has already been recorded. The operation test performed attests to the beneficial effect of the method at TŽ. The consumption of redressing substances dropped by 50 %; with the actual spray guidance already adjusted, the most suitable raw materials for enriching the MgO slag are yet to be selected. The maintenance of the working lining using the slag splashing technology in steelmaking applications at TŽ is one of the ways for us to meet the objectives set in the domain of the life of the converter linings, i.e. 4000 heats.

5. Scrap Preheating Technology and Use of the So-called Steelmaking Sinter

5.1 Scrap Pre-heating

The introduction of the scrap preheating technology sought to allow for further increase in the share of scrap in the charge and improvement in labour safety when filling up the pig iron, especially in rainy weather and in winters. Two fundamental types of scrap heating technologies were tested:

- Short scrap heating – removes moisture, ice and any oil from the scrap surface. This helped to diminish the reaction experienced when filling up pig iron, inherently improving labour safety.
- Regular scrap preheating – besides the improved labour safety referred to above, this option allows for a marked growth in the volume of scrap added thereby substantially reducing the consumption of pig iron without impacting the output of the steel mill.

Gas coal or anthracite is used as the fuel for pre-heating scrap at TŽ. The use of individual types of scrap pre-heating technologies yielded an increase in the share of scrap in the charge. With short preheating, the increase in the share of scrap amounted to o 2 – 3 %; with regular preheating of the scrap, the rise was up to 6 %.

Since 1997 when it was introduced, scrap preheating has been a part of the steelmaking technology at the BOF converters at TŽ. The annual shares of the use of the scrap preheating technology range between 65 and 80 % - **Figure** 5.

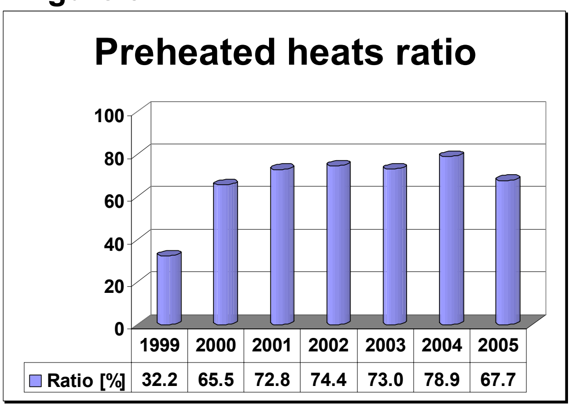

Figure 5 – Scrap preheating

5.2 Use of Steelmaking Sinters at TŽ, a. s.

The year 1999 also saw the introduction of using basic sinters in converter steelmaking. The design envisaged using sinters for the conditioning of the converter slag as the source of MgO, ferrous oxides and CaO. The basic sinter has fully replaced dolomite lime that had been used until then.

Various types of basic sinters are used for various purposes in the oxygen converter:

- FeOx sinter as a fine coolant, flux, raw dolomite replacement;
- MgO sinter as flux, dolomite lime replacement, source of MgO in converter slag
- CaO sinter as a flux, replacement of raw dolomite and dolomite lime, for better dephosphorisation in the converter.

The actual composition of the sinters depends on the method in which the sinter is used. The following limits have been set for the individual types of sinter:

- FeOx sinter – maximum FeOx content in the sinter is 65 %
- MgO sinter– maximum MgO content in the sinter is 30 %
- CaO sinter – maximum CaO content in the sinter is 50 %.

As the basic sinter is not hygroscopic, it may be stored outside indoor shops and therefore, larger reserves may be produced within a campaign; at TŽ a monthly reserve of sinters is common.

The properties of basic sinters may be summarised in the following way:

- steelmaking sinters – new type fluxes;
- display more stable results in terms of physical and chemical properties, they are stiff and do not hydrate
- improved handling and storage, basic sinters may be stored within several months
- when handled, they are not subject to material degradation
- use of basic sinters for oxygen converters provided better process stability, improved refining and increased steel yield.

6. Converter Steel Nitrogenisation

The use of the slag splashing technology allowed the development of nitrogenising technology. Via the oxygen nozzle, additional N_2 is blown in during the main blowing process, which may be used to add nitrogen to the steel grades where increased N_2 content is required.

A technology of controlled nitrogen addition into converter steel during the blowing process was developed along with the combined blowing through porous shaped bricks in the converter bottom. Presently, 3 oxygen blowing modes are employed depending on the required N content - see **Tab. 2**. The nitrogen is added in the amount of 1/6 of blown oxygen up to 85 or 95% of the total oxygen blowing time.

Tab. 2: Parameters of O_2 and N_2 blowing for nitrogen pick-up

Type of blowing	N blowing time	Achieved N (ppm) after tapping	Avg N (ppm) after tapping
O_2 only	-	max. 60	31
O_2 + N_2	Up to 85% of O_2 blown	50 - 110	86
O_2+N_2	Up to 95% of blown O_2	60 - 140	102

The achieved N_2 contents as per the individual blowing versions are shown in **Figure 6**.

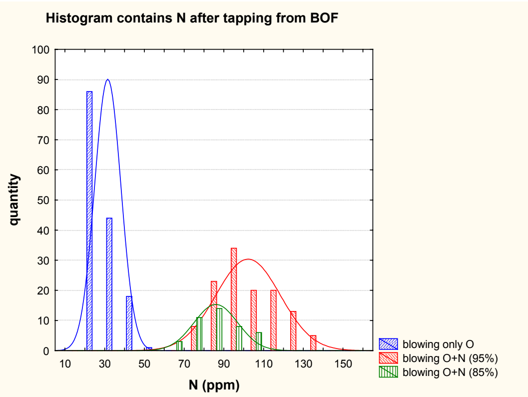

Figure 6 – Distribution of obtained Nitrogen values with the use of various O_2 and N_2 blowing modes after tapping

Steel nitrogenisation is dependent of the C content in the melt during the main blowing process. With lower C contents N for the required steel nitrogenisation may be used in a more efficient way. The final C content after the main blowing ranges between 0.04 and 0.07 % C.

The use of the steel nitrogenisation technology via an oxygen lance along with combined blowing through the bottom of the converter may facilitate nitrogenising the steel grades produced to the value of approx. 100 ppm N with possible savings of nitrogenising agents (FeMnN, $CaCN_2$) in the secondary metallurgy department. The only disadvantage inherent I the technology involves prolonged oxygen blowing type by approx. 2 min.

7. Direct Tapping Technology Based upon P Content Prediction

Dephosphorisation remains one of the key functions of metallurgical production units under the current production technologies. Achieving very low phosphorus contents is, however rather complicated representing severe lining loads and requiring increased consumption of pig iron and fluxes.

The commonly used method of determining the phosphorus content involves taking samples and submitting them to evaluation in a chemical laboratory. Yet the application of the method is time consuming, which is why methods of determining the phosphorus content in the bath are being sought in order to reduce the time of melt retention in the converter and reduce the converter loading or increase the productivity rate, if possible, by conducting the direct tapping.

The most flexible and suitable solution to the issue involves installation of a probe for continuous measurement of the phosphorus content in steel and prediction of phosphorus content on the basis of active coefficients, steel and slag temperatures, respectively. Introduction of the above method will eliminate the time required for the transport and analysis of the sample.

The development of the algorithm for P content prediction through measurements with a special sublance probe takes place in several stages. Initially, the evaluation algorithms were trimmed through measurements and comparing the results obtained with those reached in laboratory conditions. During the second stage a series of measurements were run in order to determine the accuracy of the results, see **Figure 7**. From the frequency distribution obtained it is clear that 81.91 % may be regarded as satisfactory in terms of accuracy, i.e. the difference in P values determined spectrometrically and those obtained from the probe measurements (predictions) ranged from –0.005 % to +0.005 %.

During the third stage, a certain part of the range of steel grades produced was singled out to be submitted to strict operation tests of P content prediction. The objective was to increase the ratio of heats produced under the mode of single blowing with direct converter steel tapping based on P content prediction.

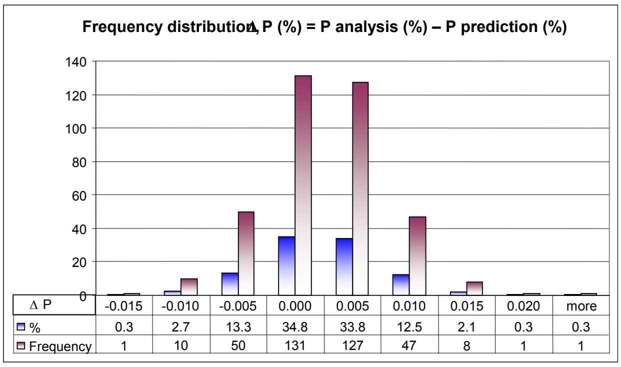

Figure 7 – Frequency distribution, delta P (%) = P analysis (%) – P prediction (%)

8. Slag Free Tapping Issues

One condition that must be yielded in order to allow for stable secondary metallurgy parameters to be provided involves stopping the converter slag from getting into the ladle. IN order to achieve that condition, a system of slag indication using infrared spectra and the so called “floating stopper” is used..

Indication of slag using infrared light of the MPE/ITEMSA system is installed on both converters and is currently subject to verification. The so-called slag signal from the camera, which implies radiation energy within the range of infrared waves is interconnected with the converter tilting mechanism. The hardware and software of the entire system allows the entire duration of converter steel tapping to be monitored and the time of tapping to be completed. **Figure 8** gives an example of three steel casting steam statuses during the tapping procedure, which the system registers and works with. The entire system provides for the possibility of storing the most important information on the tapping. Judging from the initial experience, it is clear that the entire system must be adapted to the converter conditions and tapping technology.

Contact-free slag detection system

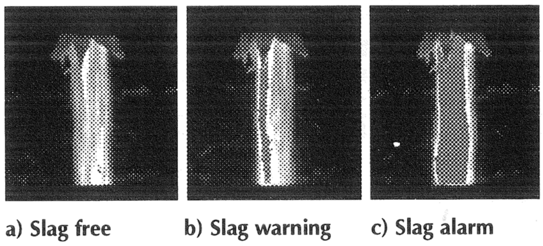

Figure 8 – Indications of steel during the tap – 3 different statuses

So-called “floating stoppers” are moreover used to increase the efficiency of slag-free tapping, fed into the tapping hole inside the converter towards to end of the tap. The most important aspect of the floating stoppers is the specific weight and the shape of the conical stopper part, which fits to the tapping hole.

Besides the improved conditions of the secondary metallurgy the slag-free tapping should also lead to cost reductions in the domain of alloying and de-oxidising additions due to lower burn-outs.

9. Summary and Conclusion

The most recent engineering and technological knowledge is being applied and optimised at two 180-tonne converters at Třinecké železárny with the objectives to:

- render the steelmaking converter process as stable as possible;
- achieve optimal technological parameters of steel yielding the required secondary metallurgy conditions – in terms of, for instance, management of “inclusion rate”, de-oxidisation control, alloying and providing a narrow range of chemical compositions of steel;
- allow for the production of new steels with higher added value – with so called high quality parameters;
- reducing production costs.