Steelmaking by Injection of Oxygen and Lime Powder Irsid-O.L.P. Process

B. Trentini
M. Allard

THE injection of powdered materials capable of reacting rapidly with a metallic bath has long been considered, and for several years IRSID has pursued a systematic study of "metallurgy by injection of powders". This research has already led to known industrial developments, such as the desulphurisation of pig iron by powdered lime, the treatment of siliceous pig iron in the basic Bessemer converter, and the thermal controlled thermal adjustment of the operation in the converter.

Numerous technical developments made during these research projects, as well as the acquisition of new fundamental data, have led IRSID to expand this techinque and to develop a new steelmaking process which can be applied to pig irons of any phosphorus and silicon content.

Technology of the O.L.P. process

The O.L.P. process is characterised by a complete modification of behaviour of the jet of oxygen which strikes the bath ; this is obtained by control of the suspension in oxygen of finely divided lime, which is utilised in concentration varying with the nature of the iron and the phase of the operation.

Figure 1 represents a scheme of the O.L.P. process.

After numerous small scale tests, the process is now applied at the industrial scale of 30 tons. The vessel used is a basic converter in which the ordinary bottom with tuyeres has been replaced by a tight bottom of rammed dolomite ; the lining is composed of dolomite bricks made in a press. On a new lining the static depth of the bath is 33 in, and the volume 900 cft. or 30 cft. per ton of metal.

The lance placed above the bath is cooled by a flow of water of 1,000 cft. per hour.

The distributors for powdered lime were specially built by IRSID ; they permit the injection of all the lime needed for refining, with a very uniform flow and a rate depending upon the nature of pig iron and the stage of refining.

As far as pig iron is concerned, mainly high phosphorus pig iron has been blown. A typical composition is the following :

C : 3·8%, Si : 0·4%, P : 1·8%, Mn : 0·8%, S : 0·04%.

Dr. B. Trentini, chief of Steelmaking Division and Mr. M. Allard, General Manager, Institut de Recherches de la Siderurgie, France

However some tests have been made on hematite pig iron, of typical composition :

C : 4·0%, Si : 1·0%, P : 0·3%, Mn : 2·0%, S : 0·03%.

Lime is of industrial quality and of typical composition :

CaO : 86%, CO_2+H_2O : 11%, S : 0·12%.

Oxygen of commercial quality with 99·5% O_2 is supplied under a pressure of 210 p.s.i. before regulation, the blowing pressure being around 80 p.s.i.

As far as cooling additions are concerned, both scrap or rich iron ores are used ; these ores contain around 56% Fe, 2% CaO, 11% SiO_2.

Metallurgy of the O.L.P. process

High Phosphorus pig Iron : The very easy dephosphorisation obtained in the O. L. P. process is shown Fig. 2 comparing the C and P evolution of the two processes : basic Bessemer and O.L.P., during the refining of a high phosphorus pig iron. One can see how easily phosphorus is removed in the O. L. P. process, even under a high carbon content in the liquid metal, an important feature for the direct production of high carbon steel.

For the refining of a high phosphorus pig iron, the two general principles are :

(*i*) Blowing lime powder from the beginning up to the end of the refining.

(*ii*) Removing one or two intermediate slags, thus eliminating an important part of the phosphorus initially contained in the pig iron.

As an example, Fig. 3 represents the chemical and thermal evolution in the refining of a 30-ton heat of a 1·7% phosphorus hot metal, for making a low carbon rimming steel.

After charging scrap and iron ore (the total corresponding to 500 lb per ton of metal), the hot metal is poured and the vessel is tipped up to permit the lowering of the lance and afterwards the admission of oxygen and powdered lime. In the course of this first phase, about 1,700 cft. of oxygen and 240 lb of lime powder per ton of metal are blown. At the end of this phase the metallic bath contains 0·7% carbon, whereas the phosphorus content is only 0·105%. Because of the high temperature at this moment (1,580°C) the slag is liquid and can be poured out in great part. Such a slag contains 57% CaO, 22% P_2O_5 and only 8% Fe in the form of oxide.

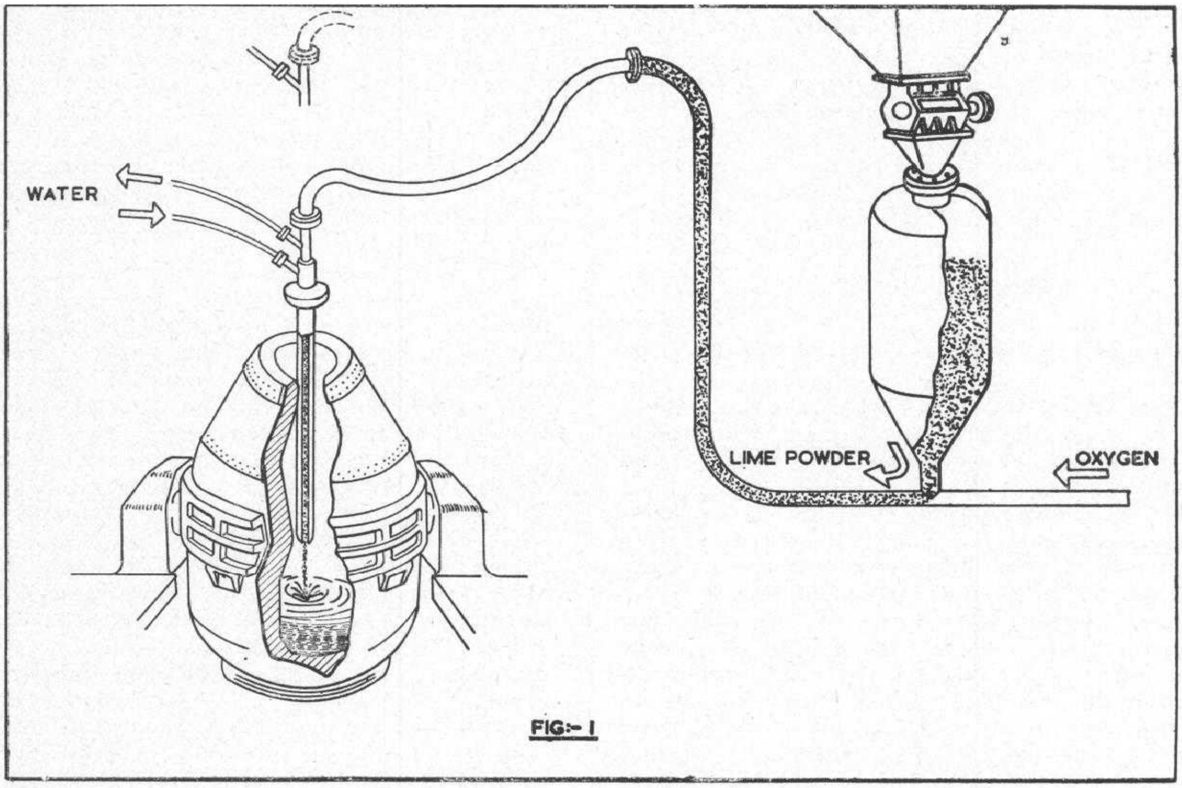

WATER
LIME POWDER
OXYGEN

FIG:- I

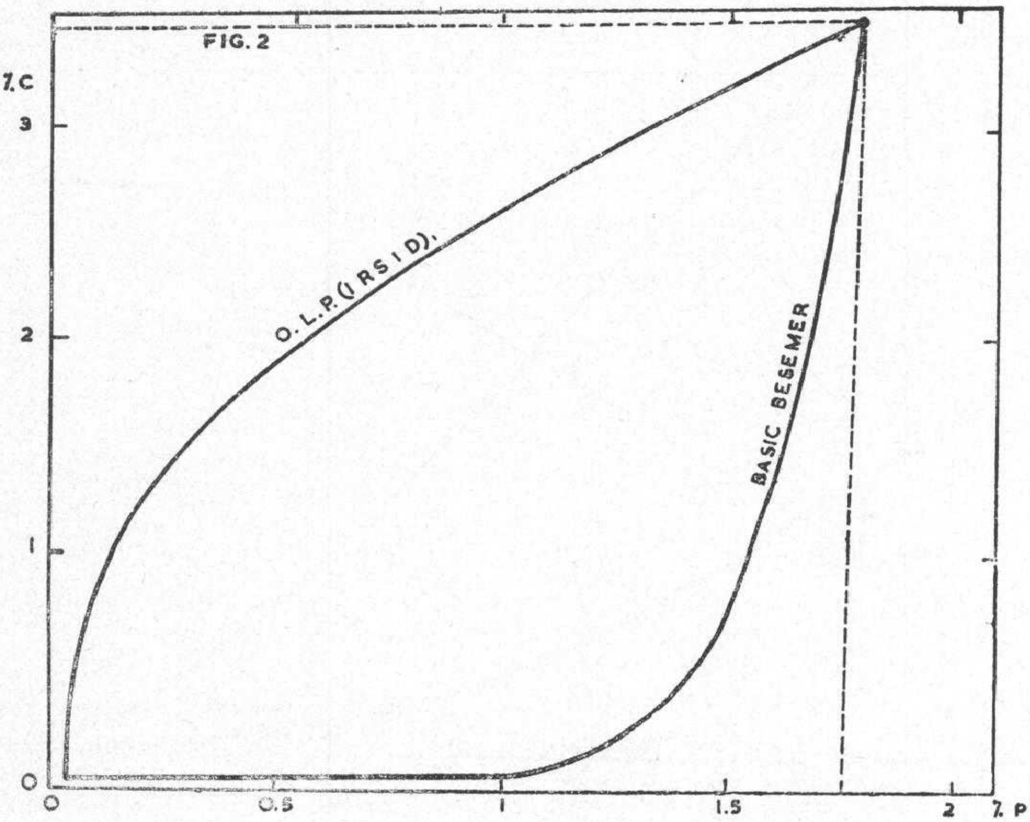

% C
3
2
1
0
0
0.5
1
1.5
2
% P
O. L. P. (I RS I D).
BASIC BESEMER

FIG. 2

After that slag removal, and the addition of scrap (100 lb per ton of metal), the blowing of oxygen (500 cft. per ton) and of lime powder (70 lb per ton) is continued until the desired carbon level. In this case of low carbon steel, the final slag is rich in iron (about 20%) but its quantity is not large because of the preceding slag removal, and it can be recovered for the following heat.

The final steel at the casting pit has the following composition :

C : 0·08% Mn : 0·31% P : 0·017% S : 0·014% N_2 : 0·001%.

This is a typical analysis obtained by the O. L. P. process.

As a generalisation the low carbon rimming steels obtained from high phosphorus pig irons are characterised by their very low phosphorus, sulphur and nitrogen contents.

This easy dephophosrisation, even in the presence of carbon, permits one to obtain directly semi-hard or hard steels with a low phosphorus content by stopping the refining at the desired carbon content.

The desulphurisation efficiency is very high, due to the removal from a high carbon bath of a very basic slag, with high sulphur partition coefficient. Desulfurization efficiency is of the order of 60 to 70% : starting from a sulphur content of 0·050% in pig iron, one obtains easily 0·015% in steel.

The nitrogen content obtained in the final steel at the casting pit is uniformly very low : 0·001 to 0·002% maximum, with oxygen of 99·5% purity.

As a summary the average data, per ton of high phosphorus pig iron are : Oxygen : 2,200 cft ; lime powder : 310 lb ; scrap : 600 lb.

The total time from tap to tap is actually one hour for a 30-ton heat. It could be brought down to 45 minutes by a larger oxygen supply (at present limited to 2,500 cft/min.) and better means for charging cooling additions.

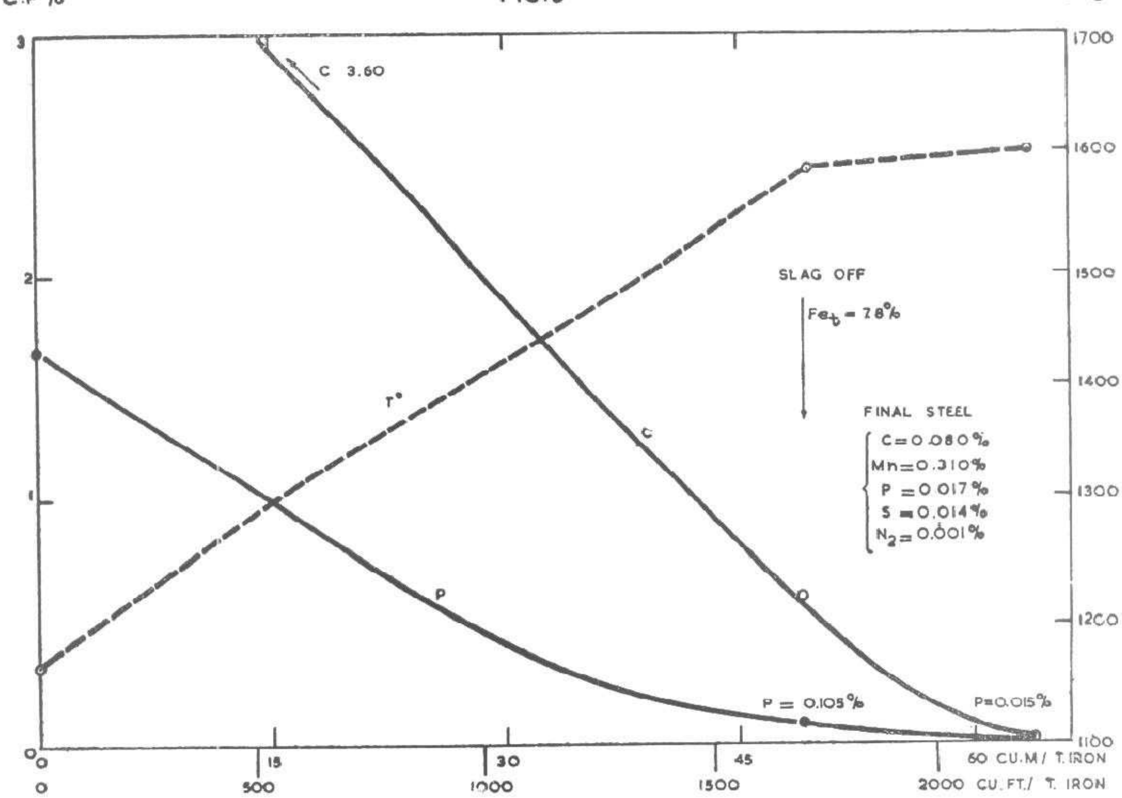
Due to the absence of splashing and foaming, and the low iron content of intermediate slags, the steel yield is systematically high : 90%.

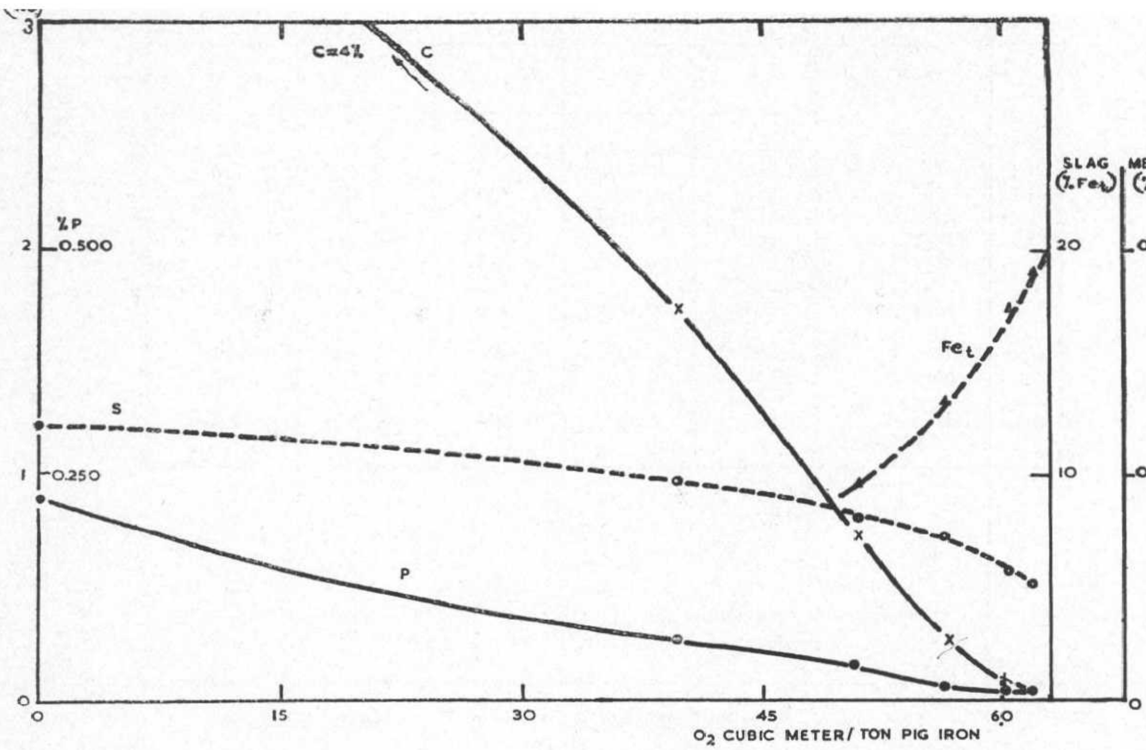
As a matter of fact lime powder injection is an excellent means to fight foaming, thus pig irons of high silicon content can be blown without the risk of violent splashing or foaming.

Moreover no fluxing agent such as fluorspar is needed to bring lime into solution : as a result lining life is very good and dolomite consumption is of the order of only 20 lb per ton of steel.

Low phosphorus pig iron : The most difficult problem, that of irons of high phosphorus content, being solved, it is easy to extend the field of application of the process to pig irons with lower phosphorus contents. The plant where the industrial development of the process has been made, ran one of its blast furnaces for a short time with low-phosphorus iron ore from Canada and North Africa, thus permitting the experimental application of the

FIG. 3





O.L.P. PROCESS: FIG. 4— LOW PHOSPHORUS PIG IRON (P = 0.230%)

process to low-phosphorus pig irons, having about 0·2% P.

Fig. 4 presents the chemical evolution of a 30-ton heat of low-phosphorus pig iron of the following composition:

C : 4·0%, Si : 0·87%, Mn : 2·10%, S : 0·029%, P : 0·230%.

Several samples of metal and slag were taken in order to follow the chemical evolution during refining. One will note in particular, in Fig. 4, the ease of departure of phosphorus, which, starting from 0·230%, decreased continuously during the blow to reach, at the last sampling, the low value of 0·011%. At that time the bath temperature was 1,620°C, as measured by an immersion pyrometer, and the final slag had an iron content of 19%. This low final phosphorus content was obtained without any addition of fluxing agent such as fluorspar.

The final steel analysis was: C : 0·05%, Mn : 0·315%, S : 0·012%, S : 0·011%, N_2 : 0·002%.

For this initial phosphorus content of around 0·2%, it is not necessary to remove an intermediate slag to assure very low phosphorus in the final steel. For higher initial phosphorus contents, for example of the order of 0·5%, it would certainly be necessary to eliminate an intermediate slag. The conditions of refining would, thus, be intermediate between those for the pig iron at 0·2%P just described, and those for very high phosphorus pig iron requiring an intermediate removal of slag.

Mechanical tests

Low carbon rimming steels made by this process have been cast into ingots of 7 to 12 tons and rolled into sheets in continuous hot and cold strip mill.

Numerous series of mechanical tests have been made and it would be out of the scope of this paper to give the details of this extensive study.

Let us mention only the comparison between a series of five O.L.P. heats and of two basic open-hearth steels of the same low carbon rimming grade. The composition of these heats is shown in Table I.

The average results on cold rolled sheets of a thickness of 1/32 inch taken from the middle part of the ingots are given in Table II (non-aged) and Table III (aged).

From this comparison one can see the excellent properties of the O.L.P. low carbon steels which can be compared favourably with those of high quality open-hearth steels of the same grade.

	C %	Mn %	S %	P %	N_2 %
O L P 315	0.060	0.330	0.012	0.026	0.001
O L P 316	0.060	0.290	0.010	0.025	0.001
O L P 317	0.055	0.285	0.010	0.024	0.001
O L P 320-1	0.060	0.300	0.009	0.018	0.002
O L P 320-2	0.060	0.300	0.009	0.018	0.002
O L P 321	0.055	0.260	0.009	0.019	0.001
O L P average	0.060	0.295	0.010	0.022	0.001
Open-hearth A	0.075	0.285	0.019	0.008	0.005
Open-hearth B	0.060	0.310	0.011	0.009	0.005
Open-hearth average	0.065	0.295	0.015	0.008	0.005

TABLE II

Comparison between open-hearth and O.L.P. steel sheets
Non-aged, 7 weeks after skin-pass

	Longitudinal section				Cross section			
	E	R	E/R	A	E	R	E/R	A
O.L.P. (middle) Average	26,200	42,300	0.617	59.7	29,000	43,600	0.665	59.3
Open-hearth " Average	32,200	45,000	0.714	53.6	34,300	46,200	0.742	54.9

TABLE III

Comparison between open-hearth and O.L.P. steel sheets
Aged, 7 weeks after skin-pass and kept 30 min. at 100°C

	Longitudinal section				Cross section			
	E	R	E/R	A	E	R	E/R	A
O.L.P. (middle) Average	30,600	44,000	0.696	57.1	33,400	44,000	0.762	57.8
Open-hearth " Average	35,600	45,800	0.776	51.4	36,900	46,400	0.791	53.2

Conclusion

A new process for refining pig iron to produce high quality steel has been developed by IRSID in plant scale tests. This process, which involves the blowing of a mixture of oxygen and powdered lime into the metal bath, is characterised by a complete modification of the behaviour of the jet of oxygen from that obtained in other oxygen processes.

The process is very flexible and can be applied without difficulty to pig irons of any phosphorus and silicon content.

The steel produced has remarkably low quantities of the impurities : phosphorus, sulphur, and nitrogen. Mechanical tests show that its properties compare favourably with those of open-hearth low carbon steels.