THE RELATIONSHIP OF PILOT PLANTS TO FULL SCALE OPERATION (*)

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The authors' chief interest in pilot plants is as a means of practical instruction. At the Banaras Hindu University a number of pilot plants have been installed so as to impart some practical idea of metallurgical processes to final year students. These pilot plants include a sintering plant, several small size cupolas, an L.D converter, a basic lined side-blown converter, indirect arc furnace and high frequency electric furnaces. The latest addition to this range of pilot plants is a small scale Edwards vacuum melting unit.

In addition to their use for instructional purposes, it is hoped, as candidates present themselves, that these plants will be more fully employed in post-graduate research, which it is felt will be of considerable importance to the development of the iron and steel industry in India. Post-graduate research, which it is felt will be of considerable importance to the development of the iron and steel industry in India. Post-graduate work of this nature must play an important role in the provision of thoroughly trained personnel for the rapidly growing industry in India.

Both these applications of pilot plants, however, demand a careful consideration of the relationship between the results obtained thereon and the results which may be anticipated in full scale operation. The reduction of plant size frequently necessitates a corresponding reduction of particle size, which may seriously affect such physical properties as porosity, specific gravity and reducticibility. In thermal processes the small quantity of metal handled may aggravate thermal losses due to radiation and conduction, whereby time factors are of vital importance.

The results obtained on pilot sintering plants would appear to bear a reasonable relationship to those which can be anticipated on a full scale plant, except that the smaller surface area should assist more uniform and immediate ignition. Since the ratio of cross-sectional area to periphery is lower in pilot plants as compared with full scale plants, one might anticipate a greater amount of fused material as a result of less resistance to the travel of the sintering zone around the periphery. It would appear

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however, that in small scale plants the sides of the pan has frequently a chilling effect, which tends to increase the percentage of returned fines. In general, as found by Voice, Lang & Gledhill, there is reasonably good correlation between the results obtained on pilot plants and those obtained in full scale operation.

Ridgion, Cohen & Lang demonstrate that both heamatite and magnetite concentrates can be successfully pelletized on a pilot plant scale, but they do point out that the translation of the process to a commercial scale may introduce problems peculiar to larger units.

Much of our existing knowledge concerning distribution of stock in the blast furnace has been derived from experiments on small scale models, with especial reference to the work of Saunders & Wild, Wild and Diamond. It must be remembered, however, that this work on small scale models does necessitate a corresponding reduction of particle size, which may seriously affect the specific gravity of the materials employed, thereby affecting the type of distribution obtained. In recent experiments at Banaras it was found that the bulk density of the coke as it would be charged into the blast furnace was 28lbs. per cu. ft., but when this material was reduced to ¼" to correspond to the size of the pilot plant, the bulk density was increased to 34 lbs. per cu. ft., thereby altering its relationship to the bulk density of the iron ore and limestone used in the experiments. This feature would lend to give a completely different distribution pattern.

Tesch & Hahnel suggest that unfortunately much of the work on distribution in the blast furnace may not reflect the actual conditions which exist, especially since the models employed have sometimes been too small, and due consideration has not been given to the upwards flow of gases. In small scale work of this nature it is difficult to assess the effect of chemical transformation of the gases, reduction of the oxides, the thermal changes and similar factors. Perhaps, however, these items are not so vitally important in such studies, since the fundamental purpose of these studies is to ascertain the distribution of the stock in the upper part of the furnace as a guide to its possible distribution in the reduction and smelting zones of the furnace. It is interesting to note, however, that the apparatus employed by these two investigators to study distribution in the blast furnace consisted of a receiver representing the top of a blast furnace, which was 4' 3" in diameter with an effective height of 5' 7". The bottom of this receiver was perforated to allow the passage of blast from an air box located beneath.

The difficulties of investigating thermal processes in pilot plants is demonstrated by the work of Sims & Toy. In their experiments, using a 1000 lbs. capacity side-blown basic-lined converter, they did demonstrate that steel could be produced by surface blowing basic pig iron with a blast of air. It was, however, necessary to preheat the hearth or converter to 1540°C owing to the heat losses associated with such a small unit.

In this pilot plant, which was in fact a small side-blown converter, they demonstrated the possibility of converting basic pig iron containing:

C	Si.	S.	P.	Mn.
3.95	1.10	0.035	0.31	1.95

into blown metal containing:-

C	Si.	S.	P.	Mn.
0.05	under 0.01	0.015/ 0.027	0.015/ 0.035	0.06/0.8

in the course of this refining, the elimination of impurities resulted in a temperature increase of 200°C (1450°C being the Hot metal temperature and 1650°C being the temperature of the blow metal) at the same time the temperature of the hearth or converter had been increased 110°C from its initial temperature of 1540°C.

This work is of particular interest since it did demonstrate that the conversion of basic pig iron, containing approximately P 0.30%, can be converted into high quality steel in a basic-lined side-blown converter. Commercial scale trials, using 25 to 30 tons of hot metal, corraborated the findings of this experimental work. Fifteen heats of 25/30 tons capacity were made in a converter lined with magnesite and two typical results are shown in Table 1.

TABLE - 1.

Example	C.	Si.	S.	P.	Mn.
1. Hot metal	4.39	0.96	0.031	0.223	2.08
blown - metal	0.015	0.003	0.019	0.008	0.037
2. Hot metal	4.46	0.70	0.039	0.214	1.58
Ladle sample (rimming steel)	0.05	0.005	0.013	0.020	0.38

Similar results have been obtained at the Banaras Hindu University employing small scale L-D and basic-lined, side-blown converters. It has been shown that the relative rates of carbon and phosphorus removal depends on slag conditions and the pressure of blast or oxygen impingement. Not only is it possible to produce high grade steel by these methods, but it is also possible to dephosphorise ordinary Indian pig iron and by suitable alloy additions to produce a low phosphorus pig iron, which can be beneficial employed in the manufacture of ingot moulds, rolls and similar applications.

A survey of pilot plant work does appear to stress the importance of due consideration being given to plant size when anticipating the possible translation of such results to full scale operation. In some cases the lack of precise control associated with large commercial units aggravate the translation, whereas in other cases the larger bulk of metal being handled, thereby reducing thermal losses, may simplify such translation. Perhaps the best capacity for a pilot plant is the smallest unit which can be operated commercially. It is also suggested that some of these commercial size pilot plants could, in the present state of Indian economy, be successfully employed on a commercial basis.

Although some large capacity, integrated iron and steel plants are essential to national economy, there is also opportunities in certain localities for the adoption of smaller, less-mechanised units. The installation of this type of plant would offer the following advantages:-

(1) The conservation of foreign currency.

(2) The provision of employment for a larger labour force.

(3) The utilisation of lower grade raw materials.

(4) The provision of a media for training:-

(a) engineers in the design and construction of iron and steel works plant and equipment, which should also fit them for the better operation and maintenance of such plants.

(b) metallurgists and operatives in the basic art and science of iron and steel manufacture, and its subsequent mechanical treatment.

Small Scale Commercial Plants:

The authors suggest that these plants should have an annual capacity of 140,000 tons of pig iron, produced in hand-charged blast furnace, having hearth diameters of 10'0". The design of such furnaces is based on similar furnaces which were employed in Staffordshire, U.K. until comparatively recently for the production of high grade and special pig iron from relatively low grade raw materials. The reduction in mechanisation would reduce the capital cost of these furnaces, but would entail a higher labour cost, which is not a serious feature in the present state of Indian economy.

These furnaces have a bosh diameter of 14'0 and a height of 60'0", which would permit the employment of a lower grade raw material. Furnaces of this design might be of particular interest in districts where lignite coke is available, or where a limited amount of imported coking-coal can be blended with local non-coking coals, such as Southern India, Rajasthan and certain parts of Madhya Pradesh. This wider dispersion of the industry possesses obvious national advantages.

A blast furnace of this capacity should be capable, operating on hot blast, of producing 200 tons per day, and the ideal unit would be two furnaces with a combined annual capacity of 140,000 tons. This hot metal would be stored in drum type metal mixers for subsequent conversion into steel in basic-lined, side-blown converters.

Harrison, Newell & Hartley have demonstrated the high rates of productivity and the high quality of steel which can be obtained in the acid-lined side-blown converter operating with oxygen enriched blast. At the conclusion of this paper they forecast that this practice will find increasing application for bulk ingot-steel production. One limitation of the process which they describe, however, is its inability to refine phosphoric pig iron, but Sims & Toy have shown that this difficulty can be overcome by the employment of a basic lining. This fact has been confirmed by pilot plant work at Banaras Hindu University.

One great advantage of the side-blown converter, as shown by Fassotte, is the fact that most of the carbon is burnt to carbon dioxide, whereby the maximum heat from the elimination of that element is achieved. As compared with the L-D converter, the Kaldo converter or the Rotor furnace, the side-blown converter offers the additional advantage of the more ready adjustment at the angle of blast impingement and the thickness of the slag, both factors affecting the relative rates of carbon and phosphorus elimination. A low pressure of impingement and a thick slag covering favours the elimination of phosphorus; whilst a higher blast pressure and a thinner slag covering, which can be readily obtained by rotating the converter to an angle of 45° from the vertical, accelerates decarburisation.

The capacity of the converter is 10/15 tons, which with a blowing time of 30 minutes per heat, should give a productivity rate of 15 tons/ converter/ hour. It follows that two converters operating a five-day week at an availability of only 70% would produce:-

$$15 \times 24 \times 5 \times 2 \times 0.70 = 2,520 \text{ tons per week.}$$

They would, therefore, be able to consume the output of pig iron from the two 10'0" diameter, hand-charged blast furnaces recommended.

The overall capacity of the plant has been influenced by the anticipated consumption of oxygen, which it will be noted would be accomodated by an oxygen plant capable of producing 50 tons per day.

It is further recommended that the steel should either be cast into 6" to 9" square ingots for subsequent treatment in a 28" rolling mill, or continuously cast into 9" square billets in a continuous casting machine which is similar to the machine in commercial production at Cail in France. In both cases the product of the first stage would be further rolled in smaller mills according to the local market requirements.

It is estimated that the capital cost of a plant of this type per ton of annual output would be about 60% of the capital cost of a more conventional and more highly mechanised plant per ton of annual output. It is not suggested that this type of plant should completely replace the more mechanised and large integrated iron and steel works, but it is considered that plants of this type and capacity would be of national benefit in certain districts as a means of utilising lower grade, local raw materials and meeting local demands for iron and steel, thereby saving transport costs. They would also provide an excellent media for the training of iron and steel works personnel.

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