Low consumption figures, high productivity, best raw material flexibility, environmentally friendly, safe, and with a perfect level of automation – One furnace fits the needs

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INTRODUCTION

The steel industry worldwide undergoes a substantial transition phase caused by the decarbonization process. The traditional production route via blast furnace and basic oxygen furnace is under pressure to reduce the CO2 emissions drastically. Since the blast furnace is the main source of CO2 it is expected that more and more plants are thinking about replacing the blast furnace by another source of liquid metal. For the integrated plants this means that the scrap rate should be increased in the BOF or a part of the raw steel, if not all needs to be produced via the EAF route. There are several options to install an EAF in an integrated plant. But many of the products cannot not be produced out of scrap only, which is the preferred charge material for the EAF. This means that the EAF needs to melt not only scrap but also a wide range of so-called virgin material like DRI, HBI, pig iron or even hot metal. The choice of the raw material allows to control the amount of tramp elements in the steel but also the nitrogen content.

The steel producers already using EAF technology will try to produce steel grades, which are normally reserved for the integrated plants, since they have a big advantage concerning CO2 emissions. But they face the same problem with the quality of the crude steel to be produced concerning tramp elements (mainly copper) and the nitrogen content. These EAF also need to take virgin material as feed stock up to 80 %, which is comparable with a BOF.

Last but not least, there are new players coming to the market, who start from the beginning with an EAF fed with DRI, scrap and other iron bearing material, while the DRI shall be produced with hydrogen and not with natural gas as today.

This means that strong challenges are coming up for the EAF process and technology. Some are already known, some are new.

CHALLENGES FOR EAF TECHNOLOGY AND PROCESS

- High flexibility on raw material input to control tramp elements and nitrogen content
- Change of charge mix without downtime for EAF adjustments on technology and process.
- Electrical power supply which is suitable also for so-called weak grids.
- Chemical energy input concept, adapted to less usage of carbon.
- High degree of automation, especially to adapt process models to the changing charge mix.
- Furnace design over a wide range of tap weights since the converters to be replaced are tapping in some cases more than 300 t.
- Manipulators and robots to handle all activities around the EAF.

FURNACE CONCEPT

The furnace is designed to take various charge materials.

- Hot metal (up to 80 %)
- DRI cold or hot (up to 100 %)
- HBI (up to 80 %)
- Scrap up to 100 %

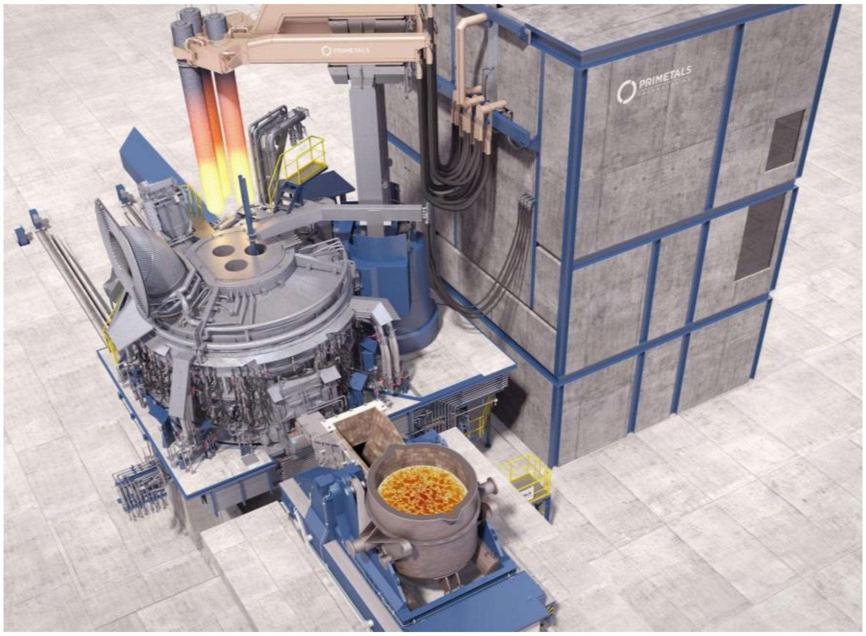


Fig. 1: EAF Fusion® with top lance for oxygen injection

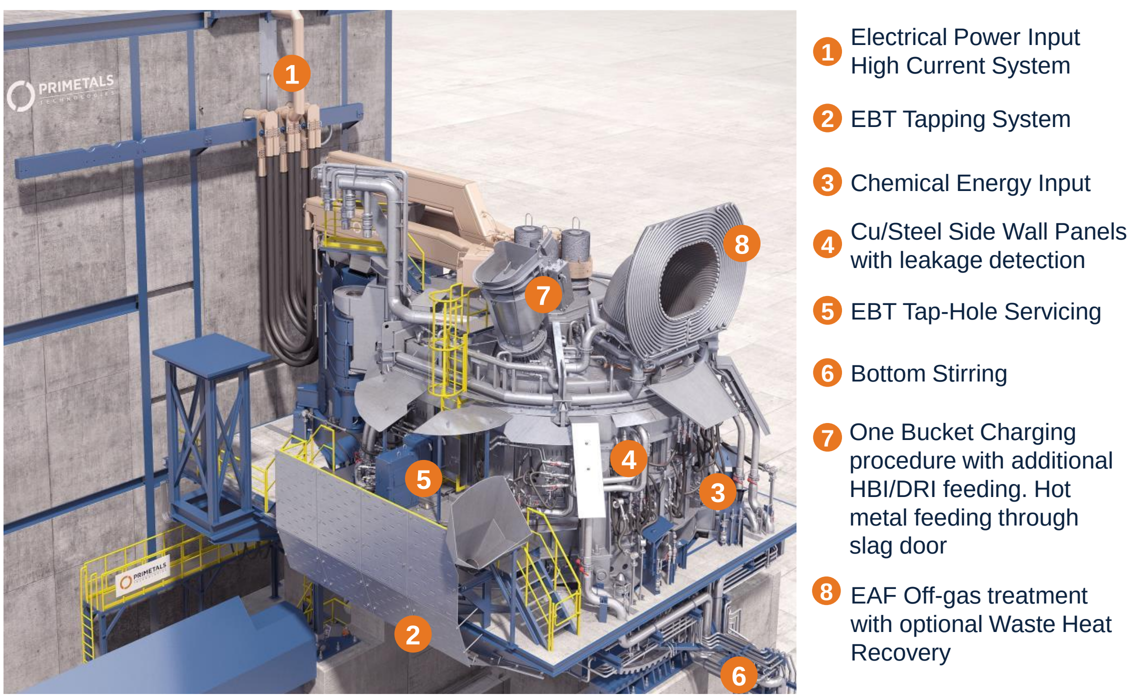


Fig. 2: EAF Fusion® with technical features

The furnace is equipped with an additional top lance to inject oxygen for refining in case of very high hot metal ratios (up to 80 %). The top lance is mounted on the same gantry as the electrode masts. When the hot metal ratio is high enough, no electrical energy is required. The electrodes swivel to the side while the lance then can be introduced to the EAF through one of the electrode holes. The oxygen blowing is supported by side wall lances. CFD calculations show the effect of the top lance (see next picture), which allows a fast decarburization in combination with four side wall burners.

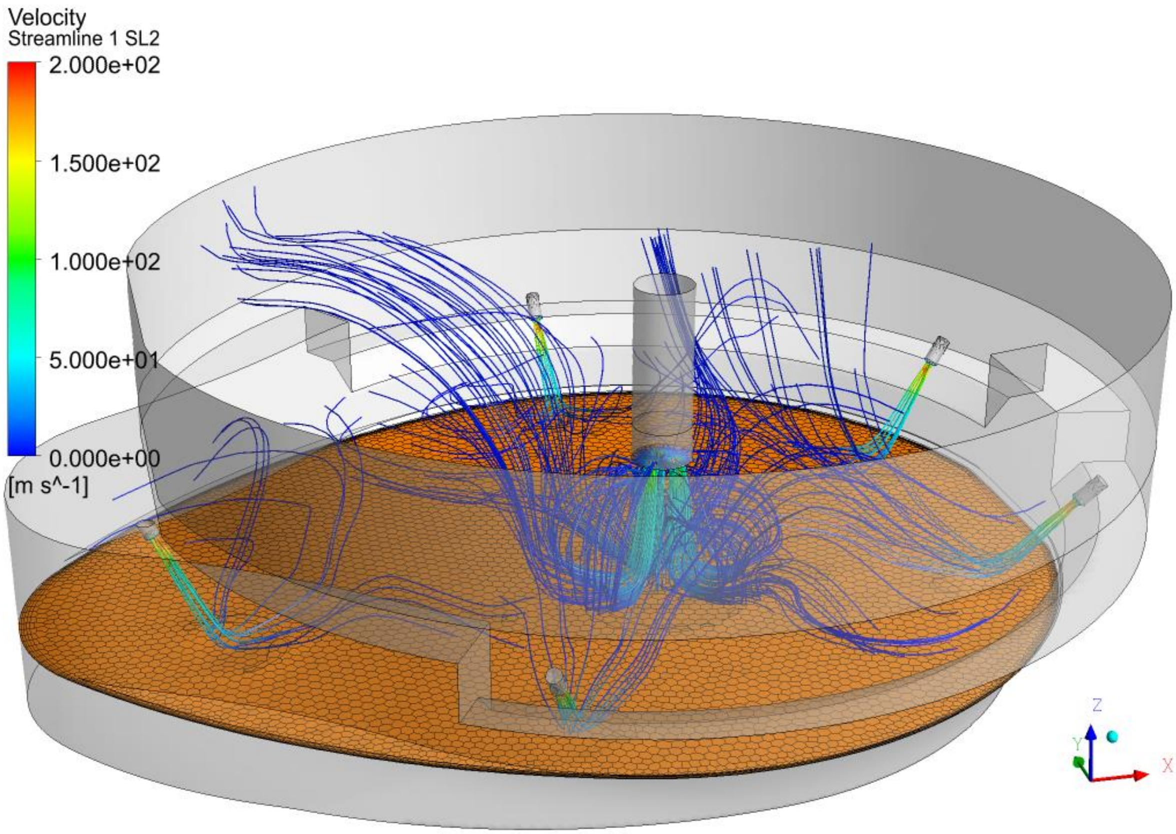


Fig.3: CFD simulation results of top lance for oxygen injection with four RCB burners

For a fast decarburization a good mixing of the steel bath is necessary. To improve mixing, there are four bottom stirring porous plugs installed, which are also shown in a CFD calculation.

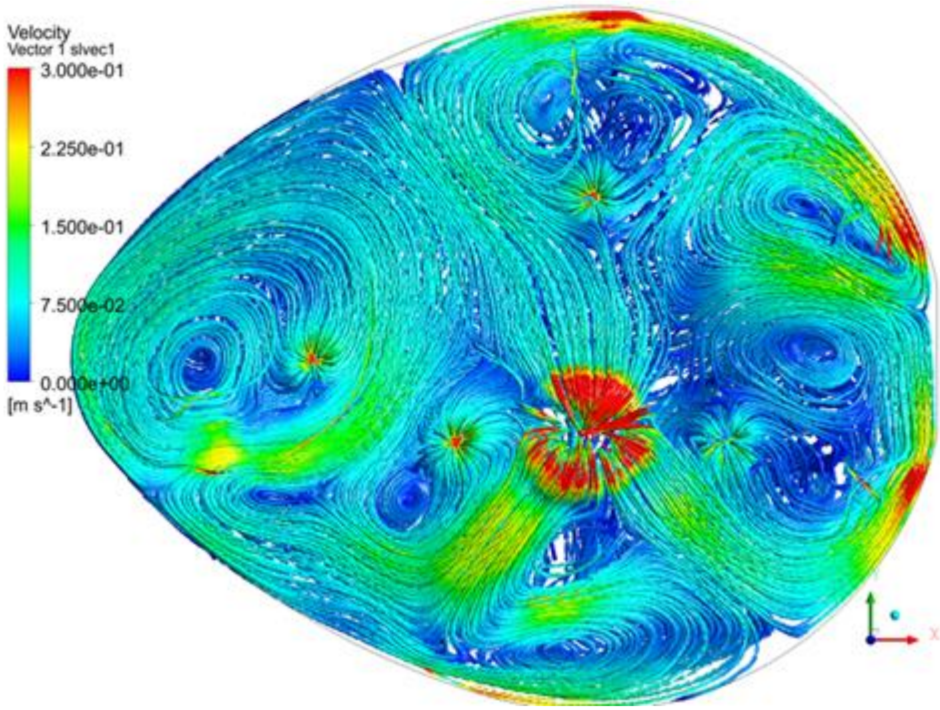


Fig. 4: CFD results with four bottom plugs for stirring.

The hot metal is added through the slag door via a launder. The hot metal ladle can be added via a crane or a tiltable hot metal ladle car as shown in the following picture.

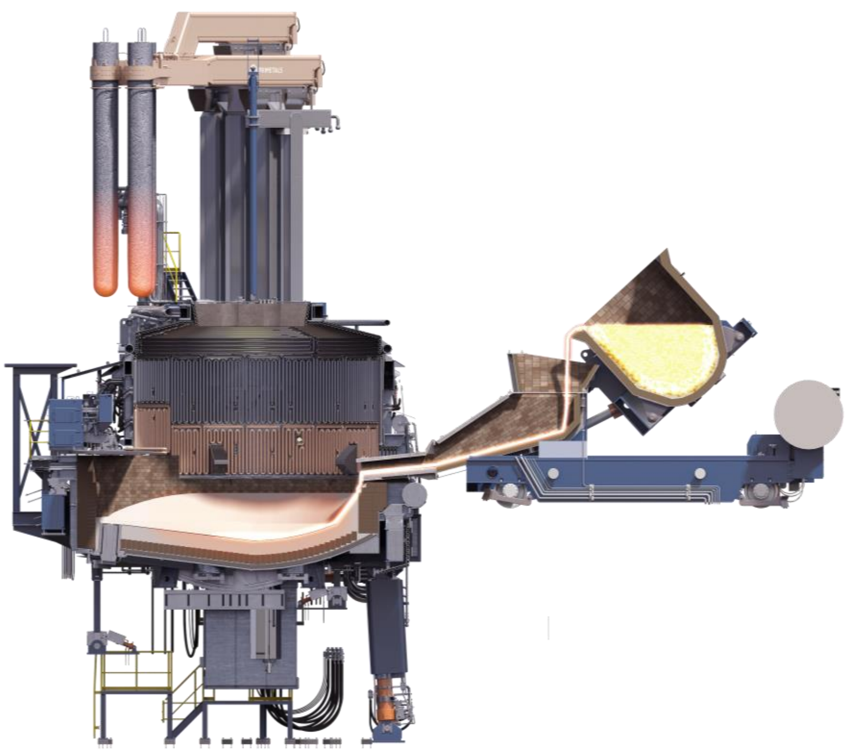


Fig. 5: *Hot metal addition via a launder through the EAF slag door.*

In case the heat has not reached the final tapping temperature after refining, the oxygen lance can be swiveled out and the electrodes back in to heat up the steel to the requested tapping temperature.

The EAF concept includes several additional features as shown in the following picture:

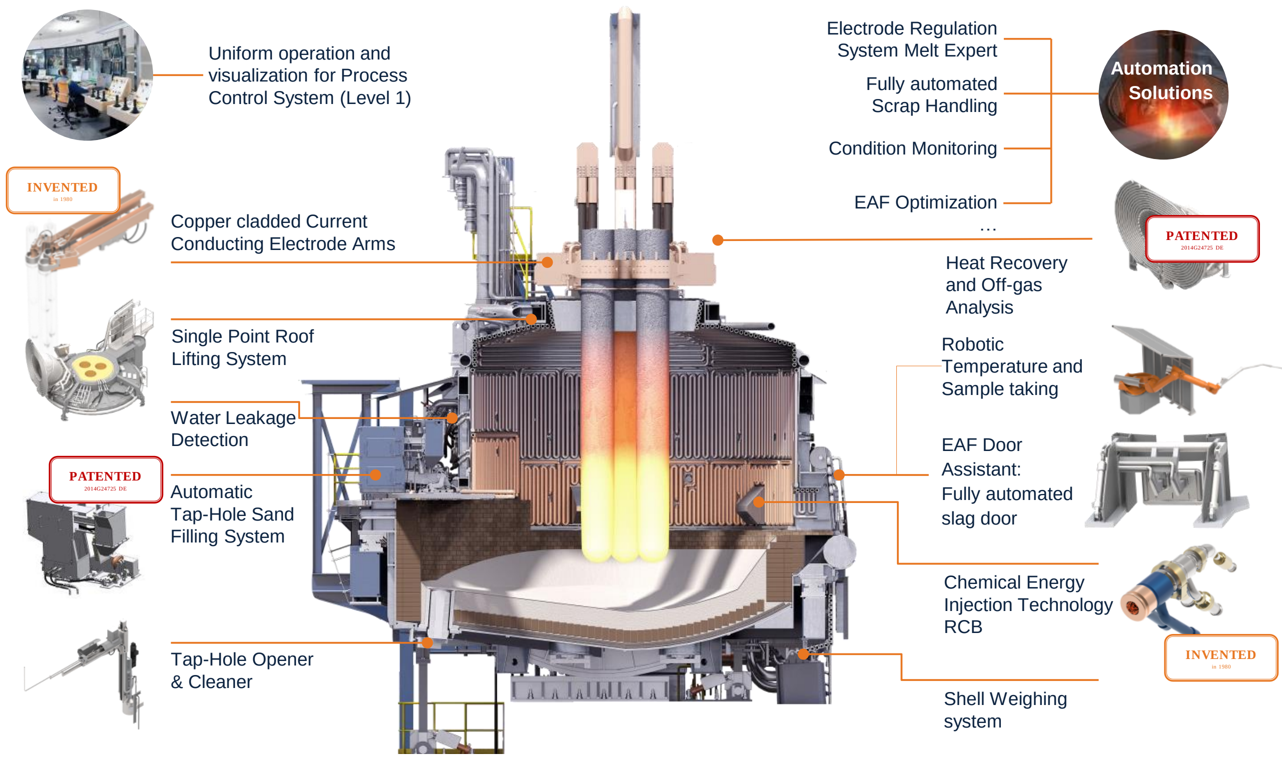


Fig. 6: *Technological Highlights of new EAF concept*

The EAF is equipped with a slag door assistant which is closing the slag tunnel of the upper shell, in a way that no scrap can fall into the tunnel. IT can also hold back the foamy slag. After deslagging the door can also clean the tunnel with a special movement of the door itself.
The roof of the EAF is lifted by a single-point and swiveled out together with the electrodes. But it can be also disconnected from the gantry in a way that the roof is laying on the upper shell and the electrode can swivel out without the roof. This is the precondition for the fast implementation of the oxygen lance without time loss.
Most of the operations around the EAF will be done automatically by manipulators or robots:

- Automatic taphole refilling
- Automatic taphole opener and cleaner
- Robot for temperature and sample taking

Additionally, the EAF is equipped with a water-leakage detection system as well as a shell weighing system.
The furnace dimensions are defined by the tap size but also the input material. A bigger diameter makes it easier to decarburize to allow a decarburization rate of 400 kg/h m^2 bath surface and more. Tap weight can be as high as 300 t. The EAF diameter up to 10,5 m.

The height of the upper shell is defined by the ratio of scrap to be used. The aim is to allow a 1-basket operation.
Continuous DRI feeding is a proven technology for many years now, especially in the Middle East. For fast melting it is fed through the roof between the three electrodes. DRI can be added in cold or hot condition or even in combination.

Fig. 7: *DRI feeding pipe into EAF roof.*

The feeding rate is depending on the active power input and the feed material itself. Typical feeding rates are shown in the table below:

MATERIAL	FEEDING RATE
CDRI	38 – 42 kg/min MW
HDRI (600 °C)	50 – 65 kg/min MW
HBI	28 – 30 kg/min MW

Table 1: Feeding rate of input material

The feeding rate is defined as the amount of DRI in kg divided by the product of minute and the active power input in MW. For hot DRI the maximum feeding rate with average active power input of 100 MW would be:
65 kg/(min*MW) * 60 min/h *100 MW = 390 t/h

EAF PROCESS

A mixture of several different charge materials requires a specific operating diagram. In case of a mixture of scrap, HBI and hot metal, the optimum operational pattern is as follows. First the scrap is charged into the EAF. While starting the meltdown of the scrap with the electrodes, the hot metal is poured into the EAF through the slag door with a rate of 8 to 12 tons per minute. Once the liquid heel in the middle of the EAF is big enough, the HBI feeding starts. The oxygen injection, the average power input and the carbon injection are adapted to the feeding pattern. The complete operating diagram is shown in the following picture:

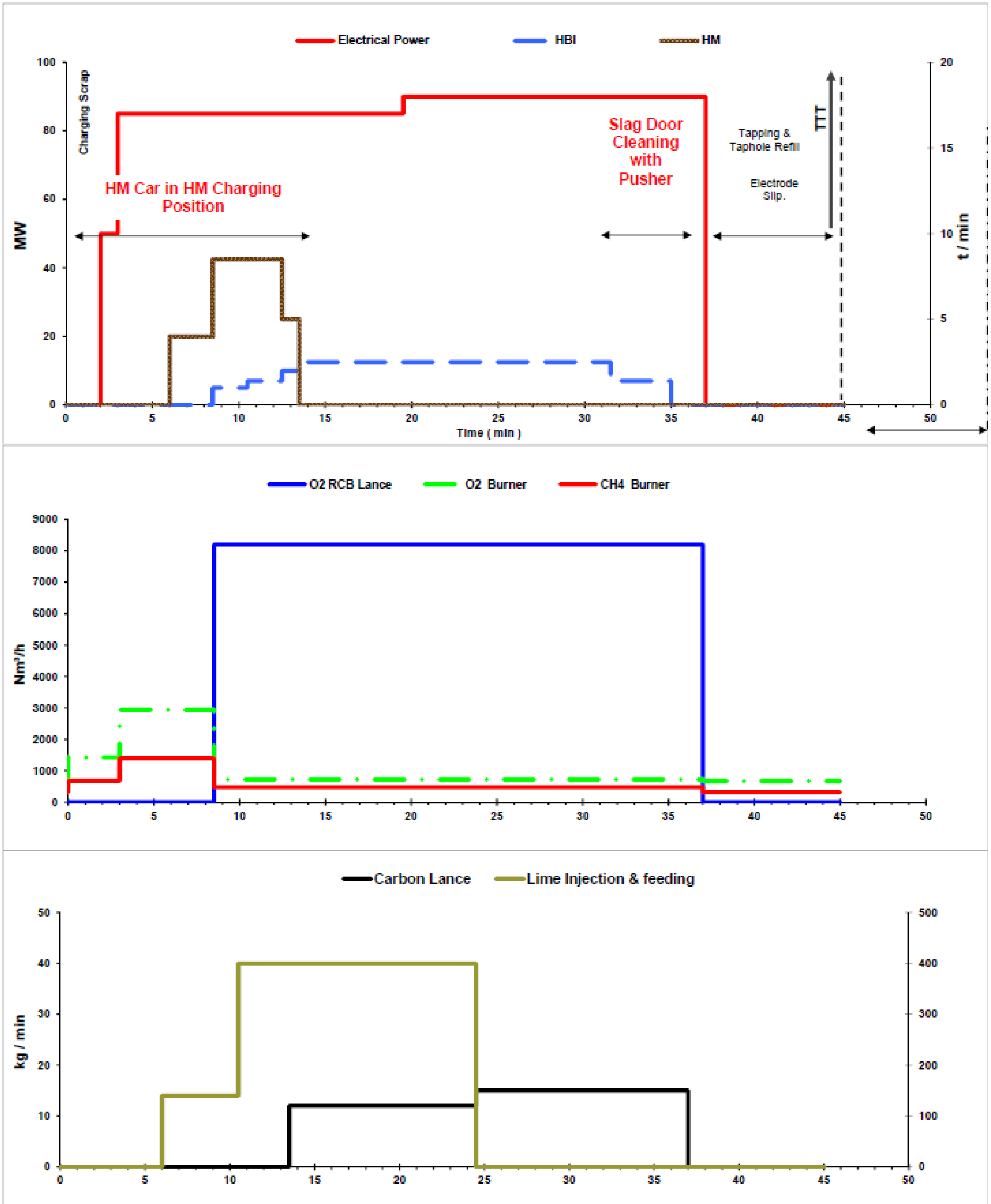


Fig. 8: *Operating diagram for the charge mix scrap, hot metal and HBI of an EAF in Mexico.*

STEEL QUALITY

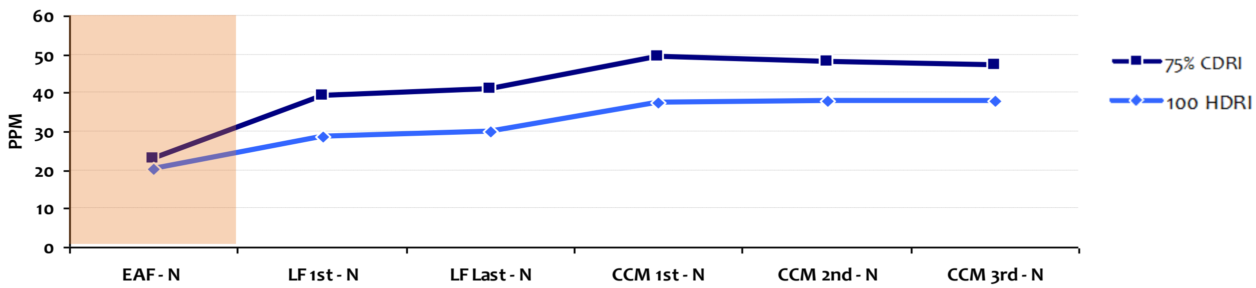
While using high amounts of virgin material, the tramp element problem of the EAF route seems to be solved. But this material is not always available and other measures might be necessary. One possibility is the scrap management and selection of scrap to take out non-ferrous material out of the scrap get a so-called design scrap. This would allow to increase the scrap rate and therefore lower the production costs and increase the productivity. But this is not part of this article.

100 % scrap based EAF steel making leads to nitrogen values in the steel before tapping of 90 to 120 ppm. This means that there is also a limit for the scrap amount in the charge mix.

The following measures help to keep the nitrogen level low in the steel produced from EAF:

- Tight EAF design to avoid false air ingress.
- Low NOx burners
- A raw material mix with high amount of virgin material which allows flat bath operation
- Correct foamy slag practice to cover the electric arc
- Turbulence free tapping to avoid air intake while tapping.

Nitrogen level analysis along the production line of an EAF plant shows that nitrogen levels of less than 50 ppm are possible at the casting machine when using at least 75 % DRI in the charge mix along with 25 % scrap. The results are shown in the graphs below.



Nitrogen level along production line

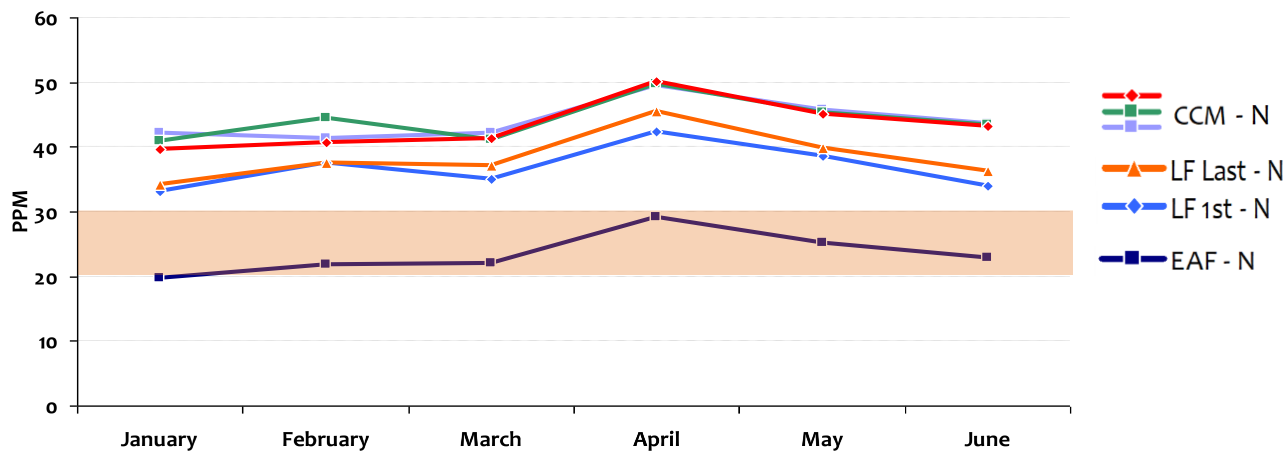


Fig. 9: *Nitrogen levels with 75 % DRI 25 % scrap charge mix along production line for six months.*

RAW MATERIAL FLEXIBILITY IN PRACTICE

There are already several EAF installed, which are using a wide range of feed material. They are all following the above-mentioned principles. The following table shows the possible charge material mixtures in such kind of furnaces. There are also charge mixes shown for different EAFs around the World.

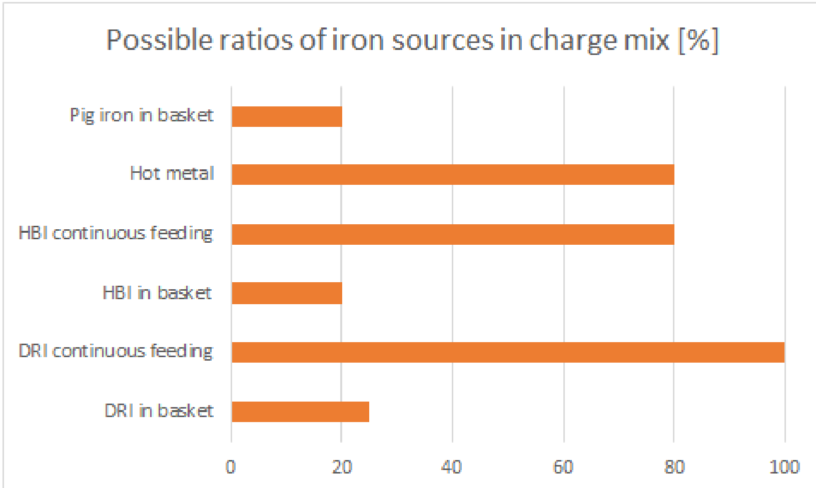


Fig. 10: *Possible ratios of iron sources in charge mix*

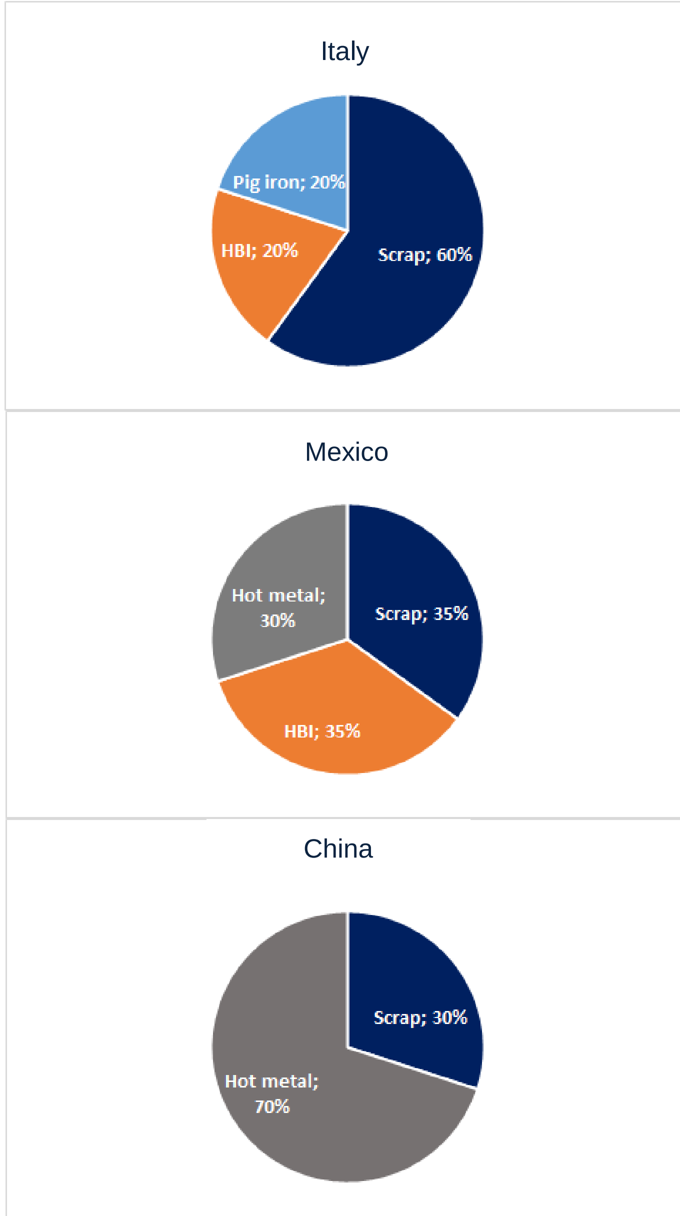


Fig.11: *Charge mixes for furnaces in Mexico, Italy and China*

CONCLUSION

Furnaces can be built, which have almost no limitation concerning the charge mix. The furnace can be adapted to these mixes just by adding an oxygen lance during operation and back to electrode operation without any equipment change or downtime. The furnace can be equipped with different kinds of feeding devices to allow continuous feeding of solid and liquid materials. The oxygen technology and the power supply are prepared to supply whatever is necessary for the different charge mixes. But there are still a few topics to be solved.

Today the limit in EAF tapping weight is mainly linked to electrical power supply. This makes it difficult if not impossible to directly replace a BOF with an EAF at tapping weight higher than 250 t.

In the future the DRI quality, which will be available for the EAF route will change. Also, BF grade pellets need to be used in an EAF. DRI will be produced with hydrogen in the future at least partially. Consequently, the carbon content in the DRI is going down, in some cases close to zero. This makes it a much less favorable charge material for the EAF. New processes and equipment are therefore development to support this transition phase in steel making.