Metallurgically Engineered Flux for Liquid Steelmaking

Bohdan Irmler, Karel Klimek, Zbignev Piegza
Třinecké Železárny
Průmyslová 1000
Třinec – Stare Městro
Czech Republic
Tel.: +420 (659) 432 001
Fax: +420 (659) 321 331
E-mail: Bohdan.Irmler@trz.cz

Grigori Galperine, Michael Petrounine, Barry Schrader, Jaroslav Opletal
ZapTech Corporation
4275 Shackleford Rd., Suite 200
Norcross, GA 30093
USA
Tel.: (770) 925 8125
Fax: (770) 921 5635
E-mail: bschrad@attglobal.net

Key words: BOF, steelmaking, flux, slag, refining, cost, coolant, sinter, scrap, fuel

INTRODUCTION

Třinecké Železárny is a traditional integrated mill. It has four strands at the sinter plant, two blast furnaces, a BOF shop with two 185-ton vessels and rolling mills. The rolling mills produce long product such as rails, wire, reinforcement steel, and shapes. The plant's goals are to increase profitability through the production of higher quality steel grades. The BOF shop produces more and more low phosphorus and low sulfur steels. The Phosphorus content of the hot metal varies from 0.080% to 0.145% (0.11% in average).

A few years ago projects were begun to improve the BOF shop's operation. Productivity was variable. Sometimes it was high. Sometimes it was low. When production was low more hot metal should be consumed at the BOF. When production was high, scrap consumption needed to increase to take advantage of the production opportunity. However, the increased scrap consumption could have a negative effect on quality. The strategic plan is to continuously increase production of critical specifications. As with all steelmakers, the goals included increased steel yield and increased lining life of the vessels. In summary, the goals were to improve quality, productivity, and lower costs. Increased flexibility with the hot metal to scrap ratio, as well as, improved chemistry and temperature control were keys to these improvements

In 1998 Z-BOP Technologies was licensed from ZapTech to help meet these goals. ZapTech is the owner of proprietary steelmaking technologies. These technologies improve slag formation allowing for much greater refining and energy recovery. These improvements allow the shop to improve cost, productivity, yield, and refining. All aspects of the liquid steelmaking process were improved.

The technologies were implemented. After implementing the technologies, ZapTech continued to work with us further improving our process. When we discuss the use of Z-BOP Technologies, we talk of two phases of implementation (Figure 1). Phase 1 was implementing the basic Z-BOP Technologies. Phase 2 is the continued improvement of operations through joint development with ZapTech. After the initial implementation of Z-BOP Technologies we implemented their proprietary preheating technology, technology for slopping prediction and control, and sintered flux material production and use. This paper will focus on the sintered flux materials.

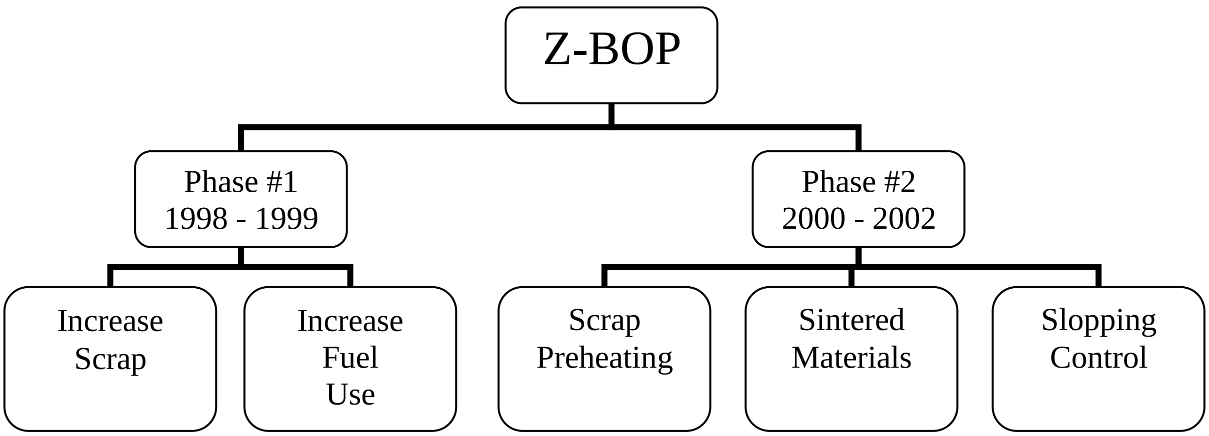


Figure 1: Phases of Implementations

DISCUSSION OF RESULTS

The main goal of sintered flux use at Trinecke Zelezarny is improving refining. However, other benefits are:

1. Traditional fluxes are delivered to our plant from suppliers some distance away. As with all lime products quality is a concern.
2. Waste materials are used to manufacture the sintered flux materials. Our environmental experts are excited about this.
3. Třinecké Železárny does not have facilities for flux production. This technology did not require any capital investments as the fluxes are produced at the existing sinter plant.
4. The technology lowers costs.
5. The sintered fluxes are not hydroscopic and have good strength and density. This allows long storage periods, improved handling, and cleanliness.

Now, the sinter plant produces fluxes for use in the BOF and blast furnace. These materials are produced with a wide range of chemistries allowing optimization of physical and metallurgical properties for specific applications. Limestone and raw dolomite are the major components. In addition, blast furnace slag, acid oxides, and iron oxides are used. Iron oxides are used from wastes, mill scales, and/or iron ore. A fuel is added to the mix to deoxidize and add energy.

It is well known that burnt fluxes (dolomitic lime and burnt lime) require time for dissolution in the BOF bath. Slow dissolution of fluxes plays a negative role in the refining process. There is less time and limited opportunity for refining.

The sintered fluxes are designed to be a synthetic slag. The sintered fluxes have a low liquidus temperature and dissolve quickly into BOF slag. The result is lower energy requirements and improved refining. The properties of the sintered flux material are very consistent providing very stable steelmaking performance. Also, the significant problem related to hydration of burnt lime and burnt dolomite is eliminated.

Types of Sintered Flux Materials

At the beginning of 2000 the first batch of sintered flux material was produced and tested. About 300 tons of sintered flux was produced in this first batch. This sintered flux was strong and resistant to the generation of fines. The material did not absorb moisture. The initial trials in the BOF used this form of the sintered flux as a coolant and an accelerator for slag formation. After this first success, we experimented at the sinter plant and BOF. We concluded that three kinds of sintered materials are required to optimize our operation. Every sintered material has to supply three components into the slag. Theses components are iron oxide, magnesia, and calcium oxide (Figure 2).

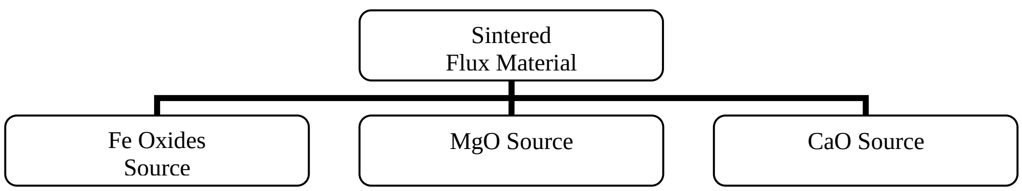


Figure 2: Types of Sintered Materials as Oxides Sources

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. This flux can be used as a means of adding low cost iron units. On the other hand, if the goal is vessel maintenance, magnesia in increased through a greater portion of dolomite. Finally, the material containing predominantly iron and calcium oxide is manufactured for improved removal of sulfur and phosphorus.

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%

The moisture content is less than 8%. However, 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 our 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 5-40 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. The handling of the material does not create a large volume of fines. This increases flexibility. It can be handled numerous times without degradation.

A comparison of burnt fluxes and sintered flux materials are shown in Table 1.

Table 1: Comparative Properties.

Characteristics	Burnt Fluxes	Sintered Materials
Storage	*Limited*	*Unlimited*
Hydroscopic	*High*	*Low*
Reactivity	*Average*	*High*
Competitive Price	*Average*	*Low*

Results of Use of Sintered Flux Materials in BOF

We have touched on the use of the sintered flux material but it should be stressed that it is not a simple replacement for burnt lime, burnt dolomite or waste oxide briquettes. It is an engineered flux. You would not coat a welding rod with lime or burnt dolomite. You design a flux that allows the proper refining and protective slag to be formed.

The BOF process is a fast process. In the days of the open hearth we had time to develop a slag over time. In today's world of continuous casting, high quality steel, and production by the stop watch we need more from our fluxes. We have tailored the chemistry of our sintered fluxes to:

1. Accelerate slag formation at the start of the blow.
2. Quickly produce a slag to produce low S, P, and N steels.
3. Provide a coolant that enhances quality while providing low cost iron units.
4. To benefit lining maintenance.

MgO Sintered Flux

In the past we used burnt dolomite and recycled magnesia brick to satisfy the MgO requirements of the slag to prevent damage to the lining. We found that the brick was of limited usefulness and, for our case, burnt dolomite was relatively expensive and of variable quality. We have eliminated the use of these materials and have improved our operation.

A few years ago we satisfied the MgO requirement of the slag through use of three materials: Burnt Dolomite, Crushed Refractory and Raw Dolomite. Now we use only two materials. MgO sintered flux is used as the primary MgO source while we used a small amount of raw dolomite for slag conditioning (Figure 2)

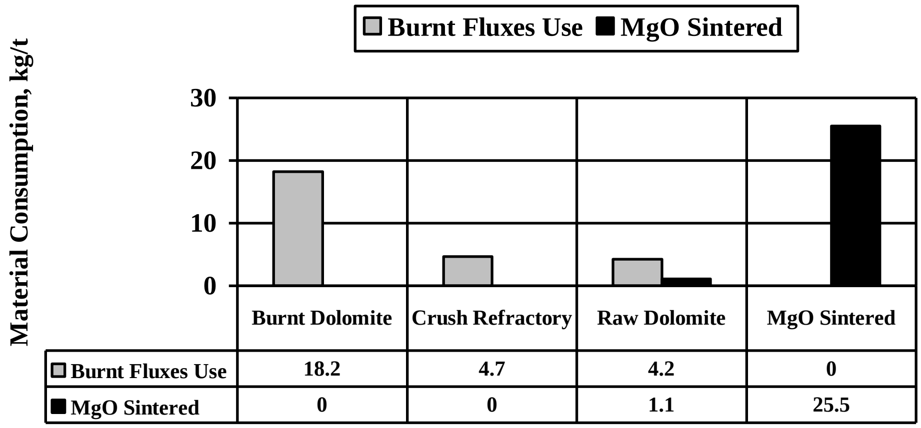


Figure 3: Consumption of MgO Content Materials

The big disadvantage of crushed refractory use is the MgO from this material did not dissolve in the slag (Figure 4). The actual MgO in the liquid slag was always lower than required. We had to add extra crushed refractory and burnt dolomite to keep required MgO in the slag.

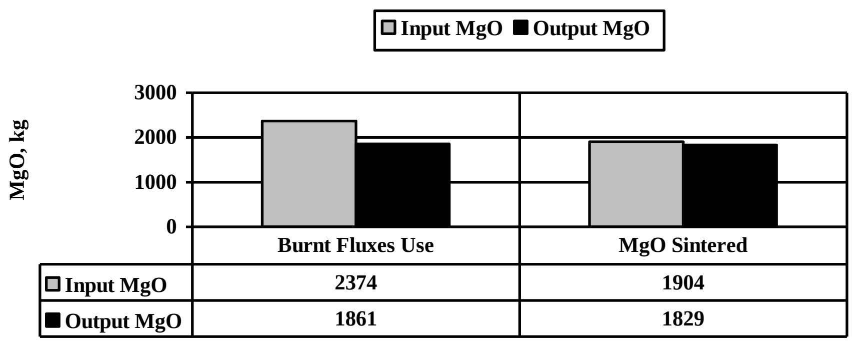


Figure 4: MgO Balance

Use of sintered flux has reduced the difference between the input and output of MgO from about 500 kg per heat to about 100 kg per heat. The MgO output is based on analysis of slag samples. It is understood that MgO floating in the slag as solid material is not measured.

The sintered flux is also stable in chemistry and physical properties. Burnt dolomite has variable properties, hydroscopic, and forms dust. Burnt dolomite with poor properties can lead to slopping and unpredictable energy requirements

Use of MgO sintered flux significantly improves slag formation at the beginning of blow. Refining and energy recovery have shown this. Computer modeling of the foaminess of the slag shows graphically the increased slag foaminess we observed in the shop. This is shown in Figures 5 and 6 below. The foaminess of the slag is an indirect measurement of the MgO level is the slag at the early stages of the blow. Foamy slag works much like the insulation in your house. It holds more energy. Also, there is less carbon loss. The process becomes more stable, energy efficient and predictable.

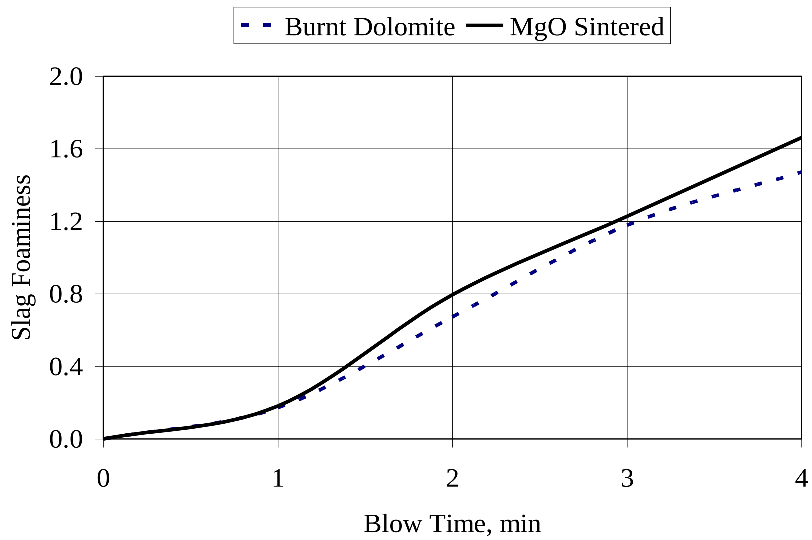


Figure 5: Foaminess of Slag at First Four Minutes of Blow

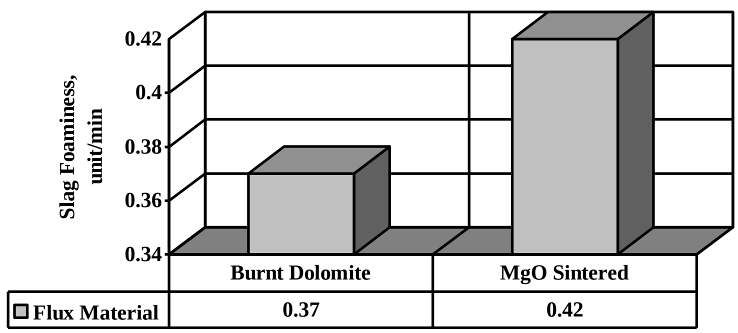


Figure 6: Slag Formation at First Four Minutes of Blow

CaO Sintered Flux

As our grade mix moved to higher quality grades, the refining requirements were more difficult to meet without increased use of fluorspar. The sintered fluxes increase the dissolution rate providing the required refining with little or no spar. Phosphorous was of particular concern before use of sintered fluxes. Our hot metal P is 0.11% and we produce many heats requiring 0.012% or less P in the steel at tap (Figure 7).

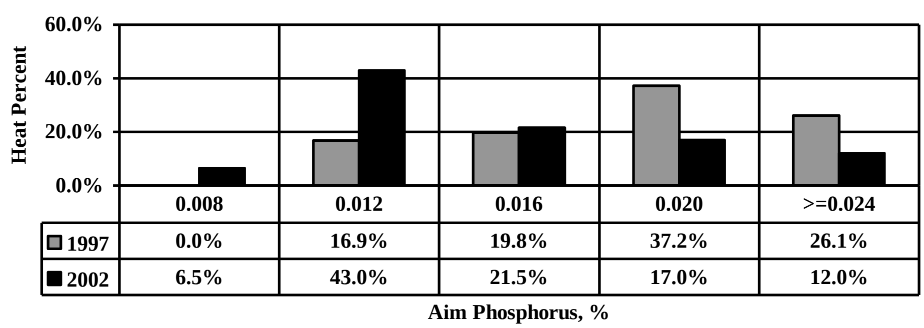


Figure 7: Steel Specifications

For these steels the final phosphorus is extremely critical. However, cost reduction efforts have raised the P content of the hot metal. About 50% of the steel we produce today is considered to have critical specifications by our in house definitions. With the use of sintered fluxes our process is more stable with predictable results. In 2000 and 2001use of MgO sintered flux resolved our problems related to production of critical specifications (Figure 8).

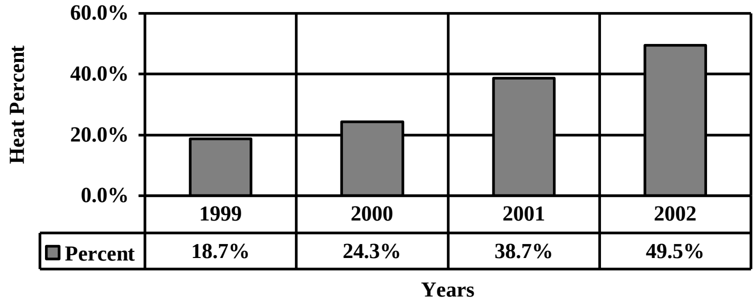


Figure 8: Heat Percent of Critical Specifications by Years

However, further increases in the critical specifications were impossible without increasing flux consumptions and significant use of CaF2. The cost of steel production would increase significantly. To avoid this negative effect we developed and manufactured a new sintered material. This new sintered material should improve the refining during the process at the same flux consumption. The new sintered flux we termed CaO sintered flux. Seven campaigns of manufacturing this sintered flux have optimized the chemistry and physical properties of this material. CaO sintered flux has higher Fe oxides and CaO contents, than MgO sintered flux.

Use of CaO sintered flux in 2002 has allowed increased production of steels with critical specifications while reducing consumption of expensive CaF2 and fluxes (Figure 9). The results are related to the specific consumption of 10 kg/t of CaO sintered flux.

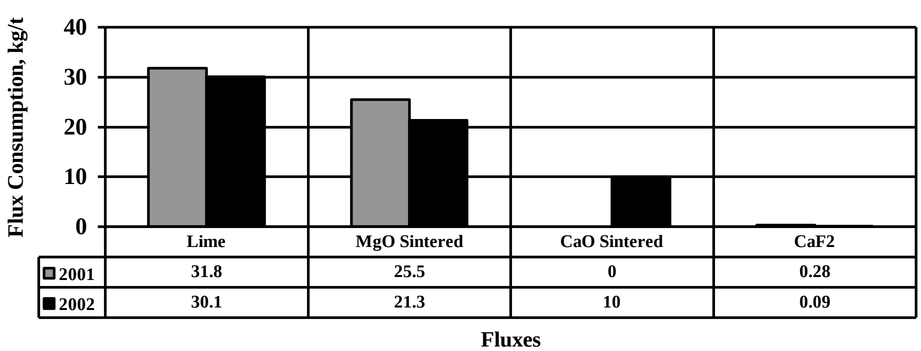


Figure 9: Flux Consumption.

FeO_x Sintered Flux

Normally, our BOF operation is short of hot metal. We need to consume as much as cold metallic charge as possible. However, as with all steelmakers we have short periods of time when we have too much hot metal and must increase hot metal consumption. We manufacture FeOx sintered flux for consumption in periods of hot metal excess. Also, it is used as a slag fluidizer and accelerator for slag formation during other periods.

The material can be thought of as a substitute for Waste Oxides Briquettes (WOBs) or iron ore. Like WOBs it has a substantial amount of waste oxides. However, it does not have any binders. FeO_x sinter flux does not have disadvantages that are specific for WOBs such as:

1. High sulfur content,
2. High carbon content,
3. Low speed of dissolution into the melt.

Many problems occur with use of large quantities of WOBs. Many times the heat slops. Slopping is unpredictable and at times extremely heavy. We believe the cause of the slopping is the combination of high carbon, slow dissolution and the potential to agglomerate the WOB addition into a single mass. For these reasons, many steelmakers do not use WOBs in large quantities. Also, problems occur when WOBs are used after In-blow measurement and reblows.

The FeO_x sintered flux does not have these problems. This flux has a low liquidus temperature. It does not contain carbon or binders. Also, it dissolves very rapidly. The CaO and MgO content in the FeO_x sintered flux are significantly higher than in the WOBs.

Therefore, this material can have two functions. The first function is use as a coolant similar to WOBs. The second use is as a flux. WOBs are not a good flux. FeO_x sintered flux can provide higher hot metal consumption when used as a coolant and provide 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). Our experience with WOBs is that they 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 our shop and we have determined this through our experimentation. Another shop may find that their optimum use level is different.

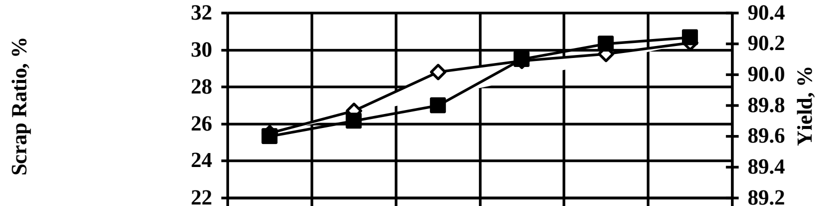
Table 2: Results of FeOx sintered flux use

Items	Units	Consumption
FeOx sintered flux consumption	kg/t	30.0
Reduction of Lime Consumption	kg/t	3.6
Reduction of MgO sintered flux consumption	kg/t	6.1
Reduction of Scrap Ratio	%	4.1

Scrap Ratio and Yield

Since 1997 we have consistently increased yield and scrap ratio (Figure 10). The goals continue to increase. We talk about our improvements in two Phases. The first is the implementation and optimization of the Z-BOP

Technologies without Preheating. The second is the incremental increases from improved control, implementation of in vessel scrap preheating and the use of anthracite to replace coke.



	1997	1998	1999	2000	2001	2002
Scrap Rario	25.5	26.7	28.8	29.4	29.8	30.4
Yield	89.6	89.7	89.8	90.1	90.2	90.2

Figure 10: Scrap Ratio and Yield

Yield increased in Phase 1 through optimization of slag formation and endpoint control while lowering flux consumption and reducing slopping. Yield continued to increase in Phase 2 from optimization of Sintered flux use and Slopping Control. We used coke as a fuel before 1997. However, the quantity and efficiency of its use increased after the adoption of Z-BOP.

CONCLUSION

1. Sintered Fluxes are superior to traditional fluxes.
   a. They have consistent properties both chemically and physically.
   b. They are strong.
   c. They do not hydrate.
2. Handling and Storage are improved.
   a. Materials can be stored for many months.
   b. The material does not degrade through handling improving storage flexibility and housekeeping.
3. Use of the sintered fluxes at the BOF Shop provides stable results with improved refining. We have lower costs, improved our yield, and increased the scrap melting capability.
4. Our cooperation with ZapTech lowered costs at the BOF by $2 per ton in Phase 1 and further reduced costs by $4 per ton in Phase 2. These costs do not reflect the improved profitability provided by the improved grade mix.
5. ZapTech continues to work with us for continued improvement.

ACKNOWLEDGEMENTS

We thank the engineers, melters and operators that participated in these projects. Their knowledge, skill and power were an integral part of achieving the results.