

The application of prerefining for steelmaking processes

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INTRODUCTION

MANY PROCESSES have been developed for the pretreatment of pig iron before its final refining in open-hearth furnaces. At the turn of this century the 'washed metal' process, developed in 1890 by Campbell,¹ was used in the USA to remove silicon and phosphorus from pig iron before final steelmaking in the acid open-hearth process. About this time the Bertrand Thiel process,² Hoesch and Talbot processes³ and the Monel process⁴ were developed. These processes were chemically attractive, but were abandoned because of excessive iron losses due to chiling and difficulties in the maintenance of the refractories in the vessels utilized. However, the advantages of working with prerefined metal of known and regular composition were proved inasmuch as the processes were flexible and variations in technique could be employed to suit variable conditions. The heat developed during prerefining can be utilized either to melt up unwieldy pit scrap or, alternatively, ore can be used to control temperature with an attendant useful gain in yield.

It is interesting to note that since Henry Bessemer's revolutionary discovery of steelmaking by the process which now bears his name, many attempts have been made to apply the process to prerefine blast-furnace iron for subsequent use in OH and electric furnaces. This technique is referred to as 'duplexing'.

Apart from duplexing, which was practised chiefly on the Continent, little work was done in this field until the immediate postwar period when in 1948 the use of gaseous oxygen for desiliconization was developed both on the Continent and in the UK.

The increasing availability of 'tonnage' oxygen has given the steel industry a tremendous impetus and many long-known possibilities have now become a practical reality. No longer is it necessary for the steelmaker to cope with blast-furnace metal of unsuitable composition with its deleterious effects on production rates. By the use of oxygen the operator is able to ensure a supply of hot metal, suitably prerefined, rid of unwanted metalloids, and some 200 deg C hotter than when it left the blast-furnace.

All steelmakers will agree that the steelmaking process is simplified when the composition of the charged materials is known and constant and when the concentration of undesirable metalloids, such as silicon and phosphorus, is at a minimum. Where scrap charging facilities are limited, an increase in the proportion of liquid metal results in quicker overall charging and higher production rates. It is important, however, that the liquid metal be as free as possible from the undesirable metalloids.

The production rates of furnaces using oxygen are governed by the quantity and nature of the slags produced in the early stages of the process. Oxygen jetting can be started earlier in the heat and at higher rates if the sili-

SYNOPSIS

The development of the prerefining of blast-furnace hot metal before steelmaking, from the turn of the century to the present day, is discussed and the overall case for 'pretreatment' or 'charge preparation' for the final steelmaking process is given. Two processes are described in detail, namely the Brymbo process and the newer spray refining process developed by the British Iron and Steel Research Association. Operating experience and data are given for the Brymbo prerefining process applied at an electric melting shop producing 0.25 m. ingot tons annually from three 45 ton arc furnaces using 50% liquid pig iron. Reductions in slag volumes, power and electrode consumptions, refractory consumptions, and gains in productivity are given. The spray refining process is still in the early stages of development but may well be regarded as a useful technique in the development of a continuous steelmaking process. The development of the process on a pilot-plant scale for desiliconization and partial dephosphorization at metal treatment rates of up to 2.5 tons/min, is described. A tentative operating cycle for the production of 1 m. ingot tons/a from five open-hearth furnaces operating at the modest rate of 30 tons/h is given.

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con and phosphorus contents are low, thus enabling the high capital cost steelmaking unit to be operated at faster rates and more efficiently utilized.

Open-hearth plants in the UK have shown increases in production of up to 20% when using desiliconized hot metal and when phosphorus has been removed increases up to 35% have been obtained.

It seems logical and inevitable that as steelmaking becomes less of an 'art' and more and more of a chemical engineering process, charge preparation and 'tailoring' of the raw materials, particularly the liquid portion of the charge for the subsequent steelmaking process, will be required.

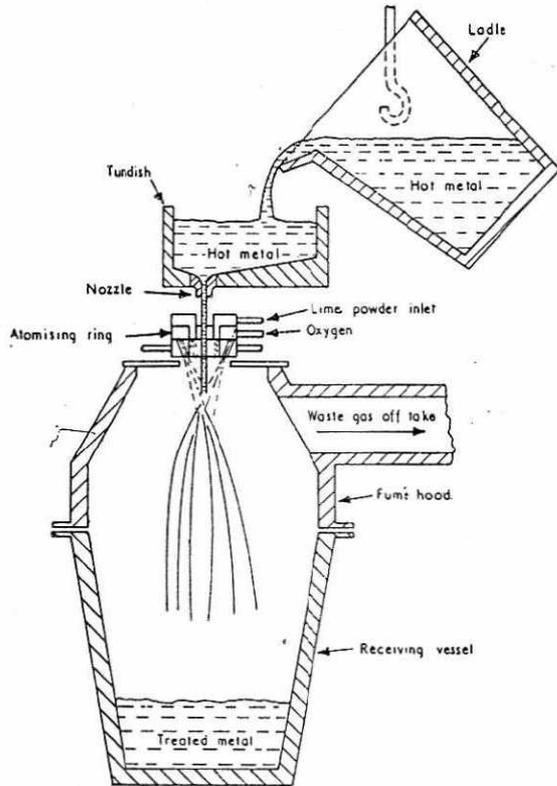
At the present time steelmaking is suffering from a policy of compromise; too many incompatible chemical actions are being carried out simultaneously in the single unit. As the demand for a continuous process increases it becomes more and more apparent that optimization will be required. A first step would be the adequate preparation of the raw materials being charged to the steelmaking unit. The value of charge preparation is amply illustrated by the experiences with blast-furnaces where increased production rates, lower coke consumption, and better quality products have been attained.

METHODS OF PREREFINING

The methods most favoured in the UK for prerefining hot metal are those making use of active mixers or oxygen lances in hot metal transfer ladles.

These methods have their disadvantages; active mixers involve high capital expenditure and the ladle desiliconizing is limited to small batches and is unsuitable for dephosphorizing. Another inherent difficulty in combined active mixer OH furnace operation on a large scale is the balancing of the units. As the OH operation is

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1 Spray refining, pilot plant scheme

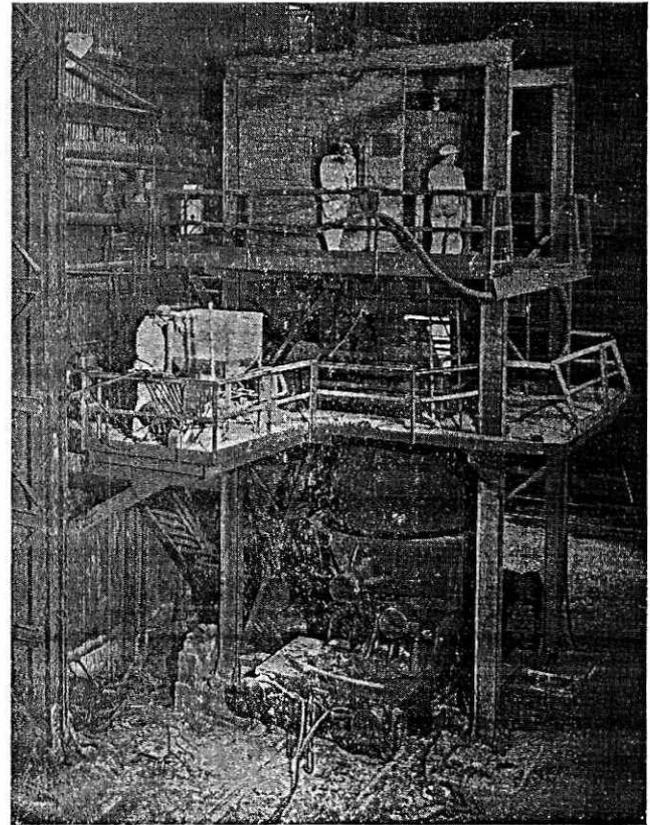
considerably shortened, it becomes difficult to synchronize the operation, particularly on a mixed quality programme, and bunching of furnaces frequently occurs. A further point is that active mixers rarely achieve any appreciable degree of dephosphorization and this practice is mainly a desiliconizing process. If the process is to be extended beyond desiliconizing it is, therefore, necessary to build a special vessel or furnace within which the required degree of prerefining can be achieved.

Other methods have been developed, such as the Rotor⁵ and Brymbo⁶ processes, both of which can be termed 'batch processes'. A further interesting development is the BISRA spray desiliconizing unit⁷ which has operated very successfully on a pilot scale at a British steelworks. Both the Brymbo and spray refining units are described in detail.

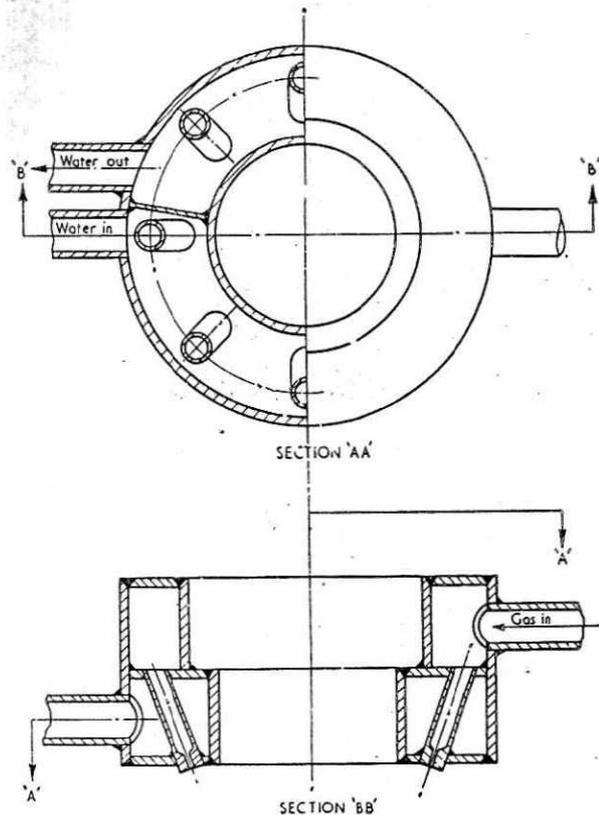
It is interesting to note, however, that the problem of reducing the metallurgical load imposed on OH furnaces by high silicon and high phosphorus iron, has been dealt with very realistically in Europe. For many years it has been the practice to direct the various raw materials, primarily iron ores, according to their phosphorus content. Each type, i.e. low phosphorus and high phosphorus ores, is segregated to produce two distinct types of iron, each of which is suitable for different steelmaking processes.

The lower phosphorus ores are used in the manufacture of *Stahleisen* and the higher phosphorus ores for *Thomaseisen*, the former being more suited to direct OH steelmaking, and the latter for 'Bessemerizing'.

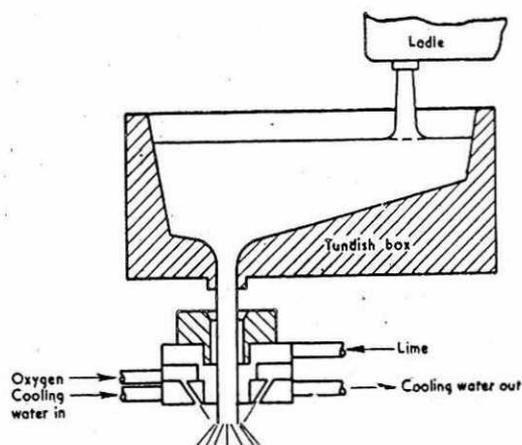
The advantages to be gained by such segregation of raw materials are quite considerable as the Continental productivity figures reveal. The improved flexibility of operation by so doing is well worth considering. It is obviously quite unsound to burden OH furnaces with liquid pig iron containing between 0.8% and 1.5% P, and fixed open hearths, at least, could benefit greatly from a reduction of this metallurgical load.



2 Photograph of spray refining pilot plant



3 Atomizing ring



4 Tundish arrangement with lime dispensing ring incorporated with atomizer

SPRAY REFINING

The rate at which chemical reactions occur during steelmaking is markedly dependent on the area of contact of the reactants. The Perrin,⁸ Kaldor,⁹ and converter processes make use of this factor to obtain efficient and rapid refining.

In the process to be described, molten pig iron is atomized by high-velocity jets of oxygen as it flows from the nozzle of a tundish into a receiving vessel. The atomization results in the exposure of large surface areas of metal to the reactant gas, and the refining reactions take place quickly and efficiently.

Experiments in the laboratory and on pilot-plant scale have shown that desilicization occurs efficiently. The injection of lime powder into the reaction zone has enabled some dephosphorization to be obtained but further investigation will be required before it can be established how far towards complete steelmaking the process can be developed.

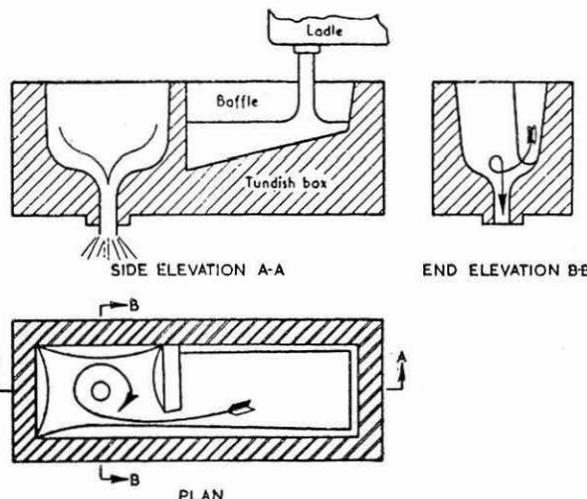
On the pilot plant, desilicization has been obtained at metal treatment rates up to 2.5 tons/min, and dephosphorization up to 30% of that present at metal flow rates of 1.0 ton/min.

Equipment

Figures 1 and 2 show the general arrangement of the pilot plant used on an experimental basis. The hot metal teeming ladle had a capacity up to 20 tons and was fitted with stopper mechanism for bottom teeming. This was required because of interference from slag when hot metal was taken from a partially empty 400 ton mixer. The tundish had a capacity of 10 cwt, and was lined with firebrick, sides and bottom sloping to the tundish nozzle. The water-cooled atomizing ring (see Fig. 3) was mounted on top of the water-cooled top plate of the refractory lined fume hood, immediately beneath and in

TABLE I Desilicization

| | | Weight of metal treated | | Metal flow rates | | Oxygen flow rate | | Lime usage | | Oxygen utilization | | Metal analysis, % | |
|------------------|--|-------------------------|------------|--------------------------|-------|--------------------|------|------------------|------|--------------------|--|-------------------|--|
| | | 15.5 tons | 39 cwt/min | 600 ft ³ /min | | 70 lb/ton of metal | | 120% | | Slag analysis, % | | | |
| | | C | Mn | Si | S | P | CaO | SiO ₂ | MnO | FeO | | | |
| Before treatment | | 3.69 | 1.08 | 1.15 | 0.031 | 1.53 | | | | | | | |
| After treatment | | 3.32 | 0.76 | 0.56 | 0.028 | 1.46 | 37.4 | 36.0 | 10.8 | 5.3 | | | |



5 Tundish arrangement

line with the tundish nozzle hole. The atomizing ring resembles an inverted gas ring from which oxygen is directed by means of nozzles inclined downwards to form a cone meeting at a point some distance below. A refractory lined duct was provided to direct the fume from the fume hood to a stack outside the building. A 40 ton hot metal transfer ladle mounted on a rail bogie was used for a receiving vessel. A lime pump and hopper were available for the injection of powdered lime. Injection could be carried out in three ways :

- (i) through a dispensing ring incorporated with the atomizer (Fig. 4)
- (ii) through the side of the fume hood opposite the atomizing zone
- (iii) through a refractory protected tube passing centrally through the tundish nozzle (Figs. 6 and 7).

Procedure

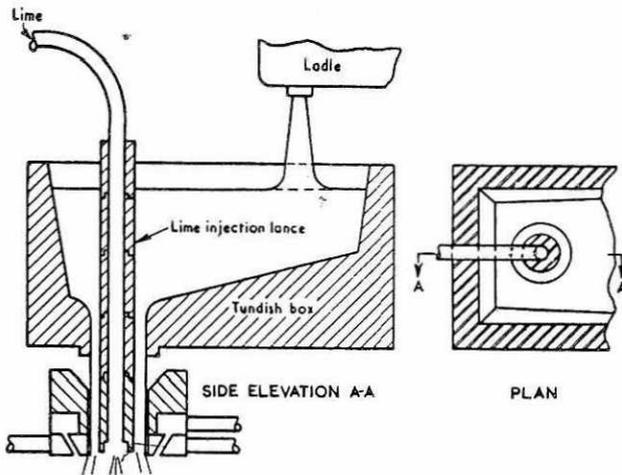
The teeming ladle was filled with hot metal at the mixer and placed in position over the tundish on the supports provided. Samples of metal were obtained and the temperature measured with a dip thermocouple. Metal was teemed into the tundish, the oxygen was turned on, and the flow through the atomizer adjusted to the desired level. If lime powder was being injected, the pump was then started. When the teeming ladle was empty the lime injection (if used) was stopped and the oxygen turned off. Samples of metal and slag were taken from the receiving ladle and the temperature of the metal checked. The receiving ladle was then removed from under the fume hood and the metal transferred to the OH ladles and charged along with the normal hot metal to the furnaces.

Results

Results obtained in typical experiments are given in Tables I and II.

TABLE II Dephosphorization

| | | Weight of metal treated | | Metal flow rate | | Oxygen flow rate | | Lime usage | | Oxygen utilization | | Metal analysis, % | |
|------------------|--|-------------------------|--------------|--------------------------|-------|---------------------|------|------------------|------|--------------------|-------------------------------|-------------------|--|
| | | 8.0 tons | 19.0 cwt/min | 875 ft ³ /min | | 130 lb/ton of metal | | 95% | | Slag analysis, % | | | |
| | | C | Mn | Si | S | P | CaO | SiO ₂ | MnO | FeO | P ₂ O ₅ | | |
| Before treatment | | 3.59 | 0.99 | 1.10 | 0.035 | 1.33 | | | | | | | |
| After treatment | | 2.50 | 0.18 | 0.11 | 0.035 | 1.01 | 40.4 | 29.0 | 8.45 | 9.7 | 6.2 | | |



6 Tundish arrangement, lime injection via tube through tundish nozzle

At metal flow rates up to 2.5 tons/min, adequate atomization and thereby desiliconization was obtained by the use of unstable metal streams. Instability of the metal stream was produced by the use of annular and/or swirl nozzles in the tundish (Figs. 5-7).

When lime powder was injected into the reaction zone, dephosphorization up to 30% of that present was achieved at metal treatment rates of 1 ton/min. From these experiments, indications were that for simple desiliconization metal treatment rates greater than 2.5 tons/min would be possible from a single spray unit and 5 or 10 tons/min seemed within possibility.

Bearing in mind the few experiments which were carried out on dephosphorization, production rates would not be appreciably reduced when the process was extended to include partial dephosphorization.

Conclusions

A new technique has been developed for the pretreatment of molten pig iron which successfully reduces the silicon content without excessive carbon removal. The technique offers a simple and cheap alternative to the conventional methods of pretreatment. Metal treatment rates up to 2.5 tons/min have been examined using a single unit.

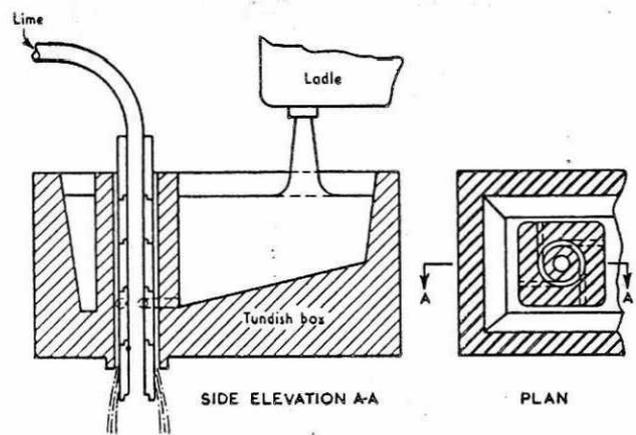
It is felt that with further development the process will accommodate higher metal treatment rates and greater degrees of refining and might well be a step along the road to a continuous steelmaking process.

THE OPERATION OF SPRAY REFINING ON A PRODUCTION SCALE

Preredfining procedure

It is assumed that steelmaking capacity of 1 m. tons/a will be required.

Hot metal would be brought to the steel plant either direct from the blast-furnaces or from the mixer in 100 ton capacity transfer ladles. Any scrap required for temperature control (up to 5% or greater depending on the composition of the liquid iron) would be added to the receiving ladles (150-200 ton capacity) before positioning under the pretreatment plant. The hot metal would be lip poured via refractory runners into the tundish; removal of blast-furnace or mixer slag would be achieved by weir arrangements as is presently done at blast-furnaces. The metal flow rate would be controlled at the desired level by the nozzle bore and head of metal in the tundish. Oxygen would be blown through the atomizing ring at a rate compatible with the required



7 Tundish arrangement, alternative to Fig. 6

amount of refining, the metal flow rate, and the composition of the hot metal.

Additions such as lime, limestone, and ore would be progressively fed by chute to the receiving ladle throughout the treatment period, as required.

After the operation, which for each 100 ton ladle would take about 20 min, the receiving ladles would be withdrawn from under the plant to a deslagging station where the ladles could be tilted by means of winches and the slag removed as completely as possible.

The preredfining metal would then be transferred to the OH plant, low in silicon and some 200 deg C hotter than normal blast-furnace metal. The whole operation should not take more than 1 h and treatments could be carried out simultaneously or in rapid succession at two units producing an OH hot metal charge of 200 tons within 1 h.

The stations would be used in rotation facilitating maintenance and preparation. A four station plant, each having two spray units in parallel and each unit operating at metal treatment rates of 5 tons/min, should be adequate. The production rate will be achieved if four preredfining operations were carried out each shift giving 8 x 100 ton ladles of preredfined iron for transfer to the OH furnaces.

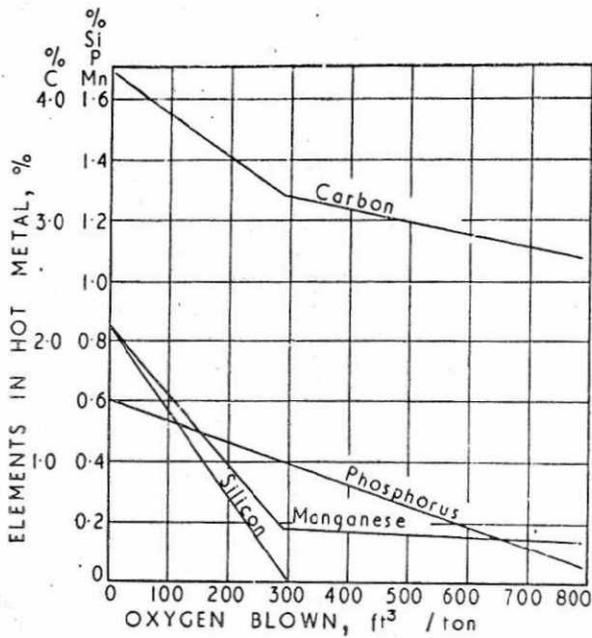
The actual spray refining of 100 tons of metal would take 20 min leaving 40 min for handling metal, ladle out, deslagging, and transfer to the furnaces. Each unit could be maintained and prepared for subsequent operation in 1 h. All that would be required would be replacement of tundishes or the cleaning of tundish nozzles of metal with oxygen and the maintenance of the refractory runners and weirs. An estimated materials balance is given in Table III.

Effect on steelmaking procedure

For an overall annual ingot capacity of 1 m. tons the weekly shop production rate for a 50 week year would be

TABLE III Spray refining materials balance

| Analysis, % | C | Mn | S | Si | P | Fe |
|-----------------------|-----|-----|-----|------|-------------------|-------|
| Hot metal : before | 4.0 | 1.0 | 1.2 | 0.05 | 0.3 | 93.45 |
| Refined metal : after | 3.0 | 0.1 | 0.1 | 0.05 | 0.3 | 96.45 |
| | | | | | <i>Fe balance</i> | |
| Blast-furnace metal : | | | | | 2 094.3 lb | |
| Scrap : | | | | | 111.0 lb | |
| Refined metal : | | | | | 2 205.3 lb | |
| Loss of Fe in slag | | | | | 2 160.5 lb | |
| | | | | | 22.4 lb | |
| Loss of Fe in fume : | | | | | 22.4 lb | |
| Yield 95% | | | | | 2 205.3 lb | |



8 Chart showing removal of metalloids during prerefining of blast-furnace metal, Brymbo steelworks

20 000 tons. With a furnace capacity of 240 ingot tons the furnace charge would be 267 tons made up of 67 tons of scrap and 200 tons of prerefined hot metal ; 20 000 ingot tons/week will be obtained from 83 heats from the 240 ton furnaces.

It is suggested that four out of five furnaces operating an 8 h cycle would be adequate. Charging the scrap and preheating would occupy 1½ h, hot metal addition 1 h, leaving 4½ h for refining and tapping and 1 h for fettling. With furnace availability of 80%, five furnaces would be adequate. At 45% CaO, slag volumes would be of the order of 7% giving a minimum of trouble from foaming and frothing, enabling oxygen to be used for refining at maximum rates with a minimum of delay before jetting could begin. A production rate of 30 tons/h tap to tap (21 heats per furnace week) should be well within the possibility of practical achievement.

Alternatively, it is suggested that without pretreatment

TABLE IV Comparison of slag volume arising from the use of (a) direct blast-furnace hot metal (b) prerefined hot metal

| Type of hot metal | Furnace charge | Lime lb/ton | Slag volume, % |
|-------------------|----------------------------|-------------|----------------|
| Basic iron % | 50% hot metal 50% scrap | 180 | 15.5 |
| C Si P S Mn | 70% hot metal 30% scrap | 220 | 19.6 |
| Prerefined iron % | 50% hot metal 50% scrap | 50 | 4.5 |
| C Si P S Mn | 70% hot metal 30% scrap | 43 | 3.8 |

In calculating the above charges, no allowance has been made for pick-up of silica from the furnace i.e. an all-basic furnace has been assumed.

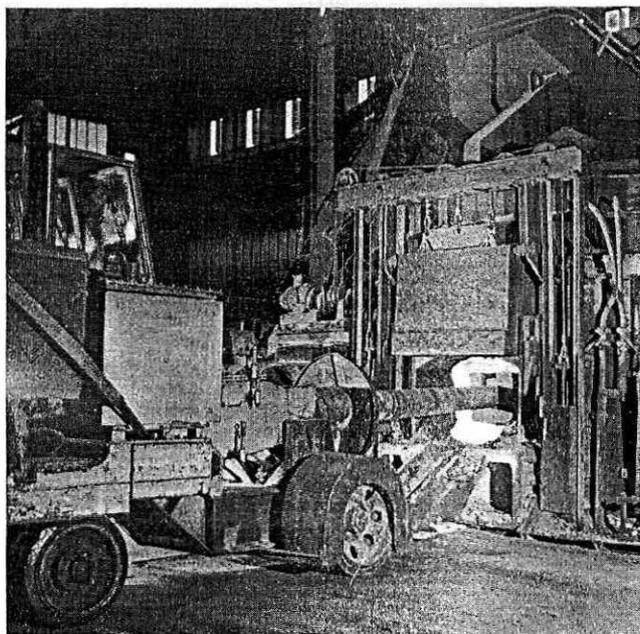
the hot metal would result in extended charging and pre-heating times as the cold charge would require preheating to a higher temperature before the cooler hot metal could be added. Further time would be required for flushing early siliceous slags before oxygen blowing could start and the maximum oxygen jetting rates would be reached later. Refining would inevitably take longer, probably resulting in tapping cycles of the order of 12 h. At 45% CaO, slag volumes would be of the order of 18%, resulting in lower overall production rates (see Table IV). In this case, the production rates would be of the order of 20 tons/h tap to tap (14 heats/furnace week) and six furnaces would be required, from a shop of eight, if availability is about 80%, or seven if availability of 85% were possible.

DEVELOPMENTS AT BRYMBO

During the early desiliconizing trials at Brymbo, it was found that comparatively small quantities of oxygen, 350-400 ft³/ton, were sufficient to reduce the silicon content from 1% and above to about 0.4%. This resulted in an increase of some 30% in the output of the fixed open-hearth furnaces. The process was carried out in 30 ton ladles and was later developed to remove not only the silicon but also the phosphorus and it became clear that,



9 Fettling the prerefiner with lime powder



10 Charging scrap into prereducer

provided a fluid slag was formed early and the reactions proceeded mainly via the slag, as in the OH process, the phosphorus could be eliminated while the carbon was retained at high levels, i.e. 2.0% and above.

It is clear that by this means the oxidation of silicon and manganese proceeds in the same order as with a bottom-blown converter, but in the case of phosphorus the reaction is quite different. As is well known with bottom blowing the removal of phosphorus from the metal does not begin until practically all of the carbon has been eliminated. Phosphorus is then oxidized during the after blow. With surface blowing it will be seen that the removal of phosphorus begins just before all the

TABLE V Typical prereduced heat

| Charge | tons | cwt |
|-------------------------|------|-----|
| Blast-furnace hot metal | 20 | 4 |
| 2% Si mill crops | 9 | 0 |
| | 29 | 4 |

Furnace log

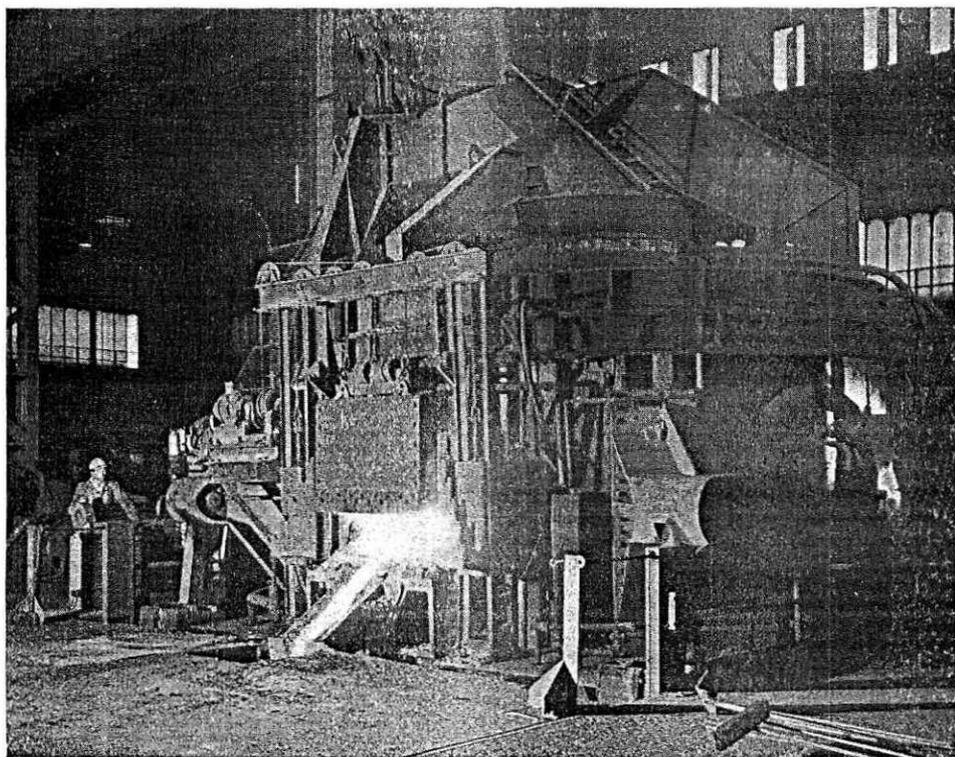
| | |
|-------------|--|
| am | |
| 10:30 | Previous heat tapped and furnace sprayed with lime powder |
| 10:40 | Scrap charged |
| 11:00 | 8 cwt lime and 3 cwt ore charged |
| 11:02 | Blast-furnace hot metal charged |
| 11:06-11:11 | 3 000 ft ³ oxygen blown with water-cooled surface lance |
| 11:08-11:25 | 18 000 ft ³ oxygen blown at 1 000-1 200 ft ³ /min with water-cooled main lance |
| 11:10-11:16 | 8 cwt powder lime dispensed |
| 11:30 | Furnace slagged |
| 11:35 | Furnace tapped |

Analysis%

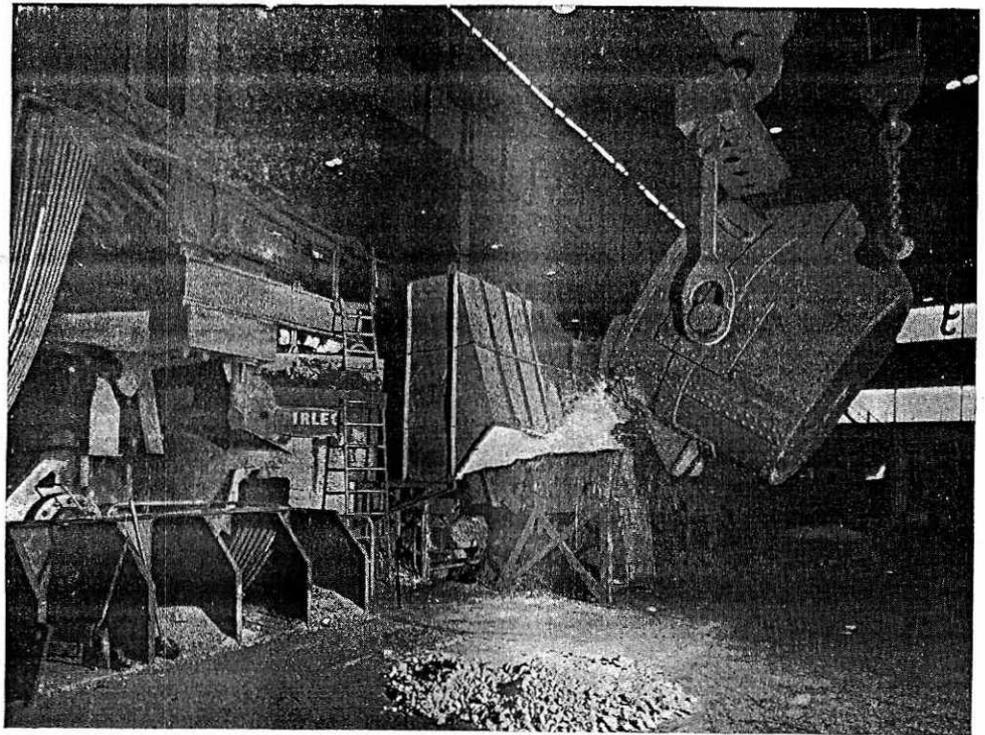
| | C | Si | Mn | S | P | Metal temp., °C |
|--------------------|------|------|------|-------|------|-----------------|
| Blast-furnace iron | 3.95 | 0.90 | 0.80 | 0.056 | 0.4 | 1 260 |
| Prereduced iron | 1.90 | Tr | 0.12 | 0.048 | 0.08 | 1 550 |

| | | | | |
|-------------------------|---------------------------------------|------|------|-------------------------------|
| Tapping slag, % | SiO ₂ | Fe | CaO | P ₂ O ₅ |
| | 17.0 | 13.0 | 40.0 | 6.5 |
| Weight of refined metal | 27 tons 3 cwt | | | |
| Yield | 93% | | | |
| Oxygen used | 780 ft ³ ton refined metal | | | |
| Scrap | 31% | | | |
| Lime | 66 lb/ton refined metal | | | |

silicon has been eliminated, and then proceeds more or less parallel with the carbon (Fig. 8). In fact, the evidence suggests and later experience has shown, that the reactions proceed via the slag as in the OH process and not by direct contact with the iron as is the case in the bottom-blown converter. On the other hand, the manganese losses depend largely on the initial manganese



11 Slagging off the prereducer



12 Charging prerefined hot metal into the 45-ton arc furnace

content of the pig iron, the slag composition, and the temperature. Effective sulphur reduction can also be achieved by lime powder injection during the oxygen blow.

As previously indicated, the desiliconizing process was carried out in ladles but when this was extended to remove both the silicon and phosphorus, a ladle was not suitable since with a silicon content of the iron greater than 0.50% foaming and slopping occur, slagging off is difficult, and the whole process is messy and undesirably long. To carry out the work satisfactorily, it was necessary to design a special furnace within which the process could be worked practically and economically.

The importance of adequate slag metal surface area was evident and it was desirable to have sufficient bath agitation without having to incorporate means for rotating the hearth. It was also important that provision should be made for fettling and burning-in, if necessary, between heats as well as the initial burning-in of the hearth. The design and operation of this furnace has been described previously^{8, 10} and only a brief description will be given.

The process is carried out in a bowl shaped vessel, the hearth of which is 16 ft dia, giving roughly 6 ft² per ton of iron and the vessel is capable of treating up to 30 ton batches of iron. The vessel rests on rockers and rollers, thus facilitating tilting to angles of 20° for slagging and 40° for tapping. The axis of tilt is so arranged that at all angles the water cooled duct for removing fume and products of combustion remain in full operation (Figs. 9-12).

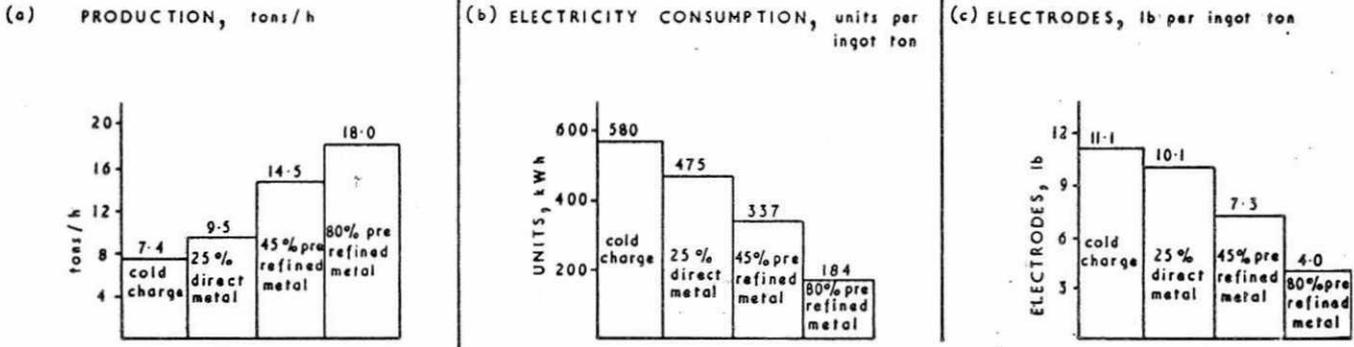
Furnace refractories

From experience gained during early trials, it was obvious that dolomite would not stand up to the high temperatures generated during immersed lancing and for the second campaign a 'Britmag' hearth was installed above the magnesite sub-hearth. The hearth and banks were well consolidated by vibratory rollers and above this a 3 in thick layer of magnesite-enriched dolomite was again consolidated by vibratory roller. The hearth and banks

were thoroughly burnt in by the use of oxy/fuel oil burners at a temperature of about 1650°C; finally the hearth and banks were slagged.

TABLE VI Prerefiner—Average materials used January–July 1962

| | % of total burden | Per ton prerefined metal | |
|--|------------------------|--------------------------------------|----------------|
| | | cwt | kg |
| Burden | | | |
| Blast-furnace hot metal | 70.2 | 15.1 | 767.1 |
| Scrap | 29.8 | 6.4 | 325.1 |
| (Average yield 93%) | 100 | 21.5 | 1092.2 |
| Oxides | | | |
| | | lb | kg |
| Ore | | 19.25 | 8.73 |
| Scale | | 0.08 | 0.03 |
| | | 19.33 | 8.76 |
| Fluxes | | | |
| Lime | | 63.12 | 28.63 |
| Limestone | | 8.69 | 3.94 |
| Fluorspar | | 0.11 | 0.05 |
| | | 71.92 | 32.62 |
| Fettling materials | | | |
| Lime powder | | 4.91 | 2.23 |
| Dolomite | | 1.60 | 0.72 |
| Coke breeze | | 0.85 | 0.38 |
| | | | |
| Oxygen | | ft ³ | m ³ |
| | | 771 | 21.7 |
| Fuel oil | | gal | l |
| | | 2.3 | 10.46 |
| Refractory consumption | | | |
| | No. of heats | Consumption per ton Prerefined metal | |
| | | lb | kg |
| Hearth (magnesite and magnesite enriched dolomite) | 6 650 (continuing) | 1.04 | 0.47 |
| Sidewalls (dolomite bricks) | 2 077 (before renewal) | 3.01 | 1.37 |
| Roofs (65% Al ₂ O ₃) | 300 | 7.76 | 3.50 |



13 Histograms showing productivity, power, and electrode consumption with varying amounts of hot metal, single slag practice

The care taken to install this lining was amply repaid as the records indicate; the hearth having completed 6 650 heats is still in operation. Tarred dolomite bricks or blocks are used for the side walls and 60-65% Al₂O₃ bricks for the roof construction. The whole installation has been highly satisfactory. A unique feature during fettling is the spraying of lime powder around the hearth, banks, and side walls immediately after tapping; this has undoubtedly contributed to the exceptionally low refractory consumption.

Oxygen injection and lime powder dispensing

In the Brymbo process, oxygen is injected into the metal through a water cooled copper lance specially designed for this process by HOAG, Germany. This lance is thermostatically controlled and lance life is excellent; up to 1 000 heats have been obtained before major repairs have been necessary. Oxygen is injected into the bath at

about 1 250-1 400 ft³/min through a 1 3/8 in nozzle and the rate of lime powder injection can be varied between 40 and 400 lb/min. This is controlled by a variable-speed motor and operated from the control desk at the melting-shop stage.

Operation of the prerefining furnace

The log sheet of a heat is given in Table V, and the procedure will be briefly described. Immediately after tapping the furnace lining is sprayed with lime powder and the scrap portion of the heat is charged by a floor charging machine. A recent development with the oxy/fuel burner has made it possible to increase the amount of scrap melted during the process to about 40% irrespective of the iron composition. As previously indicated, large pieces of pit scrap can be melted up in this way, also high silicon skulls which would otherwise be unsuitable for charging direct into the arc furnaces.

One third to one half of the amount of lime required is charged together with ore; the amount is varied according to the scrap available but a certain quantity is added to each and every heat to assist fluxing and reduce iron loss. The hot metal (20-25 tons) is then poured down a portable trough into the furnace and the furnace pressure checked. Oxygen is injected through a water cooled surface lance for a short period to form a liquid slag. The main lance is then lowered into the bath and for a short period the combined oxygen input is between 1 600 and 1 700 ft³/min. The remainder of the lime can then be added, either by charging or injection, depending on the phosphorus content of the iron and the heat completed with the immersed lance. Blowing time varies according to the requirements of the arc furnaces and averages between 15 and 20 min. A materials balance is given in Table VI.

The prerefined metal is used as 50% of the electric furnace charge and always contains sufficient carbon to ensure an adequate refining period. Table VII shows a log sheet of a typical high percentage prerefined hot metal charge.

Electric steelmaking

The prerefined metal is transferred to one of the arc furnaces within about 30 min of the scrap being charged. The timing of the hot metal addition is extremely important and it is usual to heat up the scrap just sufficiently so that the hot metal, which is at a temperature of about 1 500-1 530°C, quickly melts up the scrap. The oxygen lance can be used to speed up the melting and refining.

The effect of the varied amounts of hot metal on productivity and power and electrode consumption is shown in Figs. 13a-c.

TABLE VII High percentage hot metal heat

| | | | | | | | |
|--|--|---------|----------|----------|------|------------------|--|
| Electric furnace hot metal charge En. 45 quality | | | | | | | |
| Specification% | | | | | | | |
| C | Si | Mn | S | P | | | |
| 0.55-0.60 | 1.8-2.0 | 0.8-1.0 | 0.04 max | 0.04 max | | | |
| Charge | | | | | | | |
| Scrap | | | tons | cwt | | | |
| Prerefined metal | | | 38 | 1 | | | |
| | | | 48 | 10 | | | |
| % hot metal 78.5 | | | | | | | |
| Furnace log | | | | | | | |
| pm | | | | | | | |
| 6:05 | Previous heat tapped and furnace fettled | | | | | | |
| 6:25 | Scrap charged + lime + ore | | | | | | |
| 6:30 | Power on | | | | | | |
| 6:40 | First ladle of prerefined metal charged | | | | | | |
| 7:20 | Second ladle of prerefined metal charged | | | | | | |
| 7:45 | Clear melt | | | | | | |
| Analysis % | | | | | | | |
| Metal | | | | | | | |
| C | Mn | S | P | Slag Fe | CaO | SiO ₂ | |
| 0.94 | 0.23 | 0.055 | 0.020 | 20.6 | 44.0 | 8.0 | |
| 7 000 ft ³ oxygen at 500 ft ³ /min blow and 6 cwt lime | | | | | | | |
| 8:15 Temperature 1 580°C | | | | | | | |
| Analysis % | | | | | | | |
| Metal | | | | | | | |
| C | Mn | S | P | Slag Fe | CaO | SiO ₂ | |
| 0.56 | 0.27 | 0.041 | 0.008 | 14.7 | 49.2 | 9.2 | |
| 8:40 | Furnace tapped | | | | | | |
| Final analysis%, pit sample | | | | | | | |
| | C | Mn | S | P | Si | | |
| | 0.59 | 0.87 | 0.037 | 0.017 | 1.83 | | |
| Metallic yield 95.5% | | | | | | | |
| Consumption | | | | | | | |
| Electricity | 222 units per ingot ton | | | | | | |
| Lime (+ stone) | 84 lb per ingot ton | | | | | | |
| Oxygen | 155 ft ³ per ingot ton | | | | | | |
| Total heat time tap to tap | 2 h 35 min | | | | | | |

This development has made possible the use of blast-furnace hot metal in arc furnaces and has effected substantial savings in refractories, power and electrode consumptions.

CONCLUSIONS

After considerable experience, the operating and economical advantages of the Brymbo hot metal prerefining process have been adequately proved for the production of all classes of steel in the electric arc furnace.

The main advantages claimed are :

- (i) increased production per furnace unit
- (ii) substantial reductions in power and electrode consumption
- (iii) greatly reduced refractory consumption

- (iv) increased furnace availability
- (v) hearth and side wall refractory maintenance eased by the lime powder fettling technique
- (vi) increased flexibility of electric steelmaking process.

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