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THE SUBMERGED INJECTION PROCESS FOR IMPROVED PRODUCTIVITY IN OPEN-HEARTH FURNACES[1]

by

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RESUME

LA TECHNIQUE D'INJECTION PAR TUYERE IMMERGEE ET L'AMELIORATION DU RENDEMENT DES FOURS MARTIN[1]

par
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L'auteur de cette étude décrit la technique d'injection par tuyère immergée (SIP) qui a été mise au point par la Sydney Steel Corporation (Canada) pour améliorer le rendement des fours Martin. Cette technique repose sur l'emploi de la tuyère Maxhütte (utilisée pour l'injection d'oxygène et de chaux par le fond de la cornue dans les procédés "OBM" et "Q-BOP") qui est insérée dans la paroi arrière du four Martin, au-dessous du niveau du métal en fusion.

Les essais effectués par la Sydney Steel (essais qui ont été interrompus en raison d'un approvisionnement insuffisant en oxygène et en azote et du manque d'équipement pour l'injection de chaux) ont montré que la désulfuration est excellente et que l'on peut obtenir un métal ayant une très faible teneur en carbone. La mise en oeuvre de cette technique exige des investissements peu importants et peut être appliquée à des fours Martin de n'importe quelle capacité.

La mise au point du procédé se poursuivra lorsque l'équipement d'injection de chaux sera arrivé. Les résultats de la première série d'essais sont présentés sous forme de tableau.

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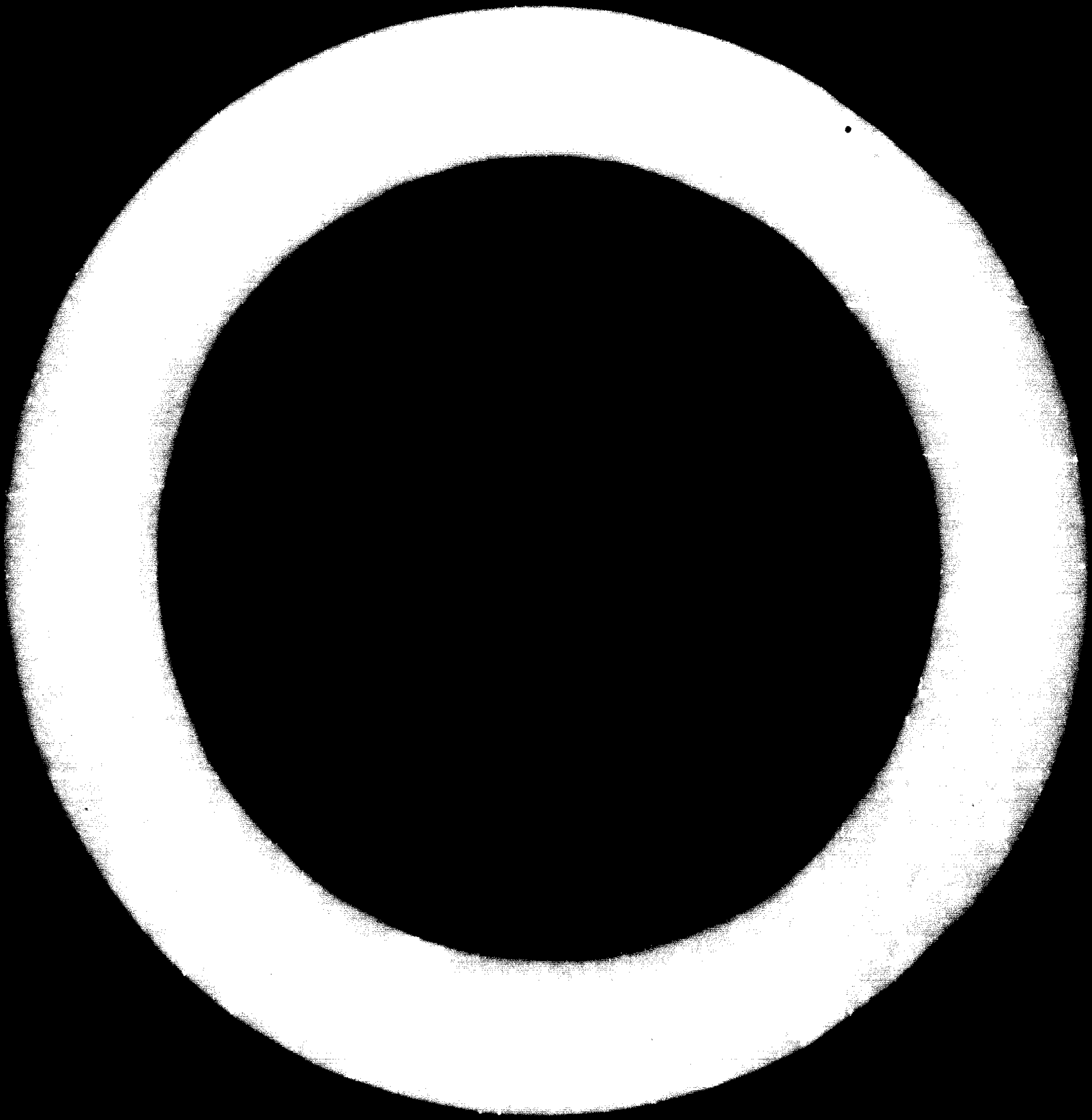
[1] Les opinions exprimées dans le présent document sont celles de l'auteur et ne reflètent pas nécessairement les vues du Secrétariat de l'ONUDI.



SUMMARY

The paper describes the submerged injection process (SIP), developed at Sydney Steel Corporation, Canada, for increasing the productivity of open-hearth furnaces. The process involves the use of the Maxhütte tuyere (which is applied to the bottom blowing of converters in the OBM and Q-BOP processes), inserted through the back wall of the open-hearth furnace below the metal level in the bath.

The experiments at Sydney Steel (which have been discontinued, owing to the lack of adequate quantities of oxygen and nitrogen and of lime injection equipment) have shown that desulphurisation is very effective and that very low carbon contents can be achieved. The process requires very small capital investment and can be applied to either large or small open-hearth furnaces.

Development of the process will continue when lime-injection equipment is available. The experimental results from the first series of trials are given in tabular form.

HISTORICAL NOTE

Early in 1969, Guy Savard, co-inventor with Bob Lee of the hydrocarbon-shielded oxygen jet, drew my attention to the advances being made in Europe in the conversion of Thomas Converters to oxygen blowing. During 1970, I visited the OBM operations of USINOR at Valenciennes, Roechling at Voelklingen, and Maximilianshütte at Sulzbach-Rosenberg. At that time, the Pennsylvania Engineering Corporation had completed for Sydney Steel Corporation the design of a basic oxygen furnace shop, using the classical top-lance design.

Because of the advantages of the OBM Process, in terms of process control, yield, and capital savings, the BOF vessels were replaced by bottom-blown vessels of the same size, and the shop redesigned. This decision was reached approximately one year ahead of the United States Steel Corporation's decision to carry out experiments with the bottom-blown converter, to which they have subsequently given the name Q-BOP.

Whilst engineering details of the new bottom-blown shop at Sydney Steel were being completed, I made the decision to experiment with the Maxhütte tuyere on our No. 5 Furnace of 220 tons capacity. First heats on the furnace were blown in November, 1971. Patent applications for the Process were submitted in the names of W. Wells and myself in February, 1972, and Maxhütte have the worldwide rights to develop the use of the Process from Sydney Steel Corporation.

SUBMERGED INJECTION PROCESS

Presenting a paper at this time on the Submerged Injection Process in the open-hearth is not satisfactory because the work on the development of the Process to take full advantage of its potential is not complete. One of the principal requirements of the system, the injection of lime, is not yet operative at Sydney. This paper, therefore, can be considered only as an interim report on a subject which will develop rapidly.

Steel production from open-hearth furnaces throughout the world is still a considerable factor in total production. Though modern, high-production BOF converters of the top-blown design have rapidly replaced the slower, more expensive open-hearth, the capital to convert all open-hearth shops is not yet available. Fortunately, technology does not stand still, and, in the Steel World, the tempo of change has become almost as rapid as in other fields.

For too long, the processes of production of iron and steel have remained stagnant, largely the fault of the Industry itself; to use a garden term, "root-bound". The invention by Guy Savard and Bob Lee in Canada of the hydrocarbon-shielded oxygen jet was slow in being accepted by the Steel Industry, and when it was adapted and developed, it was not by one of the giants, but by a small, and at that time, struggling steel company — Maximilianshütte of Sulzbach-Rosenberg.

The adaption of the hydrocarbon-shielded oxygen jet to steelmaking is the result of a combination of the efforts of Helmut Knuppel, Karl Brotzmann, and Hans-Georg Fassbinder, and its impact on steelmaking has only just begun to be felt. The invention will have a far wider effect as its usefulness and application are appreciated and understood by steelmakers and by engineers and metallurgists in other metallurgical processing fields.

Our problem at Sydney was no different from those of many other steelmakers, save perhaps that most of our equipment was completely worn out, and none of it has been kept up to the standards required by developing technology. Our decisions, therefore, to update were made on the immediate basis of earning capacity, but integratod as far as was possible to future long-term development.

Obviously, any area where improvements could be effected with minimum capital investment would help other areas, all desperately in need of modernization. So, when the advantages of the OBM Process could be seen, and whilst we were waiting for the engineering of the OBM Steel Shop to be completed, we decided to see whether there was any application of the hydrocarbon-shielded oxygen jet to improve our Open-Hearth Furnaces, where roof-lancing had been in operation for a few years.

Our initial experiment was to insert six tuyeres through the bottom of No. 5 Furnace, with an appropriate supply of protective gas, in this case, propane, together with oxygen and nitrogen supplies. Our furnaces are tilters, and we found, after ten heats, that we were unable to clear the pools of metal which remained in the area around the tuyeres. The metallurgical results and the control of the furnace had been good.

The tuyeres were removed from the bottom and inserted through the banks at an angle of approximately 45° on the tap-hole side of the furnace. Metallurgical performance was again satisfactory, but the refractory performance was not sufficiently good as to be able to call the process an unqualified success.

The problem which had been uppermost in our minds when we made the decision to place the tuyeres in the furnace bottom, was related to the ferrostatic head above the tuyere and the possibility of fountaining. This problem did not occur, either with the tuyere in the bottom or angled at 45°.

In an endeavour to improve the refractory performance still further, the tuyeres were placed horizontally through the back wall of the furnace, directed towards the front wall, and the experiment continued.

It was found quite rapidly that there was no necessity to operate multiple tuyeres. It had been thought that, with a bath length of 13 meters and a width of 4.5 meters, a large number of tuyeres would avoid segregation in the bath and prevent temperature gradients, ensuring homogeneity of analysis. It was found that, even with a bath of the size mentioned, one tuyere was adequate for the injection of the oxygen to achieve a bath, homogeneous as to temperature and analysis.

To tell you the whole story of the problems we encountered and how we solved them, though obviously not all are solved, would take a tremendously long time. Therefore, I shall present the remainder of what I have to say in tabloid form and answer your questions, if there are any, as best I can.

We converted two of our furnaces, Nos. 5 and 6, each of 220 short tons capacity. On No. 5, we completed 760 S.I.P. heats; on No. 6, we completed 539 S.I.P. heats, for a total production of over 275,000 tons of steel.

The work was discontinued because of the imbalance in wages created between the S.I.P. furnaces and the remainder of the Shop. Due to the limitation of oxygen supplies, averaging approximately 95 tons per day for the whole Shop, and small storage capacity, no satisfactory method of equalizing production levels could be found.

Until the delivery of the lime-injection equipment, work with S.I.P. will not be restarted. The personnel problems of a shop operating with such transition techniques are too great. It is not easy to convince open-hearth operators that their furnaces are processing steel as swiftly as those of a B.O.F.! The results from our experience are tabulated below.

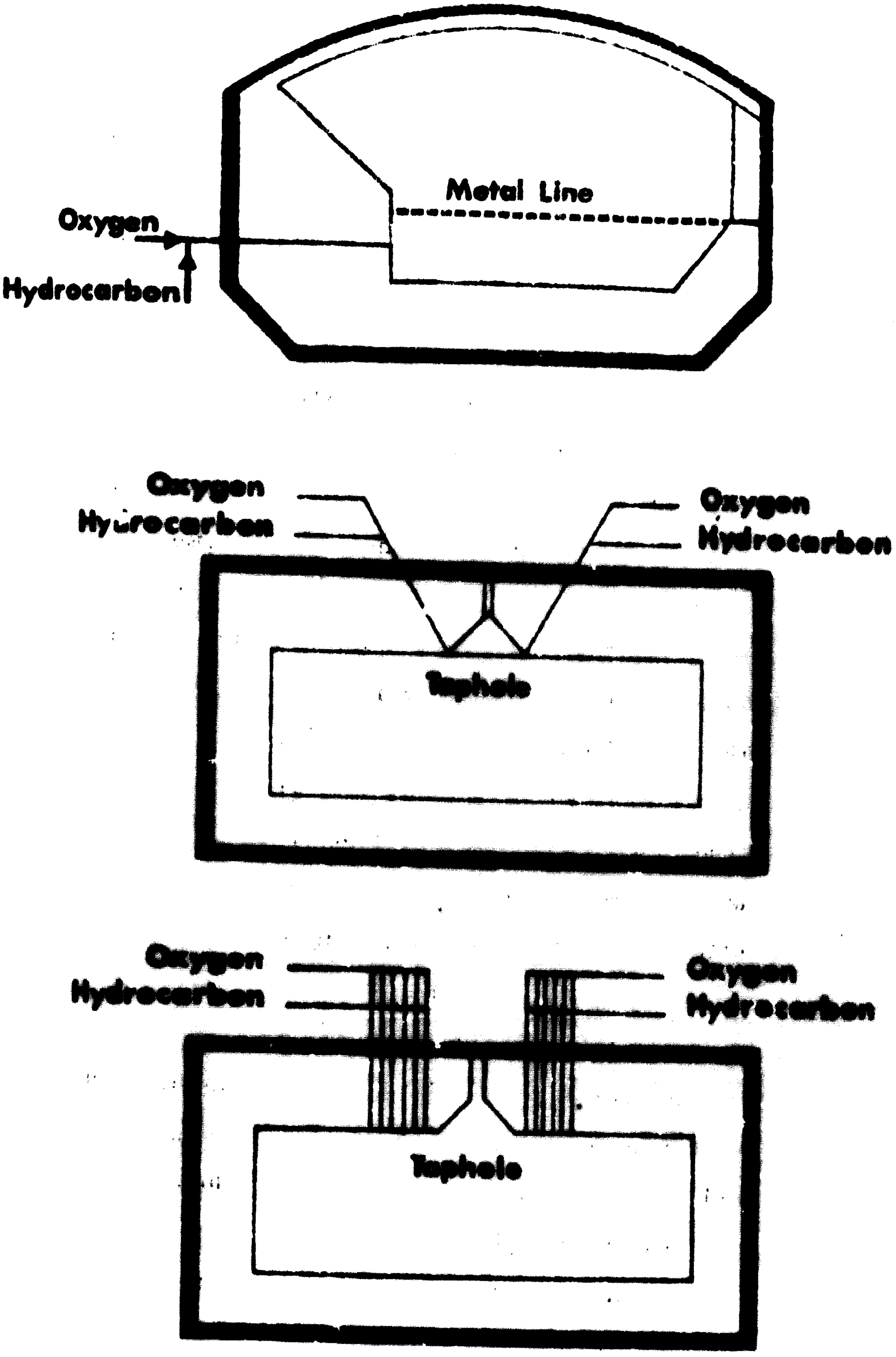


Fig. 1 - Schematic arrangement of tuyeres in SIP process

The new Oxygen Plant, capable of producing both adequate quantities of oxygen and nitrogen, is now commissioned at Sydney. Delivery of lime-injection equipment has still not been effected. We consider that, until the lime injection can be provided, the full benefits of the system will not be realized; this for two reasons:

(1) The extremely rapid formation of highly active silica at a high temperature, without a reactive base present in the molten metal, leads to rapid attack of the furnace refractory in the vicinity of the tuyere. The rapid movement of the bath metal and the wave motion in the direction of the back wall results in rapid attack on the furnace refractory in the tuyere area.

(2) The desulphurization achieved by the injection of powdered, calcined lime at high rates, under conditions where FeO is not yet being formed and at comparatively low temperature, is most effective. The intimate mixing of the molten metal with the powdered lime is most advantageous. A typical production procedure for a 220-ton furnace would be the injection of 1000 kilograms of lime per minute for two minutes, using nitrogen as the carrier gas. Upon completion of this phase, the nitrogen is immediately changed over to oxygen at the full-blowing rate, with lime injection continued at a lower rate, calculated to provide the final "V" ratio in the slag.

We have found the Submerged Injection Process to provide the following advantages:

(a) low capital cost for impressive improvement in production;

(b) ability to control both temperature and analysis, without stopping the Process;

(c) simple computer analysis to predicate results which, coupled with (b), enables performance to be verified continuously;

(d) application to both small and large installations;

(e) no modifications to an existing shop, apart from the addition of instrumentation and piping to supply the tuyeres with appropriate gases, and the external addition of lime-injection equipment;

(f) the ability to produce very low-carbon steels in the open-hearth, hitherto, an almost prohibitively expensive process;

(g) the ability to achieve good desulphurization and dephosphorization with lime injection;

(h) the ability, if necessary, to melt high scrap charges;

(i) the ability to remove the first high-sulphur-containing slag from the furnace without slowing the process.

We have found the principal requirements to satisfactory operation to be:

(a) adequate supplies of hot metal, oxygen, nitrogen, and a comparatively small supply of propane, butane, or other hydrocarbon gas. Under these conditions, full advantage of the productive capacity possible can be taken;

(b) an adequate system, easily controlled, for the introduction of powdered, calcined lime to the tuyeres;

(c) for best roof life, a high roof;

(d) an open-hearth shop already accustomed to good practices; i.e.. good fettling, rapid charging, quick analysis techniques, etc.

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Some results from the SIP operations at Sydney Steel are given in the following tables.

JUNE 23 TO JULY 5, 1972

12 OPERATING DAYS

FCE. NO.	NO. OF HEATS	AV./HEATS PER DAY	AV./TONS DAY	HOT METAL/ SCRAP RATIO	YIELD	BLOWING RATE CU.FT./HR.
1 Roof Lance	31	2.58	508.6	65.2	88.8	60,000
3 On Repair						
4 Roof Lance	30	2.5	530.2	67.6	86.1	60,000
5 S.I.P.	60	5.0	1,114.5	68.7	90.0	120,000
6 Roof Lance	30	2.5	635.0	70.01	87.8	60,000

AVERAGE STEEL PRODUCTION/DAY = 2783

AVERAGE DAILY OXYGEN CONSUMPTION FOR SHOP = 98 TONS

JULY 6 TO JULY 26, 1972

21 OPERATING DAYS

FCE. NO.	NO. OF HEATS	AV./HEATS PER DAY	AV./TONS DAY	HOT METAL/ SCRAP RATIO	YIELD	BLOWING RATE CU.FT./HR.
1 Roof Lance	54	2.57	530.6	68.3	87.1	60,000
3 Roof Lance	61	2.9	595.0	70.3	84.1	60,000
4 Roof Lance	56	2.66	556.3	72.9	86.4	60,000
5 S.I.P. on Repair						
6 Roof Lance	62	2.95	704.4	71.7	82.1	60,000

AVERAGE STEEL PRODUCTION/DAY = 2386

AVERAGE DAILY OXYGEN CONSUMPTION FOR SHOP = 107.8 Tons

SEPTEMBER 2 TO SEPTEMBER 20, 1972
19 OPERATING DAYS

FCE. NO.		NO. OF HEATS	AV./HEATS PER DAY	AV./TONS DAY	HOT METAL/ SCRAP RATIO	YIELD	BLOWING RATE CU.FT./HR.
1	Roof Lance	53	2.78	589.9	75.6	85.6	60,000
* 3	Roof Lance	33	3.0	543.6	72.3	87.3	60,000
4	Roof Lance	37	1.94	372.4	69.9	86.02	60,000
5	S.I.P.	71	3.73	818.7	71.6	88.7	60,000
* 6	Roof Lance	19	2.37	580.1	73.0	87.1	60,000

* No. 6 Furnace ran from Sept. 2 to Sept. 9 @ 2.37 heats/day

No. 3 Furnace ran from Sept. 10 to Sept. 20 @ 3.0 heats/day

AVERAGE STEEL PRODUCTION/DAY = 2340

AVERAGE DAILY OXYGEN CONSUMPTION FOR SHOP = 86 Tons

COMPARISON OF ROOF LANCE PERFORMANCE
WITH S.I.P. PERFORMANCE
NO. 6 OPEN HEARTH

	ROOF LANCE	S.I.P.
Heat No.	65508	66086
Tap to Tap Time	6 Hr. 30 Min.	4 Hr. 10 Min.
Gross Metallic Charge	475,300 Lbs.	488,000 Lbs.
Ratio Hot Metal/Scrap	76/24	60/40
Grade Made	0.5C%	0.5C%
Melt in Sulphur	0.037%	0.038%
Final Sulphur	0.040%	0.025%
Blowing Time	4 Hr. 20 Min.	2 Hr. 25 Min.
Yield %	88	89.4
Tons/Hour	64	90
Total Oxygen Usage cf^3	220,000	145,000
Oil Used - Gal.	3,500	1,110
Limestone/Ton of Steel Produced	88 Lbs.	97 Lbs.
Fe Mn in Ladle	4,300 Lbs.	3,800 Lbs.
Final Mn. %	0.72	0.74
Fe Si in Ladle	720	660

[redacted]

S.I.P. CAMPAIGN NO. 6 FURNACE

	FCE. NO.	NO. OF HEATS	DAYS	HEATS/ DAY	AV. TONS /DAY	RATIO HOT METAL /SCRAP	YIELD	BLOWING RATE CU.FT./HR.
A.	6 S.I.P.	288	70	4.12	818*	66.1	90.2	60,000
B.	6 S.I.P.	135	33	4.12	816*	69.3	87.3	60,000
C.	6 S.I.P.	59	17	3.47	798*	65.8	89.01	60,000

* FURNACE CHARGED WITH SMALL HEATS, DUE TO UNAVAILABILITY OF BIG LADLE.

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