THE USE OF SPONGE IRON IN UHP ELECTRIC FURNACES

W. Maschlanka,
P. Kehl,
H. Knapp,
H. Voss.

Summary

Since autumn of 1971 sponge iron is used in the electric furnace shop of Hamburger Stahlwerke GmbH for the steelmaking process. Both the equipment used for continuous charging of sponge iron and the melting practice applied is described. The effect of varying percentages of sponge iron in the charge on meltdown time and refining time, power consumption and further metallurgical aspects are reviewed.

In the electric melt shop put in line with the Midrex reduction plant, the metalized iron ore produced is converted into raw steel together with scrap distinctly but in any proportion whatsoever.

The most important data of the electric melt shop of Hamburger Stahlwerke are:

2 furnaces (Lectromelt — GHH)	85 t UHP
diameter of hearth	5.80 m
diameter of electrodes	550 mm
installed capacity furnace transformer	40-45 MVA
secondary voltage	160-500 V
capacity at the max. contact setting	33 MW
startup	July 1971

Put in line with it are two Concast machines with four strands each casting billets of 100-130 mm square.

Metalized pellets coming directly from the reduction furnace or out of the storage silo are transported by a conveyor belt system into six bins for intermediary storage with a loading capacity of 75 tons each (Fig. 1).

The intermediary storage bins are attached to the structure of the melt shop above the electric furnaces, from where metalized pellets are weighed continuously and then charged into the electric arc furnace. The adequate feedrate of metalized pellets in computer controlled. The charging system with only one feedpipe is attached above the furnaces in a way that the metalized pellets drop into the bath within the electrode delta. The charging system is calibrated for a rated capacity up to 1,600 kgs/min. For an ideal melting performance the continuous feeding of the sponge iron may be fully automated and controlled in direct interdependence with the power supply.

The step switch of the furnace transformer is controlled by the computer according to the predetermined melting program and specific feeding data.

Thereby the highest power level is maintained during the time metalized pellets are fed without danger of overheating the bath or decreasing the refractory life. In the event that power supply cannot be maintained, the feeding rate of metalized pellets gets adjusted by the computer.

FIRST OPERATIONAL RESULTS

Obviously a comparison of operational results is somewhat complicated due to times differing from heat to heat, which are required for charging, patching, sample-taking, tapping, and other delays.

Therefore data only of net meltdown time and fining time have been evaluated for this paper. The net meltdown time comprises the time of melting down and bringing the heat up to a temperature of 1600°C excluding any delay. This period ends at the time the first sample will be taken. The times needed for all metal-

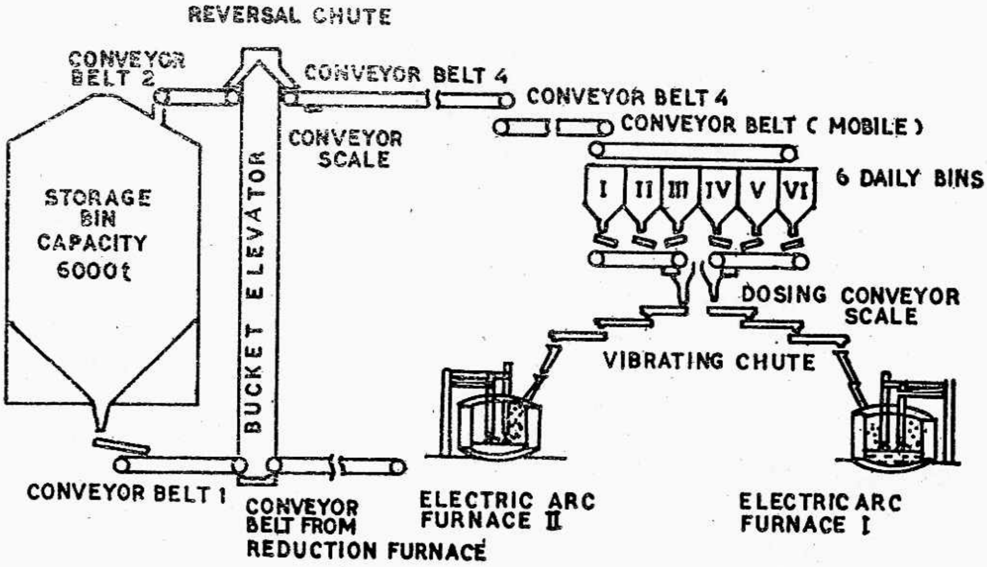

Figure 1

lurgical works including the times for adding alloys and heating the bath to the tapping temperature desired, is regarded as fining time.

It has to be emphasized that the transition from meltdown time to refining period is fluent when smelting sponge iron, since metallurgical reactions are initiated already in the meltdown period. The initial trials for a continuous smelting of sponge iron showed that metalized pellets can be smelted only, in the best way possible, within a liquid steel bath. So the condition for the beginning of continuously feeding metalized pellets is a liquid steel pool obtained by smelting down scrap or sponge iron. This pool should be at least 25% of the total weight charged.

The typical performance when using 70% sponge iron in the input as practiced to-day, is shown in Fig. 2. Meltdown of the initially charged scrap bucket is performed, as generally known, between A and C.

The power input has to be lowered at point C in order to prevent excessive damage of the furnace lining. At point D, charging of sponge iron starts at a rate of approximately 500 kgs/min, to be increased step by step within the next 10 minutes to a maximum rate of 1,200 kgs/min.

The startup point of the continuous feeding is considered to be of critical importance, since beginning at a very early stage, a so-called "iceberg" is likely to be formed, which may complicate further melting and starting too late, the life of the furnace lining will be reduced very strongly.

Since burnt lime powder will be added at point B already, a foamy slag is generated right after metalized pellets are fed into the furnace on account of which the power input at E can be increased to 31 MW at low lining corrosion. Best melting conditions were found at a bath temperature of 1550°C.

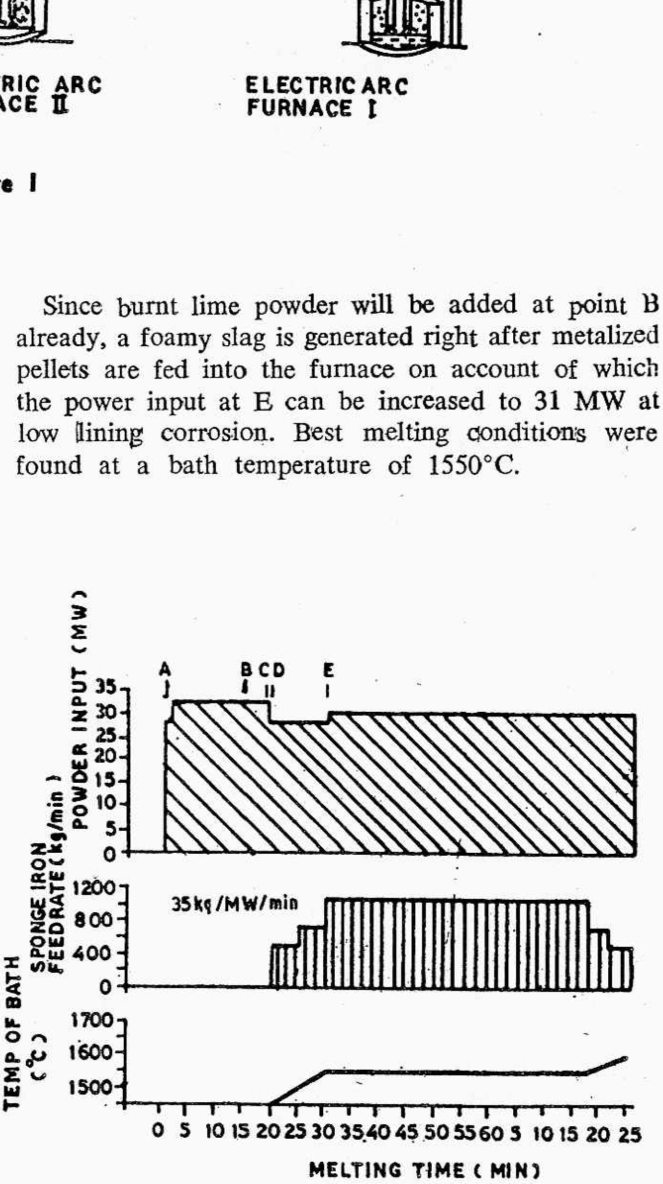

Figure 2

A— START MELTING SCRAP
B— START LIME POWDER INJECTION
C— CUT DOWN POWDER INPUT
D— START FEEDING SPONGE IRON
E— HIGH FEEDING RATE AND INPUT

During the continuous feeding of pellets possibly no slag-off should be started to avoid severe losses of Fe. Bath temperature will be increased shortly before the end of continuous feeding to accelerate the fining time. For this purpose, the feeding rate will be reduced while maintaining the highest real power possible.

Fig. 3 shows the melting performance with 100 per cent sponge iron in the burden. Before turning on power, an initial amount of 25 tons of metalized pellets are charged continuously onto the hearth out of which a pool of liquid steel will be smelted.

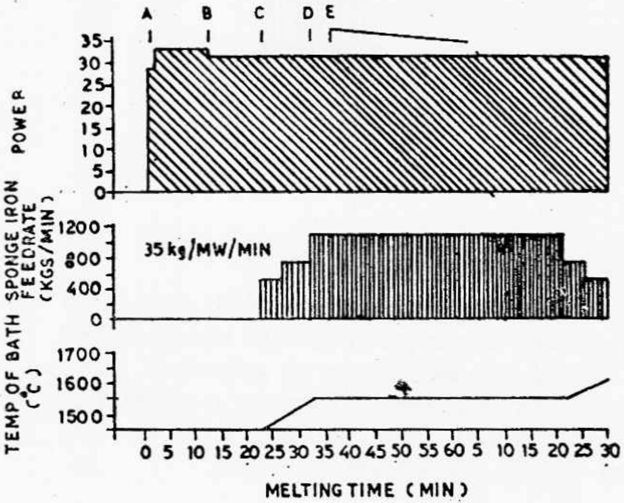

Figure 3

A— START MELTING OF SPONGE IRON CHARGED OF HEARTH
B— CUT DOWN HIGH POWER INPUT
C— START CONTINUOUS FEEDING SPONGE IRON
D— HIGHEST FEEDRATE
E— LIME POWDER INJECTION

To begin with, the meltdown period is similar to the performance already shown by using 30 per cent scrap and 70 per cent of sponge iron, but power input will have to be reduced at an earlier stage, otherwise an increased consumption of refractory has to be accounted for.

The critical period C-E of the scrap/sponge iron technique does not exist using 100 per cent metalized pellets. The foamy slag generated covers the arc at an early stage so that the energy requirements of 31 MW can be maintained up to the end of the meltdown time.

Continuous feeding starts at a later time. From that time, the performance of both alternatives is comparable. Due to the content of gangue in sponge iron the amount of burnt lime powder has to be adjusted. The higher specific energy consumption caused by a bigger volume of slag leads to a prolongation of the meltdown time by 5 minutes.

It is important to know that the specific energy consumption Fig. 4 is not altered up to 35 per cent of sponge iron, that it will be increased roughly by 25 kWh/t using 35—75 per cent, and will undergo a sharp boost of approximately 40 kWh/t when the remaining 25 per cent of scrap are replaced by metalized pellets. However, the trend only should be regarded as typical since the relatively high values have their origin in a time when the melt shop reached only 60 per cent of its rated capacity.

The evaluation of the slag analyses and amount of slag (Fig. 5) showed that there is a functional interdependence between the proportion of sponge iron

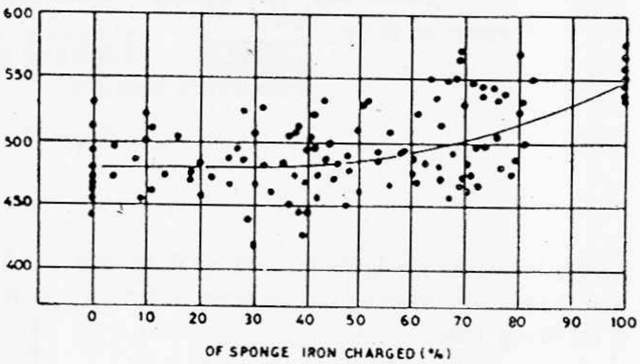

Figure 4

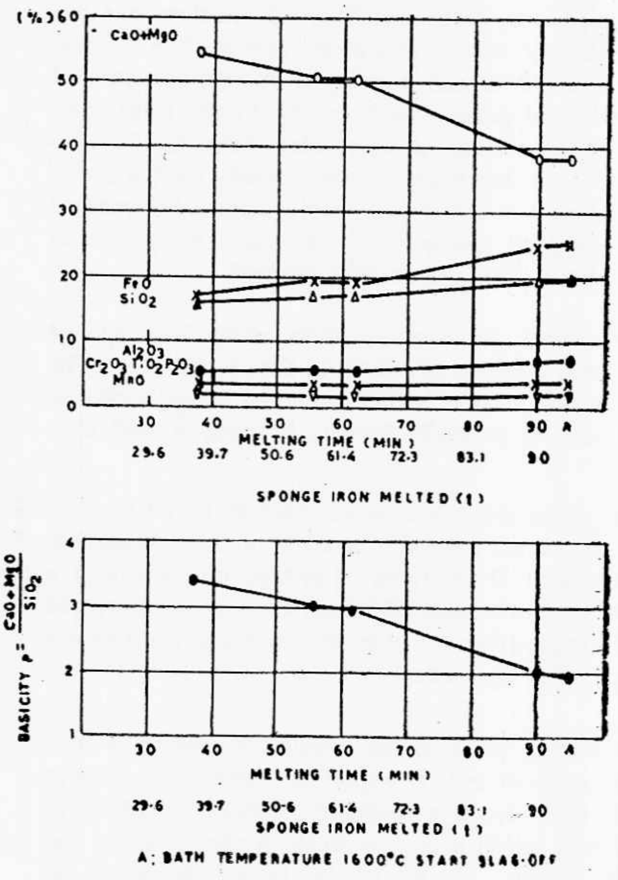

Figure 5

	BURDEN	CONTENT								SLAG VOLUME	
		SiO		CaO	MgO	Al_2O_3		$TiO_2V_2O_3$		WITHOUT FeO	WITH 25% FeO
	Kg	%	Kg	%	Kg	%	Kg	%	Kg	Kg	Kg
SPONGE IRON	1000	2.2	22.0	0.75	7.5	0.7	7.0	1.3	13.0		
LIME	30	2.0	0.6	94.5	28.4						
DOLOMITE	8	2.9	0.2	94.5	7.6	1.4	0.1				
TOTAL			22.8		43.5		7.1		13.0	86.4	99.6
SCRAP	1000	0.4Si	8.6								
LIME	30	2.0	0.6	94.5	28.4						
DOLOMITE	8	2.9	0.2	94.5	7.6	1.4	0.1				
TOTAL			9.4		36.0		0.1			45.5	60.7
INCREASED SLAG VOLUME FOR ALL SPONGE IRON											38.9

BASICITY

ALL SPONGE HEATS $P = \frac{CaO+MgO}{SiO_2} = 1.91$

ALL SCRAP HEATS $P = \frac{CaO\ \ MgO}{SiO_2}\ 3.82$

Figure 6

and basicity. The basicity can be changed from p=3.8 using 100 per cent of scrap to p=1.9 totally replacing the scrap by metalized pellets since the phosphorus and sulphur contained in the pure sponge iron used today are of minor proportion, so that specifications with respect to these elements can be met for almost any steel grade desired. In the situation described, the amount of burnt lime powder has not to be increased in comparison with heats melted out of scrap. The amount of slag, which mainly was calculated so far, is increased by a maximum of 40 kgs/ton of raw steel, however, when using 100 per cent of metalized pellets due to their amount of gangue as shown in Fig. 6.

Fining time depends, as generally known, on the analysis of the first sample as well as the steel grade to be melted.

The benefit of using metalized pellets therefore is evident since the initial composition of the raw steel is not subject to such heavy fluctuations as normally found in melt shops based on scrap and furthermore. refining can be started during meltdown period already. Following our experience, the fining time can be shortened by approximately 14 minutes with a smaller deviation (Fig. 7), when the amount of sponge iron used is increased from roughly 25 per cent to 75 per cent. For melt shops based on scrap only, the situation is likely to be more unfavourable, there are no results, however, which can be presented today.

Consequently, even by an increased meltdown period, tap-to-tap time can be reduced, thus intensifying productivity by the application of the sponge iron melting technique.

It has to be emphasized that the utlization of metalized pellets is of favourable influence on the content of trace elements and nitrogen in steel which in particular are required for wire rod by producers and

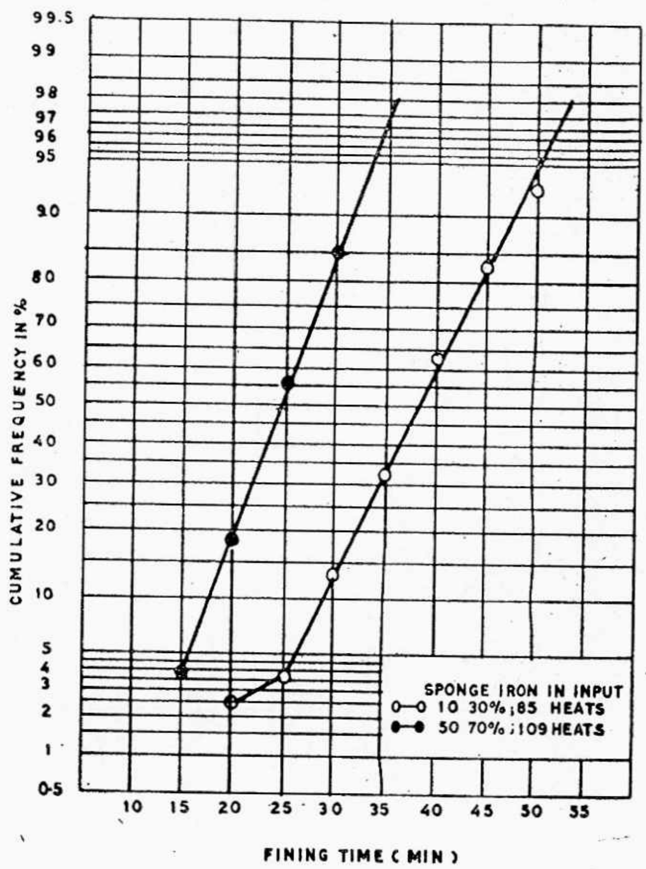

Figure 7

customers. High values of Cu, Cr and Ni are not desirable since strength factors thereby are influenced uncontrollable. Besides processing and usability are unfavourably affected by these trace elements.

At a proportion of more than 70 per cent of sponge iron, the total amount of said trace elements is below 0.1 per cent (Fig. 8). Costs for steel production are positively influenced by this fact, by using a higher proportion of metalized pellets cheap scrap of minor quality can be used.

Examining the nitrogen content in steel, it was found that in heats with a higher proportion of metalized pellets, the nitrogen content of different steel grades averaged about 0,007 per cent and thus by 30 ppm less than heats produced out of scrap only.

Initial difficulties concerning furnace lining and roof life when metalized pellets were fed continuously into the furnace were eliminated to a large extent. Due to an extended period during which the refractory of the wall was affected by radiation of the arc, the furnace lining especially opposite to the electrodes was subject to increased wear.

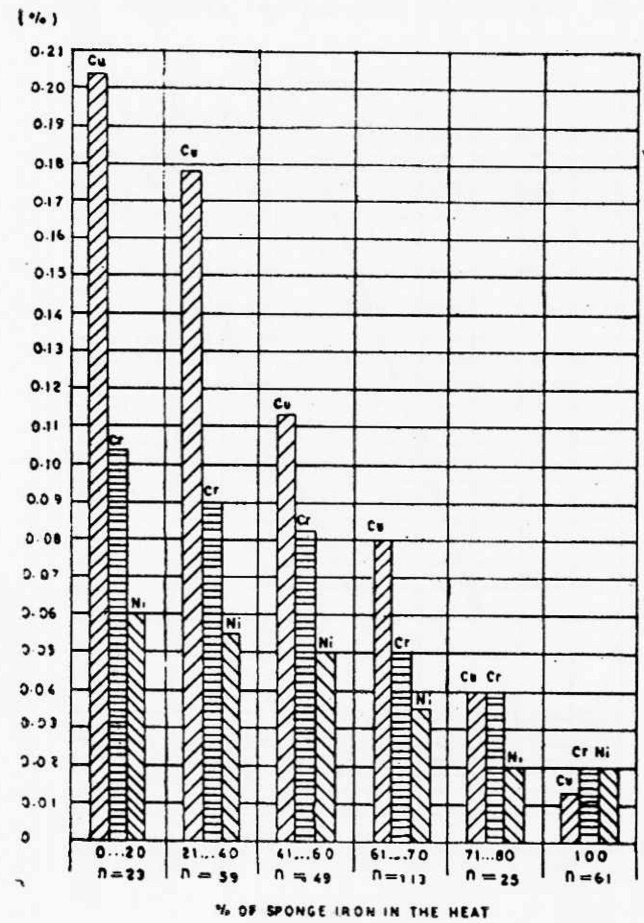

Figure 8

Due to the generation of foamy slag at a very early stage of the heat already and by setting a short low voltage arc, the detrimental exposure to radiation of the wall was reduced considerably.

The life of the roof refractory was affected by far more difficulties which can be largely contributed to the fines accompanying the metalized pellets. As we learned, fines will infiltrate the surface of the high alumina bricks of the roof generating a lowmelting eutectic compound, so that the bricks start to deteriorate at temperatures normally found in the furnace. By screening-off the fines and replacing the high alumina with dolomite or magnesite bricks in critical roof areas, the roof life could be improved, it showed, however, that normal performance data can be reached only by materials other than alumina bricks.

Electrode consumption could be cut in comparison to data known from scrap-based melt shops, because of less breakage; it shows, however, that electrode consumption is intensified by radiation and energy which cause an increased burn-off. Summarizing, no considerable improvement in electrode consumption could be achieved when using sponge iron.

FUTURE OUTLOOKS

One year of practical experience with the continuous feeding and melting of over 200.000 tons of metalized pellets clearly have demonstrated that generally no fundamental problems exist when using mainly sponge iron as input material for the electric arc furnace. Results so far obtained have proved already that the technique used by Hamburger Stahlwerke is an example for the fact that by the combination of direct reduction plant/electric melt shop, steel can be produced as economically as by conventional steelworks, or even better.

The production of steel based on this technology thus is not reserved to the classical industrialized countries only but also gives an opportunity to developing countries to use their mineral resources at low investment costs.

Further developments of this modern concept of an electric steel mill on the basis of a direct reduction process permit the qualified conclusion that in future not only wire rod, bars and small sections, but also flats are likely to be produced very economically in plants like this one. This objective may be reached already here by utilizing the existing possibilities, e.g. increasing the output of the reduction furnace as well as expanding the production units put in line, as they are required to serve modern hot strip mills. Thus already satisfactory investment cost can be improved, specific manpower requirements are not to be increased, and sharp pollution control possibly required in the future will be performed in a better way than by conventional steel mills.

Discussion

Mr. H. Nandy (National Iron & Steel Co. Ltd., Howrah): I would like to get little more ideas particularly about the composition of the charge pre-reduced pellets. Secondly, you are using 30 per cent or more of the scrap along with the pellets. What is the composition of the same after melting down? What are the particular precautions you have to take while controlling the slag during the refining period? You have recommended Magnesite Refractories for the lining of furnaces, is it the only suitable material?

Dr. W. Maschlanka (Author): Since sponge iron made of Malmberget pellets is extremely pure, there result very low phosphorus and sulphur contents as well as few trace elements after the smelting of sponge iron. The sulphur and phosphorus contents are, after smelting, generally in the range of less than 0.010 per cent. The copper, chrome and nickel contents are below 0.02 per cent. Depending on the steel quality to be smelted, the scrap proportion will be increased or lowered. On an average, 30 percent of scrap are usually being fed together with the pellets. Due to the heavily changing scrap analyses, the feed analyses may also vary. On an average, a copper content of 0.080 per cent, a chrome content of 0.05 per cent and a nickel content of 0.03 per cent will result with a proportion of 30 per cent scrap. Carbon which is contained in sponge iron in the range of approximately 1 per cent, is being reduced after smelting to approximately 0.3 to 0.4 percent. Due to the low phosphorus and sulphur contents, it is not necessary to provide for a strongly basic slag. To protect the refractory material, the basicity of the slag $\frac{CaO+MgO}{SiO_2}$ is kept to approximately 2. For economical reasons, we use magnesite for the refractory lining of the electric furnace. The use of dolomite will be possible, however, it will lead to a considerable reduction of the wall life.

Mr. R. D. Gupta (National Metallurgical Laboratory, Jamshedpur): The author had mentioned that they are using magnesite instead of dolomite for fettling the banks in their U.H.P. electric arc furnace. It is known that magnesite needs high temperature for sintering and is not normally used for fettling. Could the author enlighten us as to how the sintering of the magnesite, fettled in the banks is achieved.

Dr. W. Maschlanka (Author): For repairing the walls, we use in Hamburg a refractory injection compound containing approximately 83 per cent MgO, with a grain size of 0—4 mm. This compound contains a water glass bond in order to avoid the difficulties which might result from the high sintering temperatures of the magnesite. Apart from this injection compound, however, also dolomite is being used from time to time for the repair of the walls.

Mr. Karam Singh, (Tata Iron & Steel Co. Ltd., Jamshedpur): (1) What is the yield when sponge iron is used for steel making? (2) With low yield as indicated by the author, will it be economical to switch over to this method from scrap, specially plant which make sophisticated type of quality steels of low carbon variety, (3) Will it be economical for going to large size furnaces or to small size furnaces in view of large amount of slag handling, increase of power rate and low yield.

Dr. W. Maschlanka (Author): The yield in steelmaking with sponge iron depends firstly on the definition of this term. Relating the quantity of the input sponge iron to the quantity of liquid steel produced, the output depends, essentially on the gangue content of the sponge iron and its degree of metalization. Additionally, the carbon content of the sponge iron or the additionally brought in carbon quantity is of importance.

Since the Midrex sponge iron has a high degree of metalization, iron losses in the slag are relatively small. It has been shown that the FeO content in the slag is lower than usually being observed in scrap smelting. Since, however, on the other hand the slag quantity as compared to scrap smelting is slightly higher, both of these factors should compensate mutually so that the iron loss, as a whole, is not in excess of that in scrap smelting.

The economics increases with increasing furnace size, and we do not see any difficulties in the handling of slag quantities. The slag quantity does not increase excessively as compared with scrap operation using low-gangue raw material. Since the necessity of desulphurization and dephosphorization does not exist, the slag basicity may be kept essentially lower.

Contribution

Prof. V. A. Altekar (National Metallurgical Laboratory, Jamshedpur)

The experience described by the author illustrates the importance of high power input rates in obtaining high melting rates and thus reducing the total time cycle. The power consumption per ton of melt can be thus reduced by faster melting rates.