Increasing the capacity of open-hearth plants by the use of oxygen: technical and financial considerations of various methods

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INTRODUCTION

THE GREAT MAJORITY of the steel produced in the world is steel made in open-hearth furnaces, and because of the immense amount of capital invested in these plants, there can be no question of scrapping many of them for some time to come. For this reason great interest has been focused in the last few years on the problem of increasing output from existing OH plants by the use of oxygen.

The object of this paper is to examine some methods of achieving this, (section 1), and to compare the cost of applying O_2 direct to the OH furnaces with the cost of changing over to one of the pneumatic processes for the increased output required, (section 2). For the purposes of this paper, the authors have taken as an example a plant of 1 m. tons capacity which it is desired to increase to 1·5 m. tons.

SECTION 1

Assumed conditions of the imaginary plant

Steel plant

An annual output of 1×10^6 tons would be met by 7 OH furnaces each of 200 tons capacity, each furnace having a silica roof and a waste heat boiler. The general range of steel quality would be that of mild and structural steels. The 80 : 20% hot metal/scrap ratio of the charge would be met by an iron plant output of about 850 000 tons/a and the consumption of internal scrap; analysis of hot metal: 3·5%C, 0·3%P, 0·5–1% Si.

The open-hearth plant would be served by two drum-type inactive metal mixers each of 1 000 tons capacity.

Fuel and energy

The OH furnaces would be fired with both coke-oven gas and creosote pitch in the ratio of 70% : 30% respectively. 20% of the plant electrical power would be generated internally and the remaining 80% would come from an external supply.

General plant

It is assumed that all plant and machinery serving the OH furnaces, i.e. (*a*) scrap handling and charging; (*b*) furnace and ladle additions; (*c*) slag handling; (*d*) ladle maintenance; (*e*) transport could be increased in capacity to meet the faster demands of a 50% increase in production. The effect of these increases on the cost comparison will be discussed in section 2.

Ingot stripping, mould preparation, and soaking pits would be separate from the steelmaking plant and situated so that they could be extended to meet a production increase. This equipment will be considered as being common to all techniques chosen for comparison and their costs, for increased capacity, will be ignored.

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SYNOPSIS

The object of this paper is to examine some methods of increasing by 50% the output from an existing open-hearth plant of 1 m. tons annual capacity and to compare the cost of applying oxygen direct to the OH furnaces with the cost of integrating two LD vessels into the OH shop. A further comparison is made to the cost of a separate LD plant of ½ m. tons capacity. SR78M

Available techniques

Direct application of O_2 to the OH furnaces

This is the simplest method of achieving the desired increase in output, and if operated efficiently, can be very rewarding. It must be stressed, however, that there is nothing to be gained by using O_2 to boost the output of a furnace which is not being worked at its maximum capacity with straight fuel firing. This can only lead to increased operating costs because of the inherent thermal inefficiency of the OH process. There is no doubt that because of its low cost this method of increasing output must be the basis with which others are to be compared. As a matter of interest, it might be mentioned here that the thermal efficiency of the 'Ajax' oxygen OH furnaces at Appleby-Frodingham, England, is as high as 75% compared with the average 55% for normal fuel fired furnaces. Whilst this result was achieved by making more extensive modifications to the furnace than are suggested in this paper, it is indicative of the possibilities of the method.

Pneumatic processes

For the conditions assumed there can be no doubt that it is unnecessary to look beyond the LD process, as it has the advantages over the other pneumatic processes of lower cost, greater rate of output, and great flexibility. With the developments which have taken place within the last two years, what were regarded as the limitations of the LD process are rapidly disappearing.

The methods of adding the LD process to an existing OH plant, are very numerous and the best solution will be different for each plant. We have decided to consider: (*a*) the insertion of two LD converters into the existing open-hearth building; (*b*) the construction of a separate two-vessel LD plant on a 'green field' site.

In the case of (*a*) it can be assumed that the converters must be placed next to the mixers, and in some shops this may involve knocking down one, or even two, of the OH furnaces. This would mean increasing the size of the converters to compensate for the loss of OH tonnage. It will be obvious that there are a number of combinations that would produce the 50% additional tonnage required but we have assumed that there will either be room for two converters alongside the mixers or that only one OH furnace will have to be demolished.

Prerefining

Whilst this method is not considered in detail in the paper, there is a possibility that developments which are taking place in the UK may lead to a process which could be a serious competitor with the application of O_2 direct to the OH furnaces.

Details of chosen methods

CASE 1

Technical data : existing OH furnaces

Capacity	200 tons
Production rate	20 tons/h
Fuel consumption	35 therms/ton
Fuel	70% coke oven gas 30% creosote pitch
O_2 consumption	nil
Charge	80% hot metal 20% scrap
Bath area	750 ft²
Contour	Conventional sloping back wall with a venturi port end, twin uptakes and burner dog house. Arched silica roof.

Technical data : oxygenated OH furnaces

Capacity	200 tons
Production rate	30 tons/h
Fuel consumption	20 therms/ton
Fuel	50% coke oven gas 50% creosote pitch
Charge	80% hot metal 20% scrap
O_2 consumption	850% ft³/ton

Modifications to existing furnaces to accommodate the application of oxygen

Each furnace would be altered as follows :

(i) the silica roof would be replaced by a suspended basic roof. To allow for a larger reaction volume and to reduce the refractory wear on the roof, its height above sill level would be increased as much as possible within the limitations imposed by crane gantries, etc.

(ii) to allow for a deeper slag layer the bottom of the bath would be lowered 6in

(iii) the venturi port end would be discarded and a 'straight-through' contour adopted

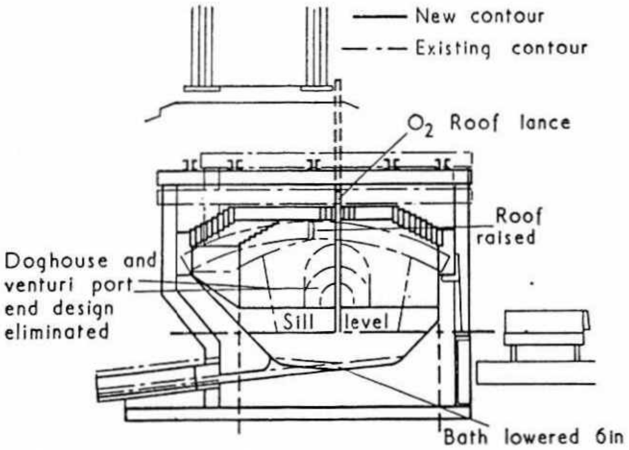
(iv) the area of the uptake would be reduced to compensate for the alteration in the furnace pressure conditions which has been produced by the redesigned furnace contour, the removal of the burner dog house, and the reduction in the maximum waste gas flow.

Further modifications

The regenerators would be rebricked to give larger openings, 12in minimum, to reduce fouling and wear rates caused by the heavy oxide dust load of the waste gases during oxygen blowing. The existing burners would be replaced by new burners incorporating oxygen enrichment. The refining oxygen will be supplied through two roof lances, one on each side of the centre line of the furnace.

Figure 1 shows the alteration which would be made to the shape of the existing furnace and indicates the roof oxygen lance in the refining position between 4in and 6in from the slag level. When not in use, the roof lance would be held 18–24in inside the furnace.

Since the lance nozzle would have an operating life of 50–150 h an adequate replacement service has to be organized. The controls for the lance position, water cooling, and oxygen supply would be fully integrated with existing services and instrumentation.



1 *Typical cross-section through modified OH furnace*

CASE 2

Technical data : LD plant integrated with OH

Capacity	Two 50 ton vessels ; one working and one being relined
Production rate	67 tons/h, i.e. 45 min heat time
Charge	80% hot metal, 20% scrap
Oxygen consumption	1 800 ft³/ton.

LD vessel services

Hot metal from the mixer plant would be charged by crane. 10 tons of scrap (20% charge) does not, in the authors' view, justify the expense of a special machine and would be charged by chute from the charging crane. Each vessel would have a set of additions storage bunkers, each bunker feeding its own weigh hopper discharging directly into an additions chute which is part of the converter hood.

LD vessel equipment

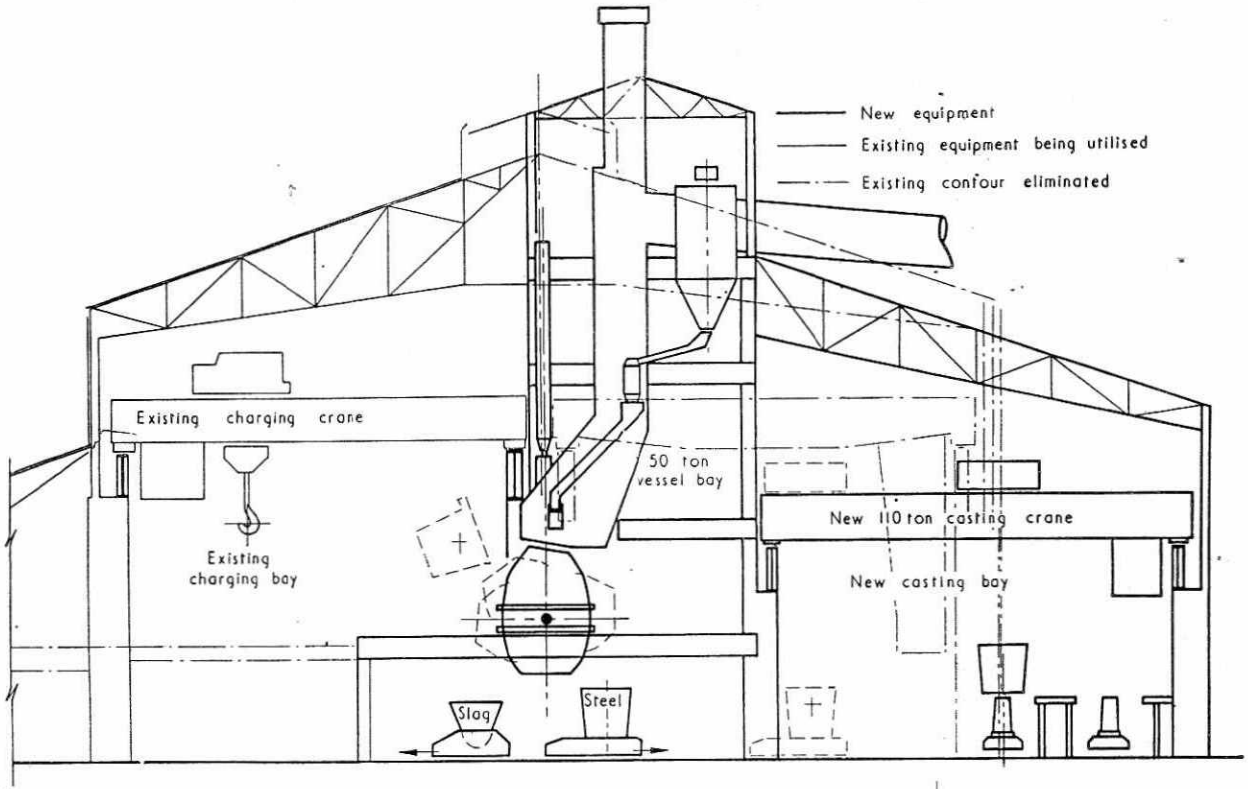
A spare lance with all ancillary handling equipment would be included. The special water-cooling requirements of the lance and fume hood would be met by a new water circulation and cooling system.

Facilities would be supplied to enable the vessel requiring relining to be put back into service 3½ days after the last tap, it being assumed that all the lining bricks would be purchased from an external supply. Each of the two vessels would have its own tilting gear and control cabins. Figure 2 shows a typical cross-section through an LD plant of this type and shows the relationship between the new plant, new handling equipment, and the existing facilities.

The teeming bay would have one casting crane of 100 tons capacity. Facilities would be planned to enable the LD steel casting ladles to be transferred to the OH teeming bay, in the event of a casting crane failure. Slag would be poured into bogie mounted slag bowls which would be transferred to the existing handling system.

Extent of integration with the OH plant

Figure 3 shows the two vessels located between the inactive mixers and the first of the OH furnaces. It will be noticed that the LD vessels have been integrated without the need to remove any existing furnaces. Costs will



2 *Typical cross-section through an integrated 50-ton LD vessel bay*

later be given should an existing furnace have to be demolished.

The LD plant has been designed so as to reduce the structural alterations to the existing shop to a minimum. The charging bay and cranes represent the only facility common to both processes. The existing casting bay and OH teeming facilities, in this area, have to be sacrificed.

Smaller ladle capacities and the more regular production cycle of the LD make it desirable to have separate teeming facilities from those of the OH. It is assumed that it would be possible to replan the existing OH teeming facilities so as to maintain the present output with the reduced area available.

CASE 3

Separate LD plant

The equipment and layout for the separate LD would be similar to that for the integrated example except for the addition of the following: (*a*) scrap handling bay; (*b*) slag bowl handling bay.

The capital costs for this plant will include a new charging bay, as this is an existing facility in the integrated example.

Comparison of oxygen plant capacities

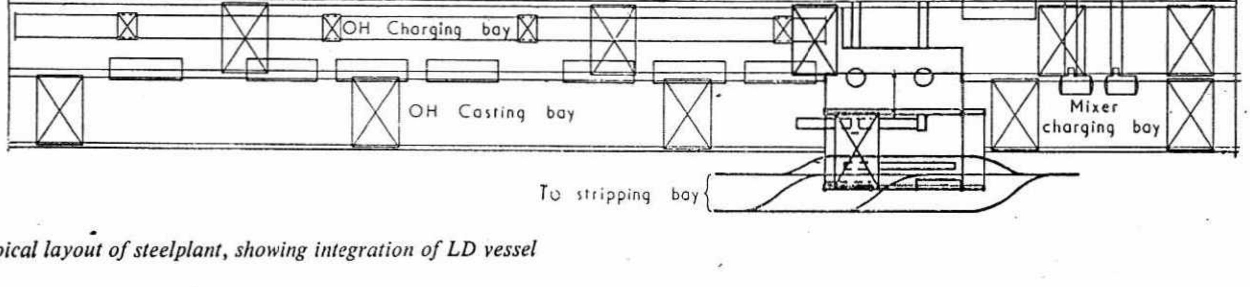
Oxygenated OH furnace plant

A daily consumption of $4{\cdot}1 \times 10^6$ nft^3/h of oxygen, with a mean flow of 171 000 nft^3/h indicates an oxygen plant of 200 tons/d capacity. After allowing about 10% for losses, etc. the remaining 4·5% would be general purpose oxygen. The amount of storage capacity provided would be based on the difference between the peak usage and the mean flow rate coupled with the frequency and duration of these demands. The capital cost of these facilities would represent only 6% of the total cost of this plant.

LD plant

A mean oxygen flow, throughout a day, of 117 000 nft^3/h allowing 10% for losses and about 4·5% for general purpose oxygen, would indicate a plant capacity of 135 tons/d. The storage facilities again represent about 6% of the total cost of the oxygen plant.

The capacities of 200 and 135 tons/d have been chosen to give a direct comparison between the different techniques. It is probable that the actual size of the plant



3 *Typical layout of steelplant, showing integration of LD vessel*

TABLE I Capital cost comparison of alternative arrangements

CASE 1
Oxygenated OH

Furnace conversion	Cost/furnace		£
O_2 lances, burners and equipment	16 700		
Oxygen pressure control equipment	1 400		
Steelwork—demolition and construction	55 000		
7 furnaces @	73 100	=	511 700
Precipitators and equipment 2 @	215 000	=	430 000
Oxygen plant, 200 tons/d		=	680 000
Charging crane, Casting crane, Charging machine			330 000
Charging equipment			50 000
Miscellaneous			40 000
Total cost			£2 041 700

CASE 2
Integrated LD plant

	£
Buildings, Civil work	370 000
Converters and equipment, Materials handling, Fume hood and precipitator plant, Miscellaneous equipment	1 040 000
Electrics	400 000
Oxygen plant 135 tons/d	550 000
Charging crane, Casting crane, Transfer cars (casting ladle)	260 000
Total cost	£2 620 000
Additional cost	
To remove one OH furnace	£45 000

CASE 3
Separate LD plant

	£
Buildings, Civil work	1 100 000
Converters and equipment, Materials handling, Fume hood and precipitator plant, Miscellaneous equipment	1 040 000
Oxygen plant 135 tons/d	550 000
Cranes and machines	600 000
Electrics	400 000
Total cost	£3 690 000

installed would be larger to provide oxygen for other uses. This consideration does not affect the present comparisons.

Comparison of waste gas treatment

Oxygenated OH furnace plant

The waste gases would pass through the existing boilers prior to a new precipitator fume cleaning plant. The seven furnaces would be served by two precipitator units each handling the waste gases from 3 working furnaces.

The reduction in the maximum flow of the waste gases from the furnace chamber and a reduction in the air infiltration throughout the system, achieved by paying attention in design to plating and sealing, would affect the efficiency of the existing boilers. It will be assumed to affect the steam make only, which would be compensated by a reduced demand.

LD plant

The gases from the converter mouth would pass through a water cooled hood, with blow-off stack, and then to a precipitator fume cleaning plant. A boiler is not included as it is assumed that the works would not require the additional steam.

Many alternative systems for gas cleaning, both wet and dry, have their particular attractions. If the waste gases could be handled without inducing air to burn the CO to CO_2, then the capacity of the fume cleaning plant would be much smaller. Several systems of this type are being developed at the present time.

SECTION 2

Capital cost comparison

To present as precise a comparison as possible the authors have chosen to consider some of the costs involved throughout the works as being common to the three chosen examples. These are as follows :

(i) increase in iron plant, soaking pit, rolling mill, and mixer capacity
(ii) increase in raw materials, and scrap storage and supply systems
(iii) additional ladles, slag bowls, ingot moulds, mould cars, and bottom plates
(iv) increase in stripping bay capacity and slag handling and processing plant.

If these costs are ignored, by virtue of being dependent upon the increase in production however achieved, the costs shown in Table I relate strictly to the chosen methods of increasing production.

Operating costs

Although the purpose of this paper is to present comparisons of equipment and capital costs, the relative operating costs must be taken into consideration before a decision as to which method of increasing capacity is best suited to any particular plant.

Some important factors are :

(i) the effect of pneumatic processes on the energy balance throughout the steelworks*
(ii) the introduction of oxygen to the steelmaking technique always presents problems of waste gas cleaning and dust handling
(iii) the introduction of new equipment will undoubtedly mean an increase in labour force, but the manpower/ton of steel produced should drop
(iv) the reduction in refractory consumption of LD as compared with OH.

CONCLUSIONS

Judged in terms of capital cost, the oxygenating of the OH furnaces is the most attractive method of achieving the aim of increasing capacity by 50%. Coupled with this it has other attractions such as (*a*) it can be introduced gradually ; (*b*) its introduction need not interfere with production.

The capital cost of the integrated LD plant is only 26% higher than the oxygenating of the OH furnaces, because it is possible to make use of much of the existing equipment.

In some cases it may be possible that the reduced operating costs of the LD plant may justify the additional capital cost.

The separate LD plant with its cost about 70% greater than that of the first method would appear to be financially unattractive, unless the existing equipment is fairly old. In this case it might be possible to formulate a sound argument for building a new shop as a start to a complete changeover to the new process.

*'The effect of the various steelmaking processes on the energy balances of integrated iron and steelworks', *ISI Spec. Rep. no. 71* ; 1962, London, The Iron and Steel Institute.