THE INCREASING USE OF PREREDUCED IRON ORES IN ELECTRIC ARC FURNACES

J. ANTOINE
J. ASTIER

Summary

Datas about the increasing use of prereduced iron ores, around the world, in electric arc furnaces.

Development of continuous charging system such of these of HyLSA (Mexico), Contimelt (Stelco-Lurgi) Korf (Georgetown, USA and Hamburg, Germany), TAMSA-TECHINT (Mexico).

Comments about continuous melting: necessity of reaching optimal conditions to melt prereduced iron ores i.e. high electrical power, low electrode consumption, low refractory wear of the lining of the furnace. Possibilities, advantage and a difficulties of utilization of electrical intensity in the arcs or shadowing the arcs in the slag.

Equipment used for IRSID experiments: 6 t 3000 kVA electric arc furnace with special continuous charging devices. Operating charging and melting pratice with shadowing of the radiation from the arcs through, first, a solid mass of prereduced iron ores in the center of the furnace and, second, the boiling slag.

Main results with a number of samples of prereduced iron ore. Relation between available electrical energy P_E and useful power P_U needed to melt and heat metal and slag and to cover the metallurgical reactions. Comparison between scrap and prereduced iron ores charging and melting.

Application to commercial plants extrapolation of our tests and operating procedure with recommendation for large scale furnaces. Automation of electric arc furnaces : principles, operating procedures ... The next step could be the continuous arc steelmaking furnace.

Introduction

As the use of prereduced iron ores in electric furnaces is growing (see Table I and figure 1), a number or researches and development works are made to find the optimum use of such raw materials and, specially, the way of charging them in electric arc furnaces.

This development (1) (2) (3) (4) led to a more popular use of continuous charging equipment and the first part of our communication will deal with this subject. In the meantime, the use of continuous charging technics can lead to new ways to operate an electric arc furnace; the second part of our communication will be devoted to this point with emphasizing the IRSID method of running an electric arc furnace with continuous charging of prereduced iron ores. We must emphasize such processes can also be applied with the same advantages to the use of fragmentized scrap (shredded scrap produced by several different processes commercially used or being developed) in electric arc furnaces.

1. The Development of Continuous Charging Devices

Following experiments made, a long time ago, in Sweden, with a system such as the one shown figure 2 (5), a number of procedures have been more or less established during the last five years.

TABLE I

Expansion of prereduction plants feeding electric steelmaking shops

Year	Company and location	Type of prereduction plant and capacity		total capacity, cumulated t/year
before 1967	Various companies in Sweden Echeverria (Spain)	Hoganas Wiberg Echeverria	40 000 150 000 (30 000)	
	Total estimated at maximum capacity............. and now at......................			(220 000) 100 000
1957 and 1960	HyLSA (Mexico) Monterrey	H·y L	235 000	335 000
1968	TAMSA (Mexico) Vera Cruz	H y L	165 000	500 000
1969	HyLSA (Mexico) Puebla New Zealand Steel (Nlle Zel.) Auckland Oregon Steel Mill (USA) Portland	H y L SL RN MIDREX	165 000 115 000 350 000	1 120 000
1970				1 120 000
1971	Georgetown Steel (USA) Georgetown Hamburger Stahlwerke (Germany) Hamburg	MIDREX MIDREX	350 000 350 000	1 820 000
1972/73	SIDBEC (Canada) Contrecoeur USIBA (Brazil) Bahia Piratini (Brazil) Dunswart (Afrique du Sud)	MIDREX H y L SL RN KRUPP	350 000 200 000 60 000 150 000	2 580 000
1973/74	HyLSA (Mexico) Monterrey n°3	H y L	300 000	2 880 000

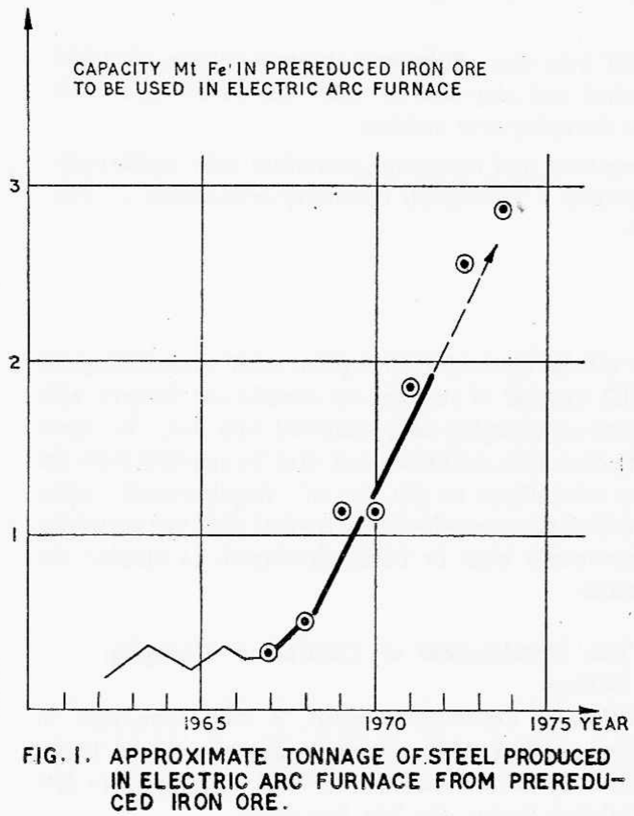

FIG. I. APPROXIMATE TONNAGE OF STEEL PRODUCED IN ELECTRIC ARC FURNACE FROM PREREDUCED IRON ORE.

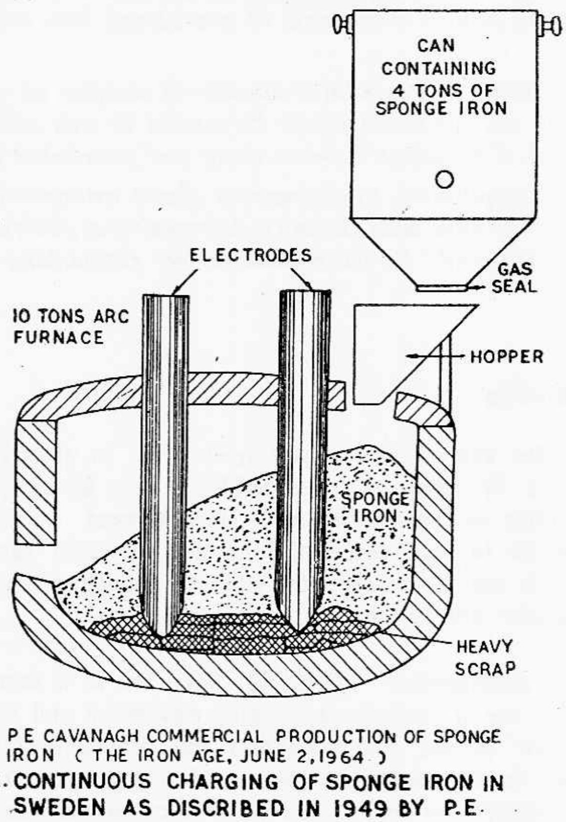

FIG. 2. CONTINUOUS CHARGING OF SPONGE IRON IN SWEDEN AS DISCRIBED IN 1949 BY P.E. CAVANAGH (5)

We can mention:

- the modification of the usual basket charging procedure developed by HyLSA in Mexico (figure 3) using a peripherical distribution specially to protect the walls of the furnace,
- the "CONTIMELT" system (figure 4) derived from research and development by Stelco and Lurgi (6) (7). This was used in quite a number of large scale trials such as, recently those of DAIDO Steel in Japan using HIMET prereduced ores (8) (9).
- the HyLSA continuous charging system described in figure 5 and used on commercial electric furnaces in Monterrey (Mexico),
- the Korf continuous charging system described in figure 6 (10) (11) and used in Georgetown (USA) and Hamburg (Germany) plants,
- and the TAMSA-TECHINT continuous charging system (figure 7) (12) used in the Vera Cruz (Mexico) plant of TAMSA.

All these systems like the one developed at IRSID and which will be described lates start with the idea, that the use of prereduced pellets is, in fact, the utilization of a *closely sized burden*. Instead of the bulky, irregular scrap charge, we have, indeed, a "prepared burden" which can give far more possibilities that the usual bucket charging system.

However, we think this is just the first step.

So the first consequence was the design of a continuous charging system. Figures 2 to 7 show that quite a number of possible devices have been tested.

The utilization of a prepared burden which, by the way, can be not only prereduced pellets, but also shredded scrap, can lead to a change in operating procedure i.e. charging, melting and refining operations.

This is the point we intend to emphasize in describing the IRSID system.

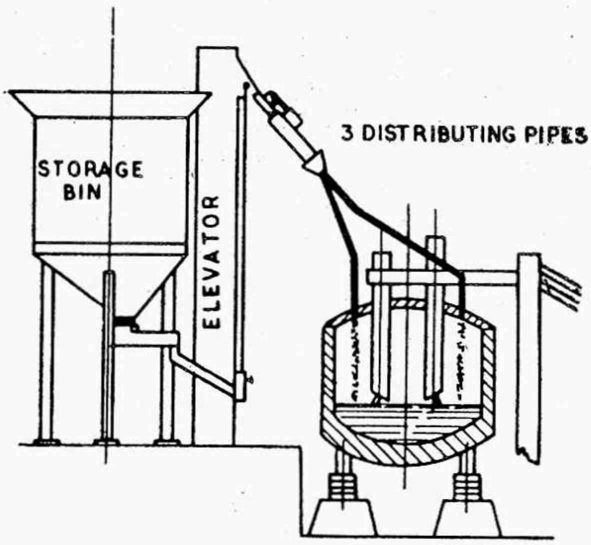

FIG.4. THE CONTIMELT CONTINUOUS CHARGING SYSTEM

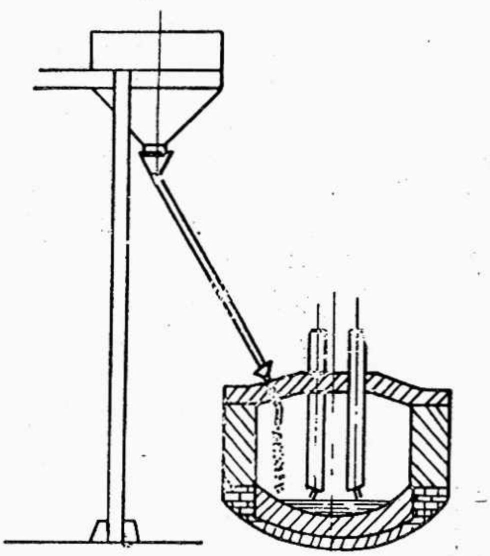

FIG.5. HYLSA-DRAFT OF CONTINUOUS CHARGE SYSTEM

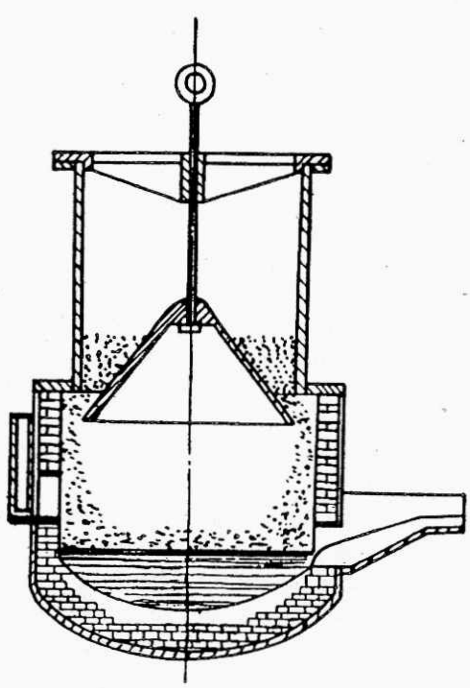

FIG.3. HYLSA-DRAFT OF PERIPHERICAL CHARGE SYSTEM

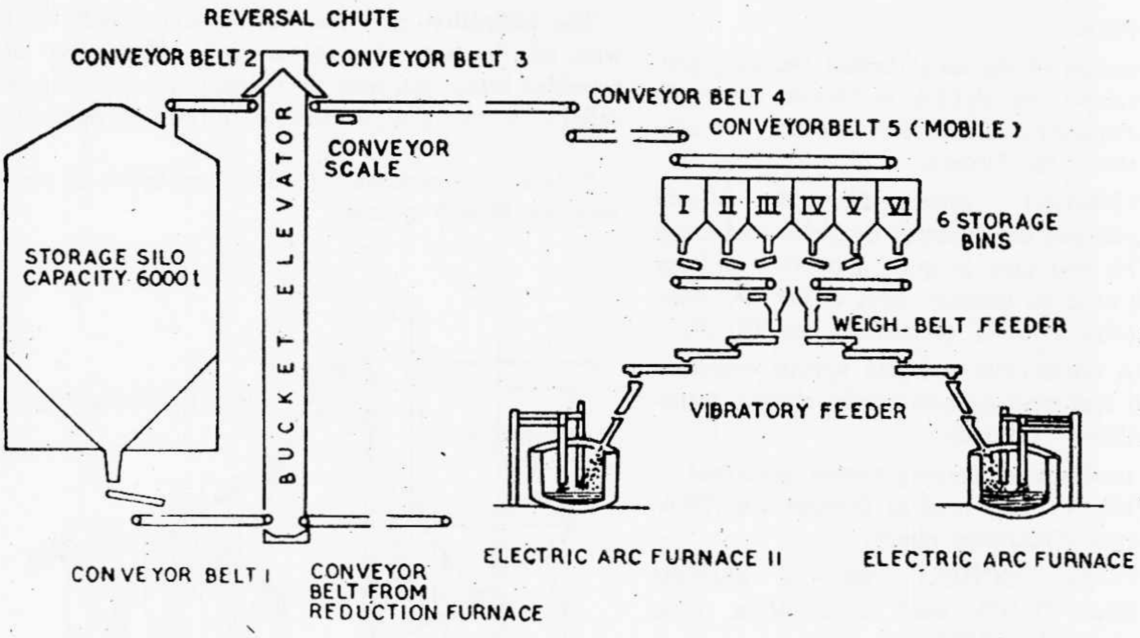

FIG. 6. THE KORF CONTINUOUS CHARGING SYSTEM

II. COMMENTS ABOUT CONTINUOUS MELTING OF PREREDUCED IRON ORES

As it was just now described physical and chemical properties of prereduced iron ores lead, in a logical way, to the continuous charging of these raw materials in electric arc furnaces. However, the problem is not only to charge those prereduced iron ores in a continuous way but to obtain the optimal melting and operation of the electric arc furnace using such a feed. To obtain such an optimal operation, it is necessary (likewise the operation with scrap) to obtain:

— the use of high power with the minimum dead time to have the best utilization of the arc furnace and the ancillary installations.

— a good stability of the arc,

— a high efficiency of the arc to minimize operating costs and specially the consumption of refractories.

Most of the methods described in the preceeding chapter are designed to feed the prereduced materials in a liquid metallic bath. In this way there is no need to shut the electric supply and the electric furnace is always under power. The arc conditions are good and there is generally a good stability of this arc as it is described in publications. However the most difficult problem is the efficiency of the arc in order to be able to use all the available power and specially the ultra high power which is usually available in modern arc furnaces with satisfactory economic results.

To obtain this, several methods are possible:

— the first method is to *select the best electrical parameters* to obtain an arc with high efficiency, thus, limited radiations on the refractory walls. This method which is the usual one for the operation of UHP furnaces, is in fact an operation with short arc and very high intensity. However this has, in several cases, the disadvantages to operate with too high intensity and, thus, to increase the consumption of electrodes, which leads to higher operation cost.

— another method which can be combined with the preceding one is to use the *properties of the slag* to catch, at least partly, the radiation energy from the arc.

It has, indeed, to be reminded that when melting reduced iron ores, the quantity of slag is usually two

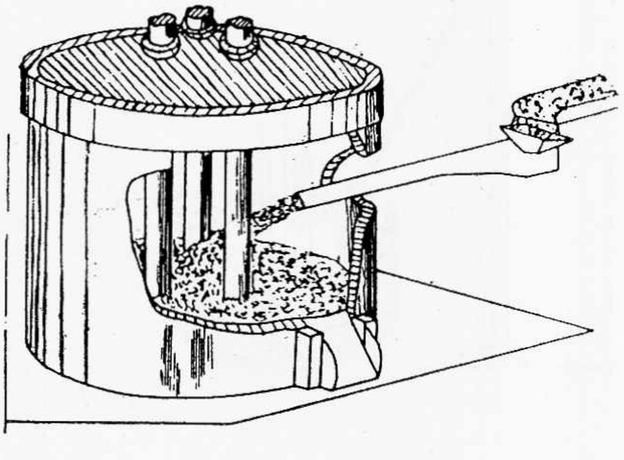

FIG. 7. THE TAMSA CONTINUOUS CHARGING SYSTEM

or three times more important than during melting of scrap. This disadvantage can be turned as an advantage by using this amount of slag to reduce the radiations from the arc to the wall of the furnace. This effect can be further enhanced by the important evolution of the CO from the bath during the melting period due to the reduction of residual metallic oxides in the prereduced iron ores.

This way looks very simple and has already been utilized in several plants. However, at the beginning of the melting period it is very difficult to utilize this effect due to the very small amount of slag present on the bath at this time; this is also the case when only a limited amount of prereduced materials is introduced in the burden. In several tests, difficulties due to these facts have been mentioned and the only way is to decrease, at least for a certain time, the active power of the furnace and to utilize if possible a shorter arc by the means of suitable electrical conditions (9) (11) (13) (14).

During the tests made at IRSID since about 10 years (15), we have tried to utilize at best the advantages given to the continuous feeding of prereduced material by the stability of the arc and the elimination of dead times; in the same time, we were looking at the best efficiency of the arc independently of the quantity of slag and without any decrease of the power or any increase of the intensity of the electric current. To do that we used to "shadow" the arc radiation: in other words, we tried to obtain the same thermal efficiency that the one with melting scrap, in electric arc furnaces, when the arc is "buried" in a mass of solid materials like the scrap burden.

111 EQUIPMENT USED DURING IRSID EXPERIMENT PROCEDURE

All our tests have been made at IRSID experimental Center at MAIZIERES-les-METZ (France). We have been using an electric furnace of 6 ton capacity with a transformer of 3000 KVA (the active power can be regulated to 2600 kW with a secondary voltage 220 Volts. When we are operating in such conditions, detailed calculations show that the radiation index (using the SCHWABE method) give a value of about 20 kW/volt/cm²; this value shows that our pilot furnace can be looked at as an average high power furnace.

The apparatus used for continuous feeding of the raw materials, specially prereduced pellets, is shown on figure 8. There is a bin where can be stocked piled the raw materials and the level of the feed can be ascertained by gauge. There is a feeding system (Weigh-feeder) which enable us to regulate the flow of the feed to the furnace. The raw materials are directed to the furnace with a conveyor belt which can be retracted to leave to the furnace the possibility of tilting for deslagging or tapping. The introduction of the raw material in the furnace is made with a special pipe, water cooled, which is situated at the top of the roof of the furnace.

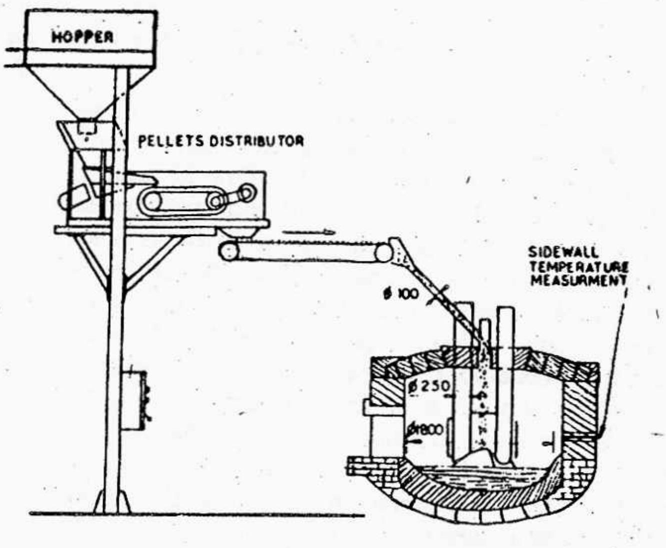

FIG. 8. IRSID. CONTINUOUS CHARGING SYSTEM

The design of this feeding system has to be made very carefully if we want, as it was decided at IRSID, to be able to charge different raw material such as sponge iron, prereduced pellets, shredded scrap, etc. In fact, after a number of trials, we have been using a pipe of 120 mm diameter through the roof and the slope for the inclined part of the pipe must be over 45°.

Regarding the established way of operation of this furnace figure 9 shows diagramatically how we are usually operating. The furnace is first fed with some scrap which, in our usual practice is about 20 to 50% of the whole charge. If it is needed, we can operate with 100 per cent solid prereduced raw material if they

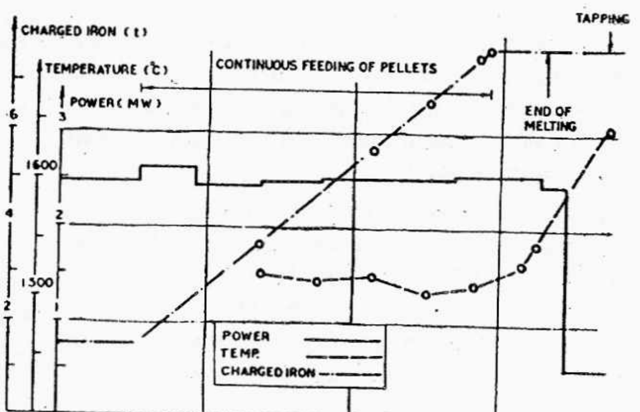

FIG.9 MELTING PRACTICE

are highly prereduced, as, in this case, we can start the arc directly on the solid burden with satisfactory conditions.

When we have used about 70 per cent of the power needed for melting this first charge, we start the continuous feeding of the furnace with a flow of material sufficient to establish a solid mass of unmelted product between the three electrodes in order to catch, as much a possible the radiations form the arc. The choice of the parameter must be such as the arc will be always on liquid metal to have a good stability. When we obtain these conditions, we can see that the electrode is buried on about 3/4 of its circumference by solid raw material and the arc has a tendency to be directed toward the center of the furnace: these two facts are very favourable for a correct melting operation. During this melting operation, temperature of the bath remains comparatively low, in the neighbourhood of the "liquidus" which gives the possibility of conducting all this melting period at a with low temperature (thus, low radiation) and to have slags which are not too aggressive toward the lining. On the other hand, when we are operating with more than 75 per cent of prereduced material in the burden, the slag volume becomes more important and the boiling of this slag is sufficient to "shadow" radiations from the arc. Decarburization of the bath through the residual oxygen of the prereduced iron ore is, of course, increasing, and, in this case, the building of a solid mass of prereduced iron ore is not so necessary than when the slag volume is less important.

When we are coming to the end of the melting period, it is possible:

— either to maintain the same conditions to have the same kind of operation than during the begin ning of the melting period, i.e. to use high power so that, when we are coming to the end of the melting period, we are completely melting the rest of the mass of solid material and heating the metal up to tapping temperature;
— or to decrease gradually the flow of the raw material in order to increase gradually the temperature of the liquid steel in the same time we are completing the feeding of prereduced material: in this way, we can use the favourable conditions of the efficiency of the arc in a deep bath of slag and with a very effective boiling.

During all these operations, carbon content of the bath was regulated in such a way that we had a continuous decarburization (carbon above 1.150%) and to obtain at the end of the melting period a carbon content approximately equal to the one which is needed for the grade of steel which is aimed to.

Usually, we are making lime additions through a powder distribution system. When there is no special problem regarding phosphorus and sulphur contents in the charge and in the grade of steel needed, basicity of the slag is relatively low:

$$\text{— basicity} = \frac{CaO + MgO}{SiO_2 + Al_2O_3} = 1.5 \text{ to } 2.$$

For such a slag and for a given temperatrue of the "liquidus" the iron content of the slag is correlated with the carbon content of the liquid steel by an equation such as:

$$(Fe)_{total} \times \underline{C} = 2{,}5.$$

It must be noted that such an equation is no more valid when we are operating with a more basic slag (basicity around 2.); for such slags, iron contents are higher.

As a summary, we have the feeling that with high percentage of prereduced material in the burden, metallurgical problems of electric arc steel-making are very much simplified. The refining period is reduced to a deslagging and a final adjustment of the chemical analysis and the temperature of the liquid metal.

IV. MAIN RESULTS OF MELTING PREDUCED IRON ORES AT IRSID

During tho tests made since about ten years at IRSID with prereduced iron ores, a number of different samples have been tested. Table II gives the characteristics of the main raw materials used during these tests. These prereduced iron ores are mainly coming from:

— SLRN pilot plant in HAMILTON and the commercial plant of FALCONBRIDGE,
— PUROFER experimental plant in OBERHAUSEN in Germany,
— ESSO FIOR experimental plant in HALIFAX, in Canada.

Table II shows all these products, are generally speaking highly metallized (degree of metallization more than 95%) but they are different regarding the amount and the chemical composition of the gangue and the contents in carbon, sulphur or alloying element, like nickel. A number of tests have also been made at IRSID with iron powder, such as the one produced in fluid bed by the NOVALFER process. As special charging and operating procedures have been devised for such powdery raw material, they are not covered in our present paper.

When we were using about 80 per cent of the whole charge made by highly metallized prereduced iron ores, melting rates were in the order of 3.8 to 4.5 ton per hour, when using electrical averagee power between 2400 to 2500 kW; in this way, the energy consumption for melting upto a final temperature of 1550°C is about 600 kWh per ton of liquid metal. This value has, of course, to be increased by 70 to 100 kWh per ton if

TABLE II

Chemical analysis of the main prereduced iron ores used during IRSID tests.

Reference *	A	B	C	D	E
Total Fe	93,0	90,3	36,7	89,5	91,7
Metallic Fe	91,9	88,1	94,5	85,8	84,0
Residual O in iron oxide	0,4	0,7	0,8	1,14	2,5
Gangue	5,4	6,0	1,6	6,2	4,1
$\frac{CaO + MgO}{SiO_2 + Al_2O_3}$	0,87	0,17	0,15	0,42	0,4
C	0,16	0,020	0,66	0,17	0,81
S	0,015	0,026	0,006	0,019	0,016
P	0,010	0,009	0,009	< 0,010	0,060
M				1,66	

Notes * AB SL/RN Hamilton
C Purofer
D SL/RN Falconbridge
E FIOR

we want to have the total energy consumption per ton of liquid metal for the whole electric arc steelmaking operation.

In the case of our 6 t furnace (i.e. relatively small size furnace), this consumption is more or less the same (or slightly increased at) as the one we have obtained when melting scrap. However, melting rates are higher with prereduced iron ores, as we have, on the average, only 2.5 to 3. ton per hour, in scrap practice depending of the kind of scrap used. This difference is still increased by the fact that when using prereduced raw material, refining periods are kept to a minimum. The elimination of dead times through continuous feeding and the utilization during the whole time of the charging and melting period of the maximum available power through a good stability of the arc and a high thermal efficiency of this arc, are, from our point of view, the explanation of this important difference in productivity. It is clear that this difference will decrease if we are using a lower quantity of prereduced material (say 50% only of the whole charge) and although the thermal needs are lower, the difference in total energy consumption is not very different as it was also demonstrated by a number of commercial tests.

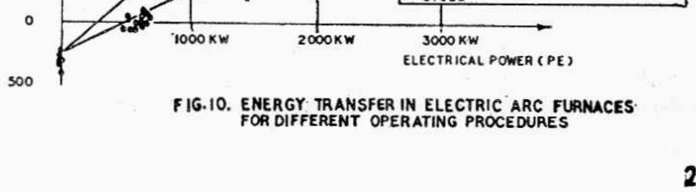

FIG. 10. ENERGY TRANSFER IN ELECTRIC ARC FURNACES FOR DIFFERENT OPERATING PROCEDURES

To explain the large scatter of results from experimental tests with a number of different prereduced materials, we have established a number of detailed thermal balances to try to correlate the influence of different parameters and specially:

— the electrical power available from the transformer (P_E)

— the useful power to cover the energy needs for melting, heating of metal and slag and metallurgical reactions (P_U)

Figure 10 shows that, for a given set of operating data, these two kinds of power P_E and P_U can be related by a statistical relation such as:

$$P_U = A\,P_E - B$$

B is constant for a given electric arc furnace and it can be expressed in the following way (17).

$$B = 80\ T^{2/3}$$

where T is the capacity of the furnace, in tons.

This means that the different charging and melting practice can be differentiated according to the value of A which is, in fact, in close relation with the efficiency of the arc.

As an example, melting of scrap corresponds to high efficiency (A is around 0.9 to 0.95) but the electrical power is not so high as the ones which is used during continuous charging and melting of prereduced pellets. This explains the difference in productivity between these two cases. On the other hand, when melting prereduced pellets, it is possible to increase the thermal efficiency: we have seen that wiith the establishment of a solid mass of prereduced material between the electrodes (a kind of floating "iceberg") the arc efficiency is increased and we can reach for the coefficient

A a value around 0.87, which is not exactly as high as with scrap practice but already quite good.

As a comparison, when there is a continuous charging of prereduced iron ores in a liquid bath, as it is very often the case during test or in commercial practice, there is no more protection of the arc by the slag and the decarburization reaction: in this case, the coefficient A is around 0.8. It is, thus understandable that it is very difficult to operate such a furnace with high arc voltage. In this case; it will be necessary to decrease the electric power in order to avoid excessive refractory wear. The beneficial effect of decarburization ("boiling action") and of the slag thickness is further confirmed by the value of A during the refining period when there is a very small amount of slag, say 20 kg of slag per ton of liquid metal: in this case, in our experimental furnace in MAIZIERES-les-METZ, we have a coefficient A more or less equal to 0.5.

V. APPLICATION TO COMMERCIAL PLANTS

They are in two different fields:

— recommendation for use of prereduced iron ores in electric arc steelmaking plants.

— automation of electric arc furnaces.

V. 1. *Recommendation for use of prereduced iron ores in electric arc steelmaking plants*

To extrapolate our results on larger and larger commercial electric arc furnaces, we can use relation between available electrical power P_E and useful power P_U. It is thus possible to predict in all the cases the operating results. As an example, when we are willing to charge in a continuous way prereduced pellets, the flowrate D will be determined by the relation:

$$D = \frac{P_U}{W_b}$$

W_b is the exact energy requirement to obtain one ton of metal from prereduced pellets.

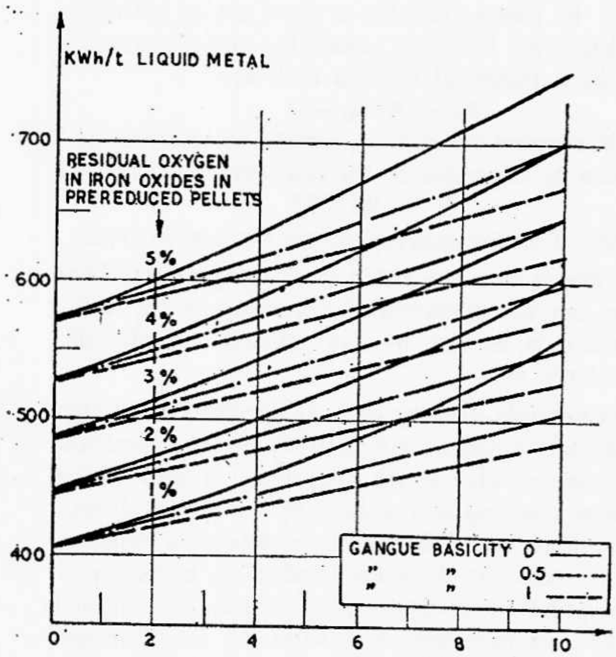

FIG. 11. THEORETICAL ENERGY REQUIREMENTS TO MELT ONE TON OF METAL FROM PREREDUCED PELLETS

Figure 11 gives in this way the energy requirement to obtain one ton of liquid metal at 1550°C from different compositions of prereduced pellets.

as an example, with a product with:

— residual oxygen 1% — gangue 6%

— basicity of the gangue 0.2 — Fe 0,92%

the theoritical need is 480 kWh per ton of liquid steel or 437 kWh per ton of prereduced pellets.

We have made calculation for two types of electrical arc furnaces and with two different operating procedures corresponding respectively to the coefficient A=0.80 and to 0.85. We have, in this way, been able to calculate the flowrate of prereduced pellets for stable operation. In this example, they are corresponding to:

— 20 to 31.3 kg of prereduced pellets per minute and per MW for one of our recommended operating charging and melting procedures.

— about 8% lower i.e. 26.7 to 26.8 kg of prereduced pellets per minute and MW for the usual practice. It must be emphasized that, in the second case, the energy which is radiated on the refractory walls will be very much increased.

It is quite interesting to compare such value with the ones which can be found in technical papers. It is generally difficult to make the complete comparison because a number of data are lacking, such as the exact analysis of the prereduced materials, the exact average value of the flowrate or the operating conditions of the furnace. However, as an order of magnitude, the values for highly metallized product are always:

— between 26 and 35 kg per MW and per minute, with the large majority of operating data,

— between 27 to 30 kg per MW and per minute.

We think such values are a good confirmation of our tests.

V. 2. *Automation of electric arc furnaces*

From the analysis of the metallurgical operation we have described, it is clear that the thermal efficiency of the melting of the prereduced material is linked to the radiation from the arc to the lining of the wall of the furnace. As a consequence, we have been trying to correlate the flowrate of the prereduced pellets with the thermal flow received by the wall to obtain the minimal value of this heat radiation flow.

It was thus necessary to develop a device which could be installed in the lining of the wall of the furnace to measure the radiation received by these walls:

This is a graphite bar, whose temperature can be used as an index of the radiation suffered by the walls (18). This temperature measurement can be used by a computer which will be able to adjust the flowrate of metallized pellets. The same computer can be, of course, used to calculate the necessary additions to regulate both the compositions of slag and liquid metal. These calculations are very easy to make, of course, inasmuch as the chemical analysis of the pre reduced material are known with a sufficient accuracy. Some spot measurements of temperature and chemical analysis of samples can increase the accuracy of this method. Figure 12 shows the scheme of such an operation, with the CAE 90.10 computer used during our tests.

The complete description of our automation system would take far more length than it is possible in this paper, so we shall only comment the schematic description of figure 12:

- before starting melting, the composition of the charge is calculated as a function of the analysis of raw material and specially prereduced iron ore on one side, and the weight of metal needed and the specifications about the grade, on the other,
- melting is started with an adjustment period which corresponds to the striking of the arc on the scrap up to the beginning of continuous feeding of prereduced pellets. Then, the flow of prereduced material is regulated in such a way that the variations of temperature measured, as it is indicated before, are remaining between a certain limit (0 to 2°C per minute). Every deviation from this limit starts a correction in the flowrate of prereduced pellets to minimize the thermal losses and in the same way keeping within limits the weight of unmelted prereduced pellets in the center of the furnace. During all this period, the amount of the carbon fed in the furnace is calculated as a function of all the variations in the charged materials.
- when melting period is finished, there is a deslagging, then the metallic bath is heated according to the required value.

From the results of our tests, a number of conclusions can be already drawn:

- there is quite a flexibility of our charging and melting system which can cope, either with erratic variations in the chemical composition of the burden, specially degree of metallization or carbon content of prereduced pellets or operating data which are difficult to know with a good accuracy, such as the exact thermal state of the furnace at the beginning of the operation.
- an important decrease in the scatter of the thermal results; as an illustration of this point for some tests with prereduced pellets, it was possible to predict the end of the melting period within seven minutes.
- some economies, difficult to appreciate exactly, regarding energy consumption and specially refractory consumption.
- and, of course, a decrease of the necessary manual interventions to cope with unexpected situations. However, we must emphasize that our system is very flexible and leads to a very fast and easy substitution of manual operation instead of automatic operation at any time during the melting operation.

Conclusion

We think that a better understanding of electric arc steelmaking operation, of the mechanism of heat

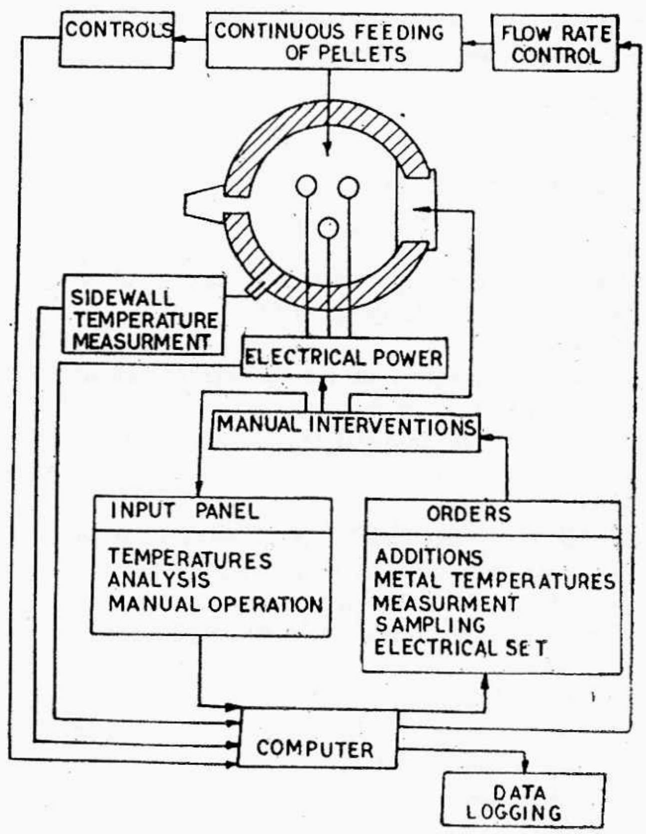

FIG.12. AUTOMATION OF ELECTRIC ARC FURNACE

transfer and also of the chemical reactions occurring, specially with prereduced raw materials, lead now to better possibilities of operations including automation of electric arc furnaces.

On the other hand, the possibility of using sized materials instead of bulky and irregular scrap leads to the possibility of continuous charging of electric arc furnace. In this way, we have been describing what could be, in the near future, the operation of future electric arc furnaces operating with such prepared burden which can be made of growing proportion of prereduced raw materials and probably of some prepared special scrap.

However, this is probably not the end of such research in that, after the continuous feeding of raw material, it could be considered as an interesting next step, to have a continuous pouring of the metal from the furnace: in this way, we would be coming to a real continuous arc furnace. Without describing in detail such a research, we want to mention that IRSID has already built a pilot plant of such a continuous furnace, and the first tests look very promising.

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(5) CAVANAGH (P.E.)
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(6) SIBAKIN (J.G.) LAYARD L.P.
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(7) POST (G.)
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(8) NODA H. FURUHASHI H., USHIYAMA H.
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(10) KEHL P., VOSS H.
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(11) MASCHLANKA W., KHEL P., KNAPP H., VOSS H.
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(12) MORELLI G., URGNANI G.B.
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(13) FOGLEMAN E.L., GLOVEN D.O.
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(15) ANTOINE J., DUMONT-FILLON J.
Electric arc steelmaking with continuous charging of prereduced iron ores. Results of tests at the pilot plant IRSID in (1).

(16) SCHWABE (W.E.), ROBINSON (C.G.)
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(17) ANTOINE J., PAQUEL N., DUMONT-FILLON J.
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(18) ANTOINE J., MATHIEU J.J.
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DISCUSSION

MR. H. S. KATIAL, (Rainbow Steels Ltd., Muzaffarnagar): (1) Cost of increased consumption of power i.e. about 100 K.W./T more for making steel with 92 per cent metallisation sponge iron, more consumption of lining and fluxes, more strict segregation of materials used for Sponge Iron etc. etc. Will it not increase the total cost of the steel manufactured? Will it be economical to make steel by above process in Indian conditions? (2) Do you suggest low voltage and high current furnaces to be more advantageous for longer life of the lining while using sponge iron.

J. ASTIER (Author): (I) The total cost of steel in electric arc furnace depends, above all, from the raw material price. From the cost of scrap, or prereduced pellets, it is possible to determine interesting ways to use prereduced products eventhough the melting costs are higher. Moreover, the continuous feeding and the shortening of refining time allow to obtain higher productivities. Then, at last, prereduced products are of real interest to get high quality steels, thus, if scraps are expensive and scarce (2) In case of working in liquid heel, any practice to limit the arc radiation should be interesting to overlook. This is why it could be good to utilize short arcs, through high intensity. Nevertheless, we must say that we should not overdo the method as the electrode consumption would increase. Besides, for ultra high power, this technic employed solely seems unsufficient to obtain a good refractory life and this is why we have experimented some melting practices which could even increase the lining protection.

Mr. S. N. BANERJEE, (Steel & Allied Products Ltd., Calcutta): We are interested to know the comparative quantities of refractories consumed per ton of steel produced by using all scrap process and by using continuously charged high percentage (above 50%) prereduced pellets. This should be given with reference to the composition of pellets — specially its basicity and FeO content.

MR. J. ASTIER (Author): The refractory consumption will mostly be dependant from the thermal yield of the arc. This is the reason why we tried to find out, in case of pellets's melting, a melting technic protecting refractories from arc radiation and arc projections during the greatest part of the melting period of time. Nevertheless, the basicity slag analysis and FeO should be accurately controlled to limit the chemical attack. This is fairly easy in case of prereduced product (which has a steady analysis). If those rules are applied, the refractory consumption, with prereduced pellets is practically the same as the one obtained with scraps.

Mr. B. S. KRISHNA RAO (Heavy Engineering Corpn. Ltd., Ranchi): As a blessing in disguise, will residual oxygen in sponge iron help in further processing of the same in steel melting furnace?

MR. J. ASTIER (Author): Yes, this is true and this oxygen, specially when combining with some excess carbon in sponge iron produces a very useful and efficient 'boiling' in the metal bath. However, this 'blessing' is not without disadvantage in that this reduction reaction $FeO + C \rightarrow Fe + CO$ is strongly endothermic and increases energy consumption in this electric arc furnace. In this way, I think:

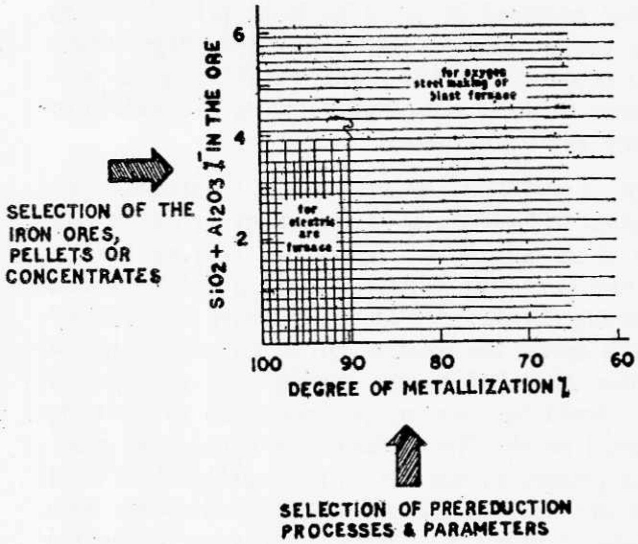
— first, it is useful (and unavoidable) to have some residual oxygen in the sponge iron

— second, it is important to limit this amount to a rather low level, depending on economic situation.

As a general rule, I suggest no more than 3% (as indicated below in Table and figure).

Table—Index of reduction or metallization of pure iron oxide

degree of metallization $= \frac{\text{Fe metal}}{\text{Fe total}}$		75	80	85	90	95	100
degree of reduction $= \frac{\text{O removed}}{\text{O maximal associated with Fe}}$		83.33	86.66	90	93.33	96.66	100
degree of oxidation 100 −d° of reduction		16.66	13.33	10	6.66	3.33	0
Composition of iron–iron oxide phase							
Fe total	%	93.33	94.59	95.89	97.22	98.59	100
Fe metal	%	70.00	75.67	81.50	87.50	93.66	100
Fe **	%	23.33	18.92	14.39	9.72	4.93	0
O	%	6.66	5.41	4.11	2.78	1.41	0
index $\frac{O}{Fe}$	%	7.14	5.72	4.29	2.86	1.43	0



DR. A. B. CHATTERJEA (National Metallurgical Laboratory, Jamshedpur): I think at the beginning I must pay my compliments to Mr. Astier for the ex cellent presentation of an interesting paper. I have to make a very minor observation. Mr. Astier told us that the use of sponge will be about 10 million tonnes in 1975. Since because in this country we are very much interested in the production of sponge iron using solid reductants. I was wondering whether figures of sponge iron production by gaseous and solid reductants can be given separately?

In so far as steelmaking is concerned, the suitability of sponge iron produced with solid reductants or with gaseous reductants needs careful assessment. My second queestion is when the 'iceberg' process was considered or invented at IRSID, the 'Contimelt' process of making steel with the continuous feeding of sponge iron was already well known. What were the conditions and the reasons for which this new process was developed by the IRSID? Besides, as we know about 7/8th of the iceberg remains under the surface of sea water while 1/8 is exposed. Does the name 'iceberg' process can be stretched to suggest that most of the sponge fed through the central opening sinks in the bath?

Mr. J. ASTIER (Author): Regarding the first question, the total capacity of direct reduction plant is now (1973) around 5 million t, from which
— about 5 Mt are related to gas reduction processes:
— and 1 Mt to solid reductants processes.

In 1975, the capacity could be of 10 million t and it is highly probable that the large majority will be again provided by gas reduction processes. For a more distant future, say 1980, predictions range between 62 Mt (Congres International sur le four electrique a arc en aciere, Cannes, France, 7, 8 et 9 Juin 1971) but; of course, it is difficult to know which will be the share of the different processes.

Regarding the second question, in fact, the so-called iceberg IRSID process and the CONTIMELT process were developed more or less at the same time and are using both SI-RN pellets.

By the way, STELCO and LURGI experts were associated with our researches at that time. They are two different ways of charging continuously sponge iron but there are also differences in the way of melting. Regarding the analogy with the real iceberg, it can be said that pellets are floating on the slag bath and also are partly immersed in this bath but they are not inside the steel bath as the density of the iceberg is not as high as those of the liquid bath.

SESSION V – STEELMAKING WITH SPONGE IRON

Wednesday, 21 February 1973

The Session was convened at 9.00 A. M. The Chairman was Dr. M. N. Dastur, Managing Director, M. N. Dastur & Co. P. Ltd., Calcutta, the Co-Chairman was Mr. J. F. Moyle, Manager, Planning Steel Division, Broken Hill Proprietary Co. Ltd., Melbourne, Australia and the Rapporteur was Mr. G. P. Mathur, Project Co-ordinator (O. D.), National Metallurgical Laboratory, Jamshedpur.