STEEL MELTING IN A PILOT PLANT SHAFT FURNACE(*)

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One of the present authors, in a paper to the Iron and Steel Institute in 1954 entitled "The Future of Steel Melting", re-introduced the idea of continuous counterflow steel melting.

In this paper it was stated that a suitable counterflow furnace, in which the heat of the waste gases from a melting chamber is used to preheat the charge in a countercurrent system, could attain thermal efficiencies of the order of 70%, compared with the maximum possible efficiency of 50% for the existing open hearth furnace.

In such a counterflow unit the temperature of the heating gases would be progressively reduced and a much lower final waste gas temperature would be attainable than is possible in the open hearth.

Further possible advantages of a counterflow system are that refractory wear due to the alternate heating and cooling which takes place in the batch process, should be reduced, heat losses from large charging doors would be eliminated, and finally, the fume in the waste gases might be reduced, as this would be collected to some extent in the charge as the gas passes through.

There are a number of possible ways in which counterflow melting units may be applied to improve steelmaking techniques, Some of them are as follows:-

(1) As a complete steelmaking unit in which a refining bath or baths would follow in the preheating zone and in which refining could be carried out batchwise or, preferably, continuously.

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As a result partly of this model work, and partly on the basis of experience gained with the experimental unit as the investigation proceeded, a large number of possible shapes were suggested from time to time.

A number of factors combined to limit the experimentation actually carried out. These were as follows:-

(a) Owing to the fact that the furnace was somewhat larger than had originally been planned, there was a factor of space limitation, and it was not possible to include all desirable features in a number of shapes tried. In some cases the final design of a particular shape was a compromise between the desired features and limitations imposed by the lack of space. Moreover the increased size of the unit rendered it more difficult and costly to dismantle and rebuild in between trials.

(b) The fuel available, towns gas of calorific value 450 B.Th.U's per cubic foot, was limited to a supply of 3,000 cu.ft. per hour.

(c) In order to obtain adequate flame temperature in the melting chamber, it was necessary to make use of preheated combustion air. This was provided by a separately gas fired air preheater. Again, owing to the increased size of the experimental unit, the air preheater available was incapable of providing the total combustion air necessary at a temperature much in excess of 400°C. In later trials this difficulty was overcome by using a small proportion of pure oxygen mixed with the combustion air for the sole purpose of simulating a condition of higher air preheat.

3. THE EXPERIMENTAL FURNACE

Refractories:

For reasons of economy, the original furnace was built throughout of first quality firebrick, and this was quickly eroded due to iron oxide attack.

In subsequent trials, both high grade silica bricks and all basic construction up to the base of the shaft, were tried.

The latter was more satisfactory.

Firing of the furnace:

Special premixing type of burners were developed for the combustion of the town's gas which was used for firing the furnace, and their operation was quite satisfactory, but with the air preheat attained (400°C maximum) a really short, intense flame was never achieved during the earlier trials.

To simulate a higher degree of air preheat, a slight oxygen enrichment of the combustion air was tried during the last 4 trials and improved results were immediately obtained.

The waste gases were extracted from the top of the shaft through a bricklined ducting, by means of an induced draught fan.

Operation of the Furnace

The furnace was always brought up to working temperature prior to the commencement of charging, since it was felt that, if the metal was charged to a hot, thoroughly soaked furnace, the risk of severe oxidation in the shaft, and the bridging of the metal which would result from this, would be greatly minimised.

Small lots of pig and scrap, sized 4" to 0 were weighed out in buckets, each lot weighing about a half or one hundredweight. The weighed pig and scrap mixture appropriate to the particular run was charged to the double bell arrangement at the top of the preheating shaft. The charging rate was adjusted to maintain the stockline at the required level. The stockline height was determined by inserting a rod through four holes arranged around the top of the shaft and noting the depth to which the rod could be inserted. As the metal at the base of the shaft was melted, the bath gradually filled up was generally necessary to tap it at roughly hourly intervals.

The procedure on tapping was to chip away as much as possible of the plug filling the tap hole by means of a crowbar, and then to finish the operation of opening up with an oxygen lance. The metal was teemed into a pan standing on a bogey running on rails in a casting pit in front of the furnace.

After tapping, the taphole was made up with a mixture of anthracite and dolomite. Steel hooks were inserted in the molten metal in the pan to facilitate lifting. After a suitable period for cooling, the full pan was lifted off the bogey and replaced by an empty one, the ingots then being weighed and transported for storage on a separate bogey.

Experimental data collected.

Details of materials charged and tapped, together with temperature measurements, fuel and air rates, waste gas analyses and furnace pressures were recorded.

RESULTS OF FURNACE TRIALS

Running conditions

It was found possible to split the 21 trials here discussed into 64 periods on a basis of the running conditions encountered and the type of charge melted. Running conditions were defined as "running well", "running fairly well", "running poorly" or "running very poorly", depending upon the ease with which the charged material flowed down the shaft and into the forehearth. The first two categories were considered satisfactory.

The factors which affected the running conditions were considered to be as follows :-

a) The height of the stock column.

b) The nature of the charge (i.e. percentage scrap in the mixture).

c) The furnace shape.

d) The hearth temperature.

e) The thermal input to the furnace and combustion conditions.

The latter two items were not completely independent. The running conditions obtained with five of the shapes tried, and for various charge compositions are shown in Table 1. The following points emerged:-

i. Of the 64 periods included in the table, 44 of them gave satisfactory running conditions. Of the 10 periods in which 100% pig iron was charged, satisfactory running conditions were obtained in seven periods. It should perhaps be pointed out in this connection that most of the runs were started on 100% pig iron, and almost no trouble was experienced. The two periods of very poor running obtained for 100% pig iron in the case of shape 'C' were due to the fact that lime was being charged with the pig to the shaft and this caused immediate blockage.

TABLE I

	Shape C					Shape D_1					Shape E_1					Shape E_2					Shape D_2					Overall				
	Well	F.Well	Poor	V.Poor	Total	Well	F.Well	Poor	V.Poor	Total	Well	F.Well	Poor	V.Poor	Total	Well	F.Well	Poor	V.Poor	Total	Well	F.Well	Poor	V.Poor	Total	Well	F.Well	Poor	V.Poor	Total
100% Pig Iron	3	2	1	2	8	1	-	-	-	1	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	5	2	1	2	10
80% Pig+ 20% Scrap	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	2	1	1	-	-	2
75% Pig +25% Scrap	1	-	-	-	1	3	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	4
50% Pig +50% Scrap	-	1	-	1	2	1	4	-	1	6	3	2	3	1	9	-	-	-	2	2	9	7	3	2	21	13	14	6	7	40
25% Pig +75% Scrap	-	-	-	-	-	-	3	-	2	5	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	4	-	2	6
20% Pig +80% Scrap	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	1	1
100% Scrap	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
TOTALS	4	3	1	3	11	5	7	-	3	15	3	3	3	2	11	1	-	-	2	3	10	8	3	3	24	22	21	7	13	64

The single run with relatively poor running conditions may be ascribed to lack of temperature in the forehearth. Generally, there was no difficulty at all in maintaining a flow of 100% pig and one would conclude that a full scale furnace for a continuous counterflow melting of pig iron would present no difficulty in full scale operation.

ii. There were 40 periods during which a mixture of 50% pig iron and 50% scrap was charged, and 27 of these produced satisfactory running conditions.

iii. The furnace ran satisfactorily during all the 6 periods in which the charge consisted of between 50 and 100% pig iron.

iv. There were 8 periods during which the furnace charge contained more than 50% scrap, and for 4 of these the running conditions were satisfactory.

v Within the very narrow range of stock heights employed (70 to 80 inches generally), this did not appear to affect running conditions (by stock height is meant the actual height of the column of metal in the shaft measured along the centre line).

vi As the percentage of the scrap in the charge increased, the running conditions became worse.

vii As the percentage of scrap in the charge was raised to 50%, the hearth temperature required for good running conditions increased.

Thermal efficiency

Apparent thermal efficiencies throughout the trials were in the region of 40%, although on several short periods with 100% pig iron efficiencies of 60% to 70% were achieved.

Analysis of the product

It became apparent that the furnace was capable of producing a high carbon melt (greater than 1%) with a pig iron content of 50% or more of the charge. Considerable dephosphorisation was carried out by adding controlled quantities of lime to the bath.

Metallic Yield

Metallic yields were determined on occasions by cleaning the ingots of slag at the end of a trial and reweighing.

The figures obtained applied to trials as a whole, including periods of poor running and emptying when the oxidation rate was more severe. They ranged from 89 to 92%, suggesting that during good running conditions, eminently satisfactory metallic yields were obtained.

Refractories

The furnace construction was eventually such that the refractories performed satisfactorily, and trials of 100 hours or more duration were carried out without severe refractory wear. It was found relatively easy to fettle the banks of the melting chamber when this became necessary.

CONCLUSIONS

1. It was shown to be extremely easy to melt charges of 100% pig iron in a shaft furnace with very little oxidation of the charge and no serious bridging.

2. It was also shown to be possible to melt pig iron and scrap mixtures in a counterflow shaft furnace, although indications were that as the percentage of scrap in the charge increased, so did the problems of bridging and oxidation.

3. During the trials only one basic shape of furnace was tried, so that it was not found possible to predict the best design for a counterflow unit.

4. The thermal efficiencies obtained in the experimental unit were most encouraging and suggest that efficiencies in a production unit of the order predicted by Thring (that is 70%, Ref. 1) should be attainable.

5. It was shown that melts of varying carbon content could be attained depending on the type of charge to the furnace, and the furnace conditions prevailing. Dephosphorisation was also carried out. Insufficient attention was devoted to the factors controlling the analysis of the melt to enable these to be elucidated fully.

6. The refractory difficulties existing in the experimental furnace were overcome to a large extent, but the indications were that in a production unit of a shape similar to that used in the trials, it would be necessary to overcome the problem of refractory wear in the region of the throat.