Optimization of BOF Operations at Trinecke Zelezarny

Jaroslav Opletal, Karel Klimek, Zbygnev Piegza, Mikhail Petrunin,
Sergey Chernyavskiy, Grigori Galperine, Barry Schrader

INTRODUCTION

This paper discusses the production and quality improvements at Trinecke Zelezarny over recent years. In 1998 Trinecke Zelezarny licensed Z-BOP Technologies from ZapTech Corporation. ZapTech has partnered Trinecke in the continued improvements at the plant.

PLANT DESCRIPTION

Trinecke Zelezarny is an integrated steelmaking facility producing a wide variety of long products including rails, wire, reinforcing rod, flats, squares, etc. This paper discusses aspects of the sinter plant, blast furnace, and steelmaking shop.

The sinter plant has 4 – 75 m^2 sinter bands producing about 2.8 million metric tons per year of sinter. The sinter is mainly for blast furnace feed. However, high basicity flux for the blast furnace and steelmaking shop are produced.

The plant has two blast furnaces with 1373 m^3 working volume. The silicon from the blast furnace averages 0.64% with a range from 0.40% to 1.45%. The phosphorous from the furnaces averages 0.10% with a range of 0.070% to 0.14%. The sulfur averages 0.020% with a range of 0.010% to 0.050%. Blast furnace operation is varied at times to aid in the production of certain grades.

The steelmaking shop has two 185 tons LD furnaces with bottom inert gas stirring. One of the vessels has been replaced with a new modern design vessel revamped by SMS in 2004. The old vessels from 1983 had an internal volume of 145 m^3 with 4 inert gas bottom stirring elements. The new vessels have a working internal volume of 163 m^3. There are now 8 bottom stirring elements. Trinecke Zelezarny plans to change shell of the other Vessel this year and then after that Trinecke Zelezarny is going to install a hot metal desulphurization station.

The vessels are blown at 450 – 600 Nm^3 per hour. The shop now has the capability to blow both nitrogen/argon and oxygen. The inert gases allow the use of slag splashing for vessel maintenance. In addition, inert gases are used to optimize blow practices to enhance performance.

There are two ladle furnaces, an RH vacuum degasser, and IR-UT ladle refiner capable of chemical heating steel. There are two continuous casters. One is a bloom caster and the other a billet caster.

Flexibility in consumption of hot metal

The BOF shop has continuously increased the steel production. The shop is now producing 2.4 million tons with the goal to reach 2.6 million tons in the upcoming year. Before working with ZapTech the best average scrap ratio was 25.7%. The range in scrap ratio used has significantly increased. On a daily basis the scrap ratio varies from 25% to 34% and heats may be produced with from 10% to 45% scrap. The most important factors determining the scrap ratio are steel and scrap market prices and hot metal availability. The long-term average is about 28% scrap at this time. However, the scrap ratio may (can) be optimized for cost on any particular heat. This is to say heat by heat the ratio can be the ratio desired for that heat. The cost of scrap varies and profitability demands the mix be continually optimized.

Usually two of three kinds of carbonaceous fuel are used. Bituminous coal and anthracite or bituminous coal and coke are the two choices. These materials are used as for scrap preheating, fuel during the main blow and for conditioning the slag for refractory maintenance.

When evaluated on a long-term basis, coke and anthracite perform with similar thermal effects. However, anthracite is more effective for use in rainy or wet seasons (spring & autumn). Coke is porous and looks like little sponges. Coke absorbs significant amounts of water in storage. Coke and anthracite are not stored under cover and are exposed to the elements. Anthracite is solid and does not absorb moisture.

Another positive aspect of anthracite is the ability to use larger quantities per heat. Anthracite is denser in comparison to coke. The small bin capacities of fuel bunkers are small. Also, the higher density provides faster fuel discharging from the scales. Discharge speed is very important large quantities of carbonaceous fuels are used. Figure 1 compares the use of coke to anthracite without scrap preheating.

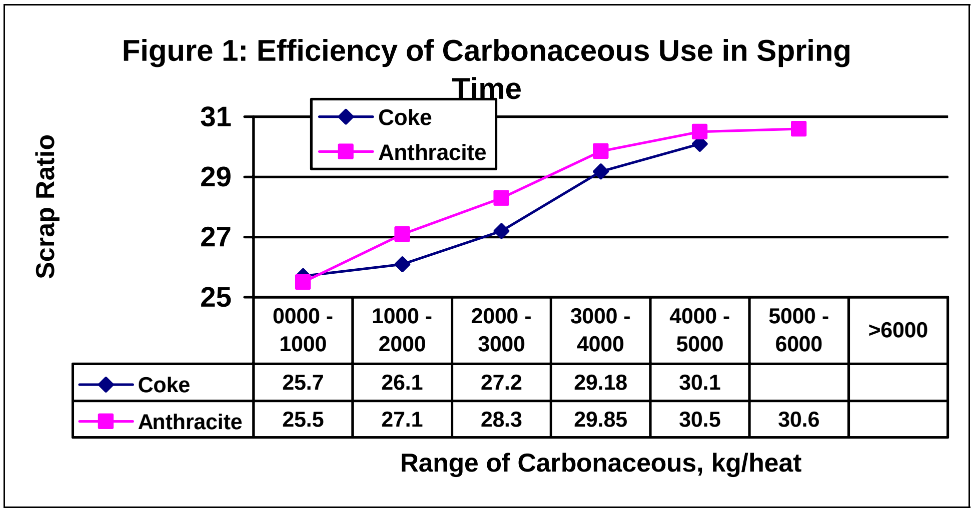

Figure 1: Efficiency of Carbonaceous Use in Spring Time

	0000 - 1000	1000 - 2000	2000 - 3000	3000 - 4000	4000 - 5000	5000 - 6000	>6000
Coke	25.7	26.1	27.2	29.18	30.1		
Anthracite	25.5	27.1	28.3	29.85	30.5	30.6	

The bunker capacity at Trinecke Zelezarny does not allow the use more than 5 tons of coke per heat. However, when anthracite is used, up to 6.5 tons of anthracite can be used per heat. Figure 1 also shows that the thermal efficiency of carbonaceous materials is reduced when large quantities of carbonaceous fuels are used. One reason for this effect is the use of very low energy hot metal for this case.

In summary anthracite provides the following benefits.

1. Anthracite is much denser than coke. Loading material into the bins, weighing the material and discharging the material are faster with anthracite.
2. If the bunker size is limited, anthracite can provide the ability to add more weight of fuel. Therefore, anthracite provides the ability to add more scrap. This allows the shop to replace more hot metal with scrap, increasing production.
3. Anthracite contains less sulfur allowing the use of more fuel for sulfur critical grades. Also, we believe that the sulfur in the anthracite is more easily combusted. More sulfur is burnt. Less is available to be absorbed into the bath.
4. Anthracite provides lower nitrogen in the steel.

Preheating

Use of scrap preheating began in 1999 to increase the scrap melted in the furnace. Scrap preheating reduces hot metal consumption and improves safety though drying the scrap before hot metal charging.

At Trinecke Zelezarny scrap is preheated with only bituminous coal or a combination of bituminous coal and anthracite. Coke can be used in place of the anthracite. ZapTech has used other combination at other shops. They have used natural gas with coke or anthracite. The technologies are very flexible. ZapTech customizes the technology to meet each customer’s specific equipment, steel chemistries, and specific goals.

Two kinds of scrap preheating are used into the vessel. These are:

- Short Scrap Preheating (3 - 4 minutes)
- Regular Scrap Preheating (6 minutes and more)

The main reason for using the Short Scrap Preheating is for safety. Short Scrap Preheating removes water, ice or some oil from the surface of the scrap. This greatly reduces the probability of reactions during hot metal charging. Regular Scrap Preheating reaches the maximum safe increase to the scrap temperature and maximizes the reduction in hot metal consumption.

Please note that experience shows significantly higher efficiency for the carbonaceous fuels during scrap preheating as compared to similar consumptions during use during main blow. Figure 2 compares heats with scrap preheating to heats without preheating. It clearly shows that preheating provides better use of fuel. At the same consumption of carbonaceous fuels, scrap preheating provides an increase of at least 2% scrap.

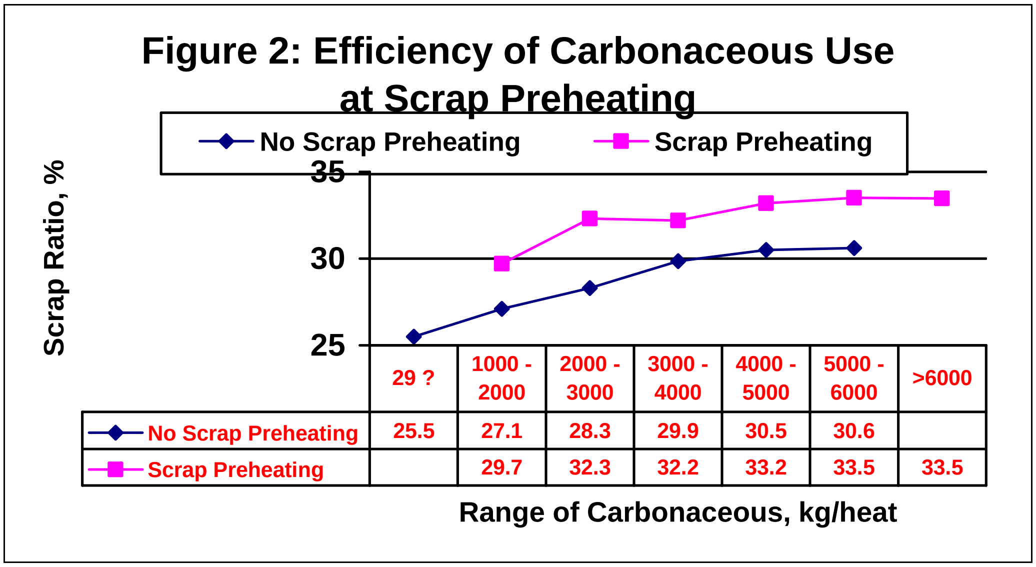
Figure 2: Efficiency of Carbonaceous Use at Scrap Preheating

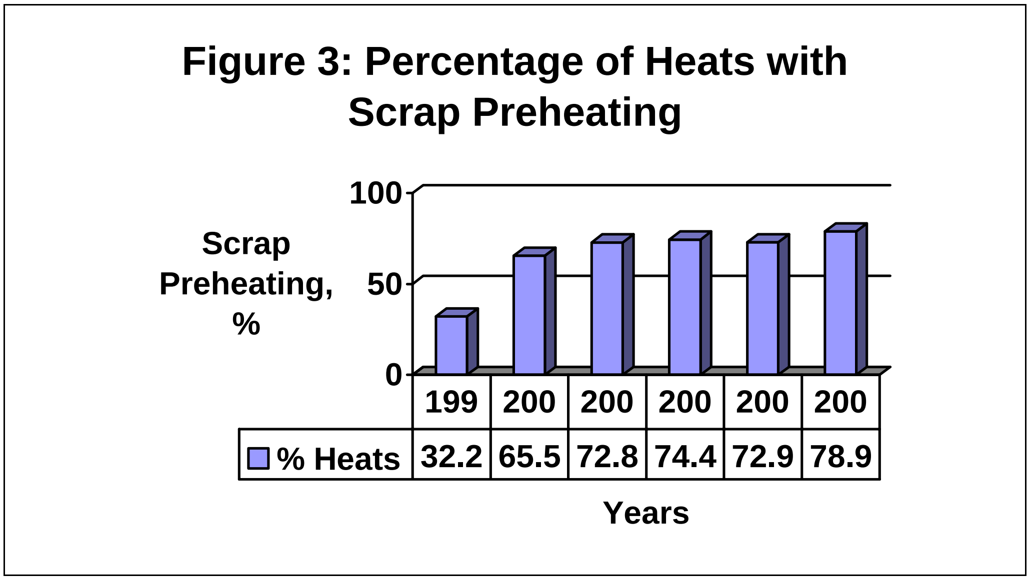
Figure 3: Percentage of Heats with Scrap Preheating

Figure 3 shows the average percentage of heats that were preheated each year from the start of preheating in 1999. Nearly 80% of all heats utilize scrap preheating.

Sintered Fluxes

Historically, Trinecke Zelezarny had shortage of fluxes for steelmaking. With this in mind ZapTech introduced technology for production of sintered fluxes at the Trinecke sinter plant to replace traditional fluxes at the BOF. It was determined that three components of the sintered flux are required to optimize a steelmaking operation. A sintered flux has to supply three components into the slag. Theses components are iron oxide, magnesia, and calcium oxide (Figure 4).

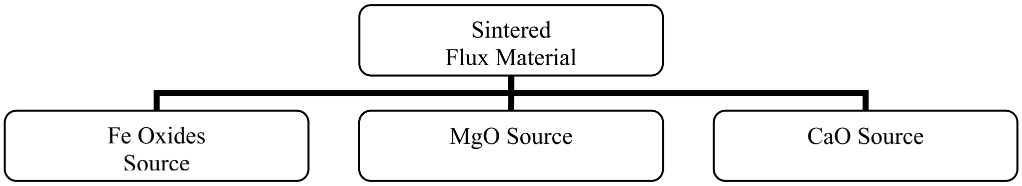

Figure 4: Types of Sintered Materials as Oxides Sources

The content of each component is varied depending on the goal. If the desire is to have a coolant and/or to consume a large amount of waste oxides, the flux material with a high iron oxide portion is manufactured.

The method to produce the sintered flux are unique and a trade secret. The material is not a traditional sinter. A true synthetic slag is formed with dissolution of the oxide components. Although the chemistry of the sintered flux can be varied, there are limits to the chemistry if strong and non-hydroscopic materials are to be produced. The limits are:

For FeOx sintered flux the maximum FeO$_x$ content is 65%
For MgO sintered flux the maximum MgO content is 30%
For CaO sintered flux the maximum CaO content is 50%
For FeOx sintered flux the maximum Zn content is 3%

In use at the steelmaking shop moisture content is less than 8%. As the materials are not hydroscopic they can be stored out of doors. It is conceivable that with storage in a building the moisture content can be lower. However, this is not practical for the Trinecke operation. The material is stored comfortably for at least 9 months. The exact shelf life is not known as the material is produced once per month and used over the following months. What do you do if you receive too much burnt dolomite or burnt lime? Storage of these calcined materials is a definite problem. Using sintered flux materials does not require special storage bins. The sinter plant can produce the sintered flux at the convenience of the sinter plant operation.

Almost as convenient, the material is strong. The sizing is stable because the material is strong. About 90% of the material is 5mm to 40 mm. This is a very good size for optimizing slag formation and minimizing losses due to fines. Also, the sintered fluxes have a bulk density significantly higher than burnt fluxes. The use of sintered fluxes has improved housekeeping at the BOF.

Use of this sintered flux with a high MgO content has allowed Trinecke Zelezarny to stop using burnt dolomite completely. This high MgO sinter is termed DoloSinter. DoloSinter provides the MgO units in a pre-fused slag. It simply melts and begins to work. This improves energy recovery, refining and yield.

FeO$_x$ Sintered Flux

Normally, the Trinecke BOF operation is short of hot metal. The shop needs to consume as much as cold metallic charge as possible. However, as with all steelmakers for short periods of time there is too much hot metal and hot metal consumption must be increased. FeOx sintered flux is manufactured for consumption in periods of hot metal excess. Also, it is used as a slag fluidizer and accelerator for slag formation during other periods. This material can be thought of as a substitute for Waste Oxides Briquettes (WOB's) or iron ore.

This material has two functions. The first function is use as a coolant similar to WOB's. The second use is as a flux. WOB's are not a good flux. FeO$_x$ sintered flux provides higher hot metal consumption when used as a coolant and provides added refining for producing low sulfur steel grades. Typically, the refining benefits provided by FeO$_x$ sinter lower burnt flux consumption (burnt lime and burnt dolomite). Generally, WOBs require increased consumption of burnt lime and/or burnt dolomite.

Table 1 shows the improvements achieved with use of FeOx sintered flux. This table was development for 30kg/t use of this material. This consumption is the optimal for Trinecke. This was determined through experimentation. Another shop may find that the optimum use level is different.

Table 1: Results of FeOx sintered flux use

Items	Units	Consumption
FeOx sintered flux consumption	Kg/t	30
Reduction of Lime Consumption	Kg/t	3.6
Reduction of MgO sintered flux consumption	Kg/t	6.1
Reduction of Scrap Ratio	%	4.1

ZapTech's Dynamic Slag Model is used to control slopping

The Dynamic Slag Model was presented previously in Indianapolis. The model is an everyday tool at the Trinecke BOF and ZapTech keeps refining the technology. The technology was adapted in the following manner. Figure 4 graphically displays the slag height from the beginning till the end of particular heat. This was an observation, and was not controlled by the technology. The Figure 4 also shows that the heat did slop.

The heat began to slop when the Slag Height reached the Critical Slag Height. Slopping continued to increase as the Slag Height increased. Slopping disappeared temporary when the oxygen flow rate decreased to as a reactionary measure. As seen in the graph the Slag Height was reduced but it is still high at that time. Therefore, the slopping began again after a short time. However the intensity of slopping was reduced owing to lower oxygen flow rate and slag height reflected this phenomenon. Slopping disappeared for the rest of the duration of the blow when the Actual Slag Height decreased below the Critical Slag Height.

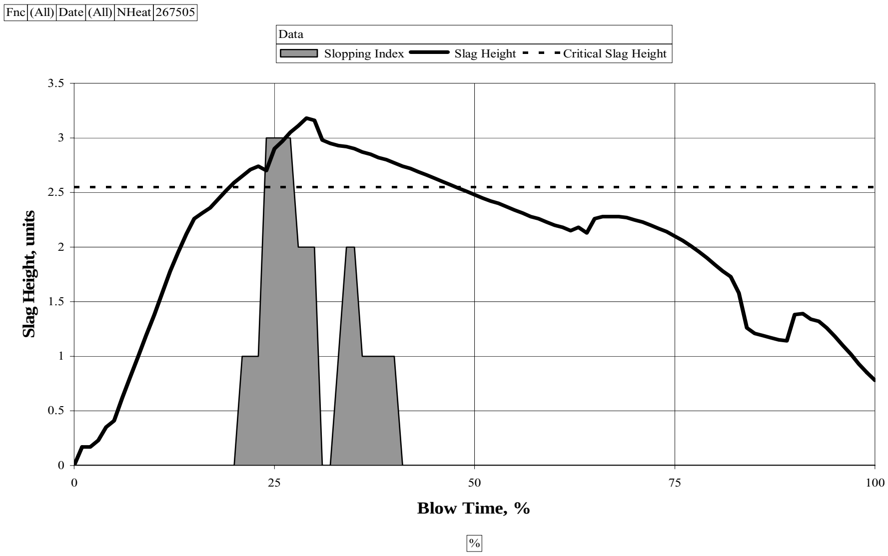

Figure 4: View of the Maximum Slag Height, Critical Slag Height and Slopping During a Heat.

The technology used to prevent slopping proposes actions at all stages of heat preparation and production. Every time the model is provided data the model calculates the Slopping Potential. Raw material changes are suggested before the blow. Flux weight and timing, as well as, blow parameters are suggested during the blow. All actions are directed to control the Slag Height. The Slag Height during the blow should not exceed Critical Slag Height. The maximum slag height is controlled by optimizing the quantity of each scrap type, fluxes, fuels, coolants while considering the aim parameters for nitrogen, sulfur, phosphorous. Blow profile, flux profiles, and Gap are also optimized. Figure 8 summarizes the actions controlled.

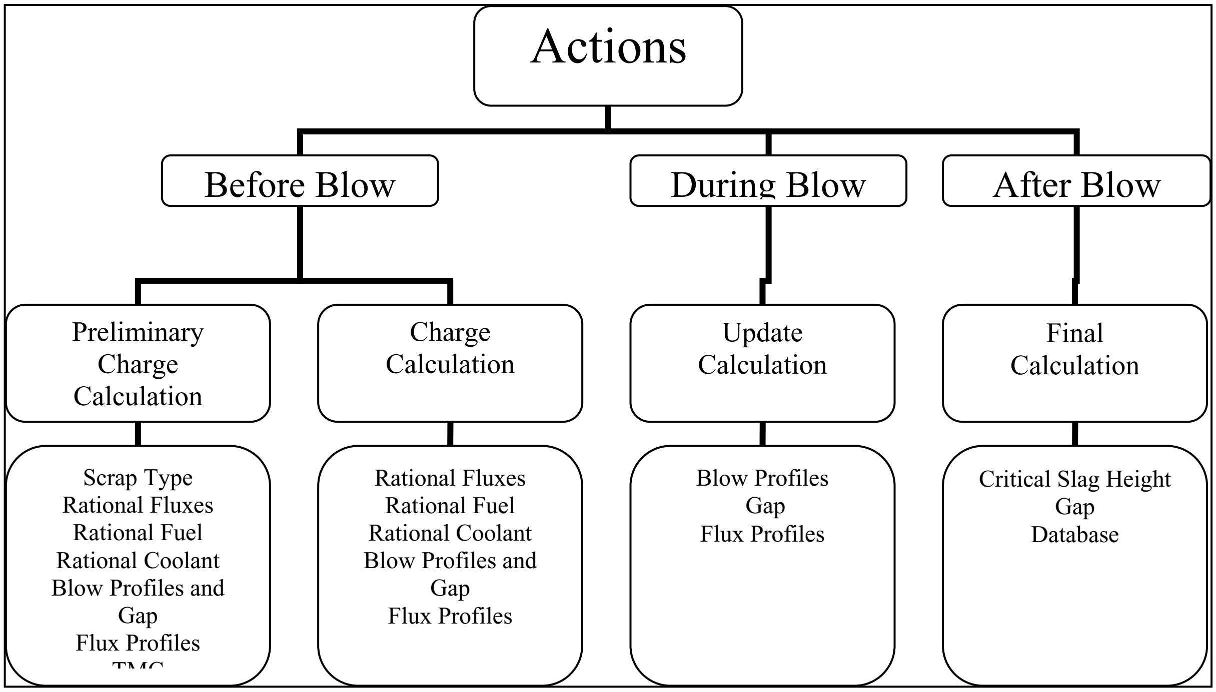

Figure 5: Summary of Actions to Control Slopping

As shown in Figure 5 there is a wider spectrum of possible actions before the oxygen blow begins. After each operation is completed in the preparation of the heat, the spectrum of possible improvements to the heat begins to narrow. It becomes especially narrow after the beginning of the oxygen blow. For example, if the fluxes are already in the weigh hopper the blow profile and Gap are the only changes that can be made. Therefore, without early corrections to the charge preventing slopping can be a difficult task.

Added Technology For Blowing Nitrogen With Oxygen

Trinecke Zelezarny uses nitrogen during main blow to control the slopping. The addition of nitrogen is made in automatic mode at the work of Dynamic Slag model. Use of nitrogen has increased yield by 0.24%

Blow Profiles

Trinecke does not use an exact blow profile as used in the traditional sense at most BOF shops. Most shops have a number of discreet blow profiles based on such elements as silicon, carbon, phosphorus, etc. Trinecke does not use traditional flux profiles either. Most shops have a set way of adding the fluxes. In Trinecke the Blow and Flux Profiles, the bath location and the total metallic charge weight depend on the Predicted Slag Height and Expected Slopping Rate calculated through the Dynamic Slag Model.

Critical Point of the Blow

ZapTech developed the use of an intermediate critical point in the blow based on gas analysis to optimize process control. The oxygen blow is stopped based on information about gas analyzes during the blow allowing accurately reaching the required carbon and temperature. The information provided during the blow allows a more accurate calculation of the end point and more accurate calculation of the final phase of blow. This has significantly increased turndown performance. Now about 90% of heats reach required the goal for tapping.

Lining Life

Production of low phosphorous steel from the high phosphorous hot metal requires a high utilization rate of inert gas bottom stirring. In the past this severely limited lining life improvements. Combining the improvements in process control provided through ZapTech with refractory maintenance improvements provided with slag splashing allows the goal of 4200 heats per lining possible while maintaining a high utilization of bottom inert gas stirring. Although some feel that inert gas stirring and slag splashing are incompatible we feel this is not true.

Lining life and production have increased while tougher and tougher steel grades are being produced. Now Trinecke Zelezarny has 2600 heats on lining. And life of tuyeres has doubled.

Began Slag Splashing

TZ began slag splashing in April 2004. Asymmetric flux additions changed the interior volume profile of vessel. The bottom grows in one place and wears in another place. In the past Trinecke Zelezarny had to use expensive materials to improve the vessel lining. Introduction of slag splashing reduced gunning material consumption and kept the required vessel lining conditions during all the campaign.

SUMMARY AND CONCLUSIONS

1. Scrap Preheating is used on a regular basis.
2. Sintered material chemistry is continually improved.
3. Anthracite replaced coke as the preferred carbonaceous fuel.
4. ZapTech's Dynamic Slag Model is used to minimize slopping and maximize yield.
5. ZapTech developed the use of an intermediate critical point in the blow based on gas analysis to optimize process control.
6. Use nitrogen dilution during a portion of the heat to optimize process control.
7. Use Slag Splashing Technology to maximize lining life.