UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

United Nations Industrial Development Organization

Distribution
LIMITED

ID/WG.14/41
27 June 1968

ORIGINAL: ENGLISH

Second Interregional Symposium
on the Iron and Steel Industry

Moscow, USSR, 19 September - 9 October 1968

B-7-2

CONVERSION OF OPEN-HEARTH SHOPS INTO BASIC OXYGEN FURNACE SHOPS AT FUJI IRON AND STEEL CO. LTD. 1/

by

S. Toyoda, H. Nakajima, M. Maeda, E. Hirao, K. Nakajima
Japan

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. The document is presented as submitted by the author, without re-editing.

id.68-2156

United Nations Industrial Development Organization

Distribution
LIMITED

ID/WG.14/41 SUMMARY*
27 June 1968

ORIGINAL: ENGLISH

Second Interregional Symposium
on the Iron and Steel Industry

Moscow, USSR, 19 September – 9 October 1968

E-7-2

CONVERSION OF OPEN-HEARTH SHOPS INTO BASIC OXYGEN FURNACE SHOPS AT FUJI IRON AND STEEL CO., LTD[1/]

by

Shigeru Toyoda, Hitoshi Nakajima, Masayoshi Maeda,
Eiji Hirao and Keinosuke Nakajima,
Japan

SUMMARY

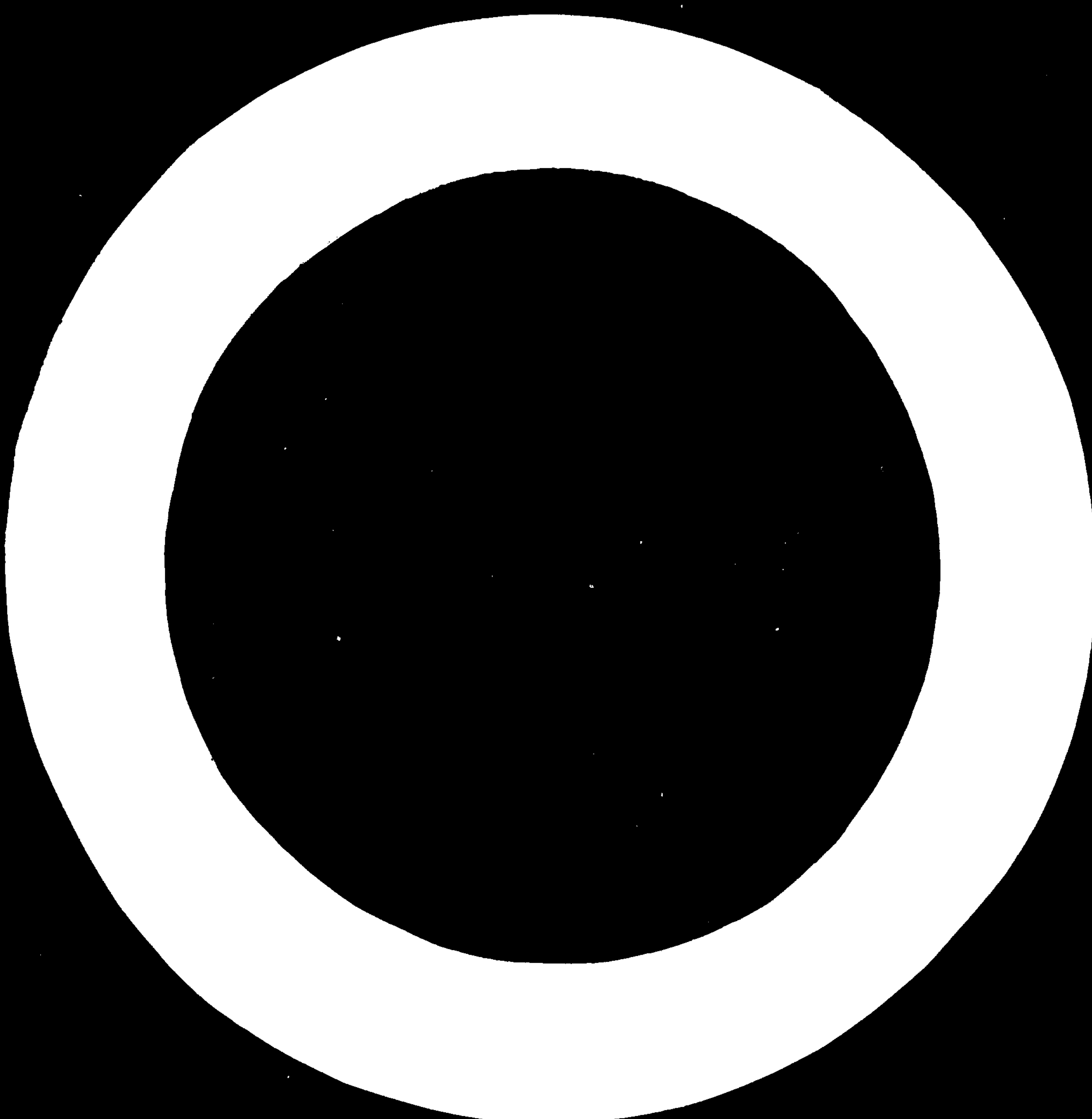
I. Introduction

The basic oxygen top-blowing process (BOF process) has made remarkable progress, and BOF steel is now assuming an increasingly large proportion in the total crude steel production of the world. In Japan, 65 per cent of the national crude steel production in 1967 was by the BOF process, and the percentage is expected to grow even greater in the future. Fuji Iron and Steel Co., Ltd has been developing the BOF process ever since it installed a two-100 ton BOF at its Hirohata Works in 1960, and as a result increased the percentage of BOF steel in the total crude steel output to 40.6 per cent by 1964 through continued expansion

* This is a summary of a paper issued under the same title as ID/WG.14/41.

1/ The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO. The document is presented as submitted by the authors, without re-editing.

id. 68-1941



of facilities. The company, after confirming the advantages of this process, experimentally replaced an open-hearth furnace at its Muroran Works with BOF in 1965. Similarly, open-hearth furnaces at Kamaishi and Hirohata were also replaced by BOF in 1965 and 1967, respectively. As a result, at present about 98.6 per cent of the company's total crude steel is produced by the BOF process. We are fully convinced of the advantages of the BOF process in terms of both productivity and quality.

This paper is a summary of the purpose and the history of Fuji's switch from open-hearth furnaces to BOF, and of its results.

II. Purpose of Conversion

From the following points of view, we have adopted the course of making use of the existing open-hearth plants in installing converters:

(1) By using the sites of the open-hearth plants and the existing facilities, construction costs can be reduced and building time shortened.

(2) A complete operational plant should be built, instead of merely experimental equipment, without reduction in production.

(3) The major objective of efforts to develop the BOF process hereafter would probably be the production of high carbon steel, alloy steels and other high-grade steels that have heretofore been produced by the open-hearth furnace or electric furnace.

(4) Maximum advantages of the continuous casting process must be effected.

III. Features of the Remodelling and Outline of the Equipment

The main features of the remodelling process are the effective use of the existing open-hearth facilities, including buildings, cranes, dust collectors, stacks and the like.

Layout of converters

In the case of the Muroran Works, the open-hearth shop consisted of a 700-ton mixer and six 200-ton open-hearth furnaces. Of the six furnaces, No. 1 was removed and a 50-ton test converter was installed in its place. Later in

December 1966, No. 2 open-hearth furnace was replaced by No. 2 50-ton converter. Thus, at present, 100 per cent of steel at Muroran is being produced by means of BOF.

In the case of Kamaishi, there has been a 1,000-ton and a 400-ton mixer and five 150-ton open-hearth furnaces in the open-hearth shop. Of these existing units, the 400-ton mixer and No. 1 and No. 2 open-hearth furnaces were removed and two 90-ton converters were put in their places.

At Hirohata, there were seven 200-ton open-hearth furnaces in the open-hearth furnace plant. Then the No. 5 and No. 6 open-hearth furnaces were replaced by two 100-ton converters.

Converter aisle and lance-lifting equipment

In the case of Muroran, a simple converter aisle was provided. The girders and beams were left almost wholly unchanged. As a result, there is only one lance in operation, without any spare.

In the case of Kamaishi, however, the girders and beams were partly rebuilt and reinforced and a converter aisle provided so that the space above the converters could be fully used. As a result, there is a lance in operation with another to spare.

In the case of Hirohata, since a converter floor was newly provided in the open-hearth furnace charging floor, two lances can be used as in the case of Kamaishi.

Converter vessel

The shell inner volume is 85 m^3 at Muroran, 133 m^3 at Kamaishi and 178 m^3 at Hirohata. The height of the converters at Muroran is 6.5 m, Kamaishi 7.9 m and Hirohata 8.5 m.

Flux-handling equipment

At Muroran, the space left after the slag pocket and the regenerator on one side of the open-hearth were removed was used to set up a storage hopper and bucket elevator. The overhead hopper, located below the crane girder, was rather small, and the bucket elevator capacity was also small, making for a somewhat long addition time. But in the case of Kamaishi, the work efficiency of the converters would not be impaired by the flux-handling equipment.

The flux-handling equipment at Hirohata is identical to the equipment commonly used at a newly constructed converter plant. Since Hirohata, unlike Kamaishi, plans to install a third 100-ton converter in the future, it has flux-handling equipment with high productivity, sufficient to keep two of the three converters in operation.

Cooling equipment

In the case of Muroran, steam recovery is unnecessary and cooling water is abundant. Accordingly, the waste-gas-boiler system was dispensed with and the hood flue system, the simplest water-cooled system, was adopted.

At Kamaishi, too, steam recovery was practically unnecessary. And to save water, the low pressure forced circulating type heat exchanger system was employed.

The route of waste gas flow is as follows:

Low-pressure boiler - Connecting flue (vertical duct) - Underground flue - Wet-type venturi scrubber - Induced draft fan (IDF) - Stack.

At Hirohata also, steam recovery is not specially necessary, but a heat exchanger system using a low-pressure boiler is employed for the saving of water, so that when steam recovery should become necessary in the future, recovery of low pressure steam will be possible. Dust collection is conducted by a wet type multi-venturi device. The exhaust gas pipe, IDF, thickener, etc. for the existing open-hearth furnaces are used without any alteration.

IV. Remodelling Process

At Muroran, the dismantling of No. 1 open-hearth furnace was started on 19 October 1963, and the test operation of the converter began on 17 April 1964. In the case of Kamaishi, the break-up work was launched on 1 February 1965, and the test operation was commenced on 1 August of the same year.

At Hirohata, the break-up work of the open-hearth furnace was begun in January 1967, and operations were resumed on 5 January 1968. But the remodelling work was completed six months after completion of the dismantling of No. 7 open-hearth furnace, which was conducted last.

V. Operational Results

The catch carbon situation is now in a satisfactory state, on the whole, through the adoption of the "double catch carbon" method and slag control. As regards dephosphorization within the high carbon range, generally satisfactory results have been obtained by adopting a slag-control system.

Although we are still experimenting in the field of all alloy steels, there is no question about such varieties as C 1.1%, Si 1.8%, Mn 1.7%, Cr 1.2% steels, and work has already been started in actual production of them by the converter.

Kamaishi converters are producing medium- and high-carbon steels to the proportion of 70 per cent of the works' total steel production. The medium-carbon steels they are producing are steels for the production of structurals, sheet piling and shipbuilding materials and the high-carbon steels are for that of machine structurals, wire rods, rails and the like.

VI. Comparison between the Remodelled Converter Plants and Newly-Built Converter Plants

In the following circumstances, the proposed remodelling method is far more advantageous than newly erecting a converter plant:

(1) In the case of building a steelmaking plant whose production capacity is not to be very large, say, from 80,000 tons to 120,000 tons a month. This method provides maximum economy in construction, and yet ensures a more than sufficient steelmaking output to make up for the original open-hearth furnace output.

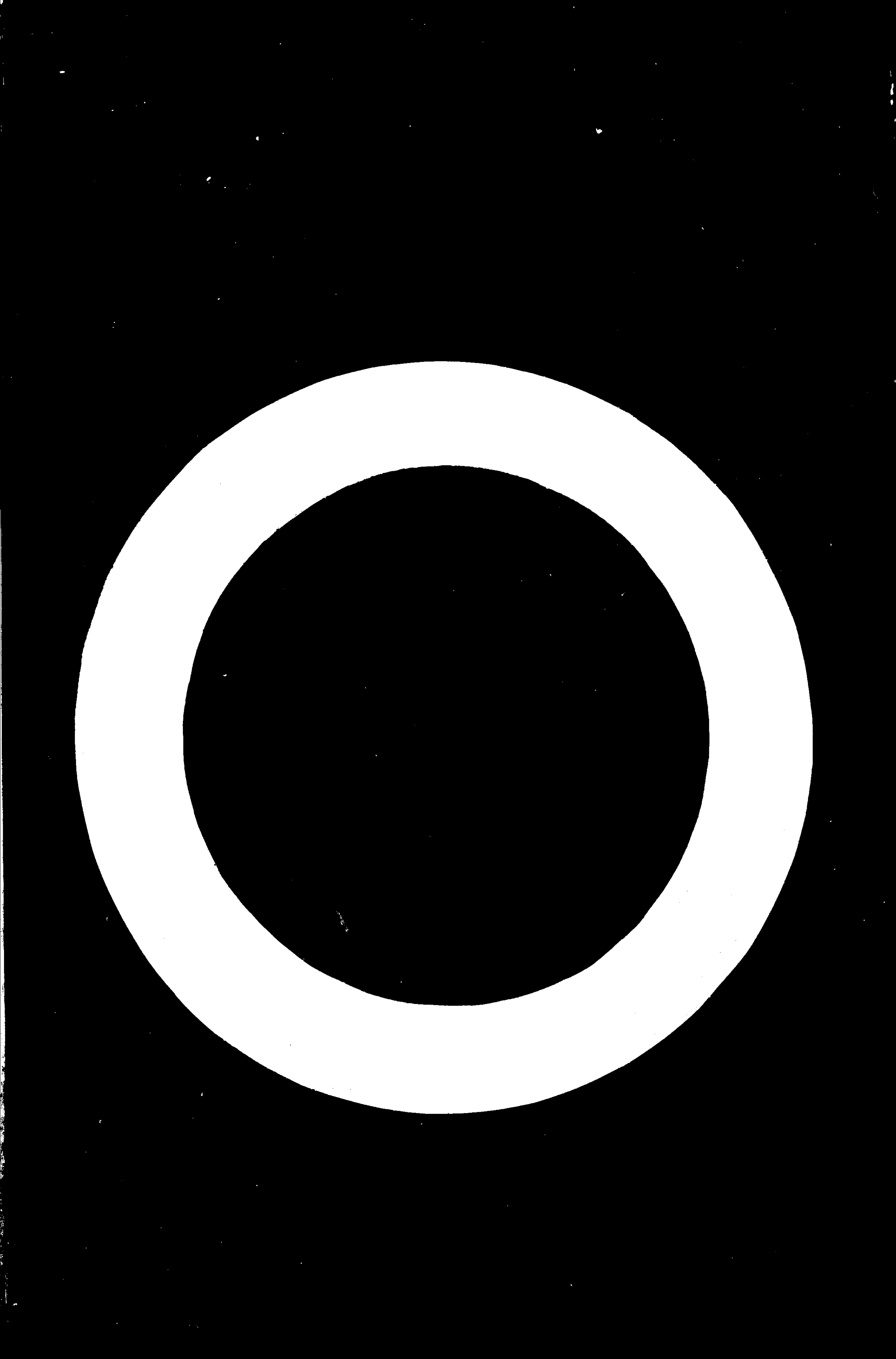
(2) In case there is no need to vastly inorease the ingot production of the steelworks as a whole.

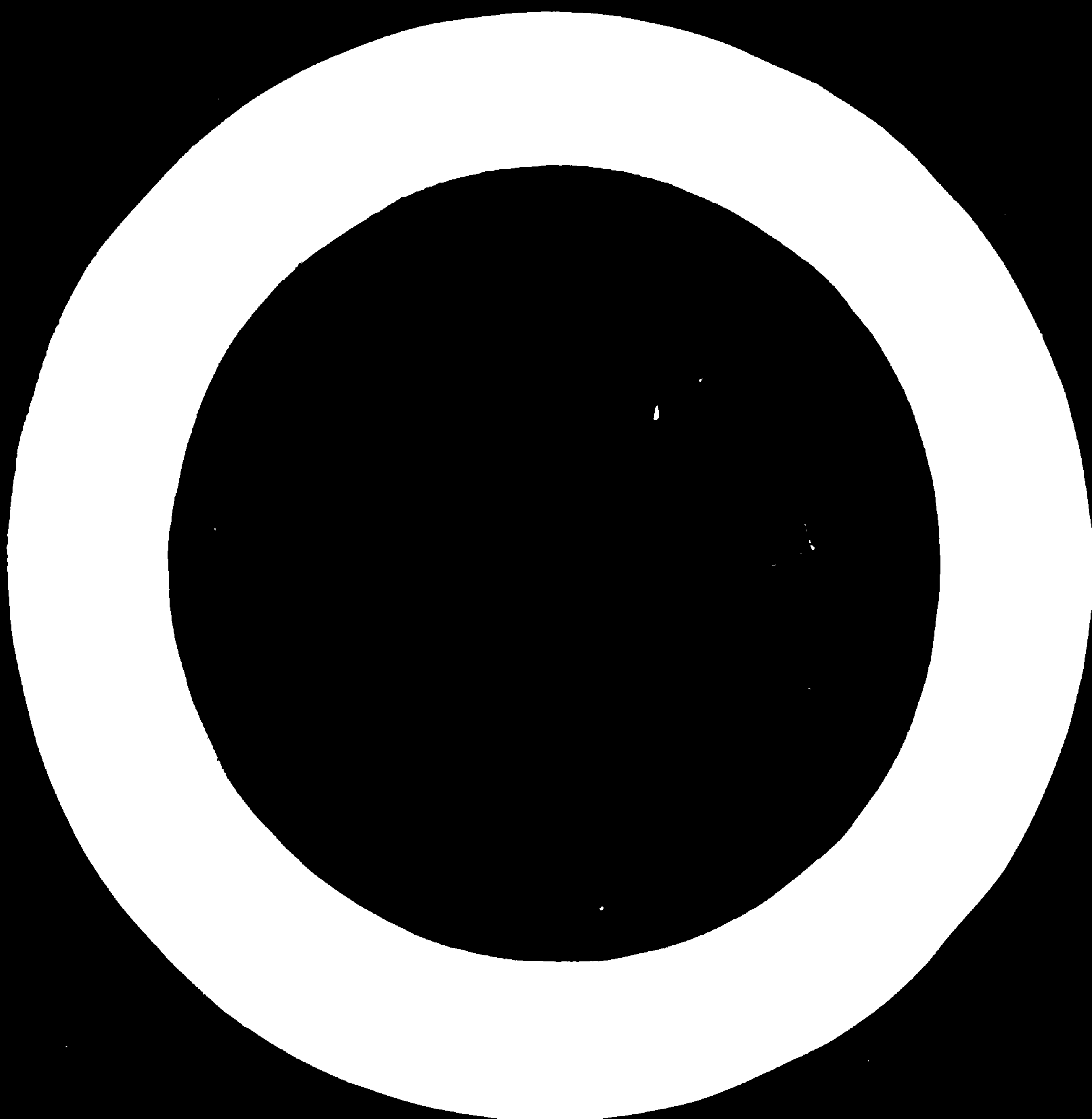
(3) In case continuous oasting equipment and degassing equipment are rationally combined for produotion work.

(4) In case the plant site is small and it is difficult to obtain an additional site for a new plant.

(5) In case the steels to be produced are very varied and orders come in small lots.

(6) In the case of aiming at quick results from investment, the short period of construction required and the small amount of investment are just the features desired.





Contents

Photos

Figures

Tables

PREFACE

The basic oxygen top-blowing process (BOF process) has made remarkable progress, and BOF steel is now assuming an increasingly large proportion in the total crude steel production of the world. In Japan, 65% of the national crude steel production in 1967 was by the BOF process, and the percentage is expected to grow even greater in the future. Fuji Iron & Steel Co. Ltd. has been developing the BOF process ever since it installed a two 100-ton BOF at its Hirohata Works in 1960, and as a result increased the percentage of BOF steel in the total crude steel output to 40.6% by 1964 through continued expansion of facilities. The company, after confirming the advantages of this process, experimentally replaced an open-hearth furnace at its Muroran Works with BOF in 1965. Similarly, open-hearth furnaces at Kamaishi and Hirohata were also replaced by BOF in 1965 and 1967, respectively. As a result, at present about 98.6% of the company's total crude steel is produced by the BOF process. We are fully convinced of the advantages of the BOF process in terms of both productivity and quality.

The following is a summary of the purpose and the history of Fuji's switch from open-hearth furnaces to BOF, and of its results.

1. INTRODUCTION

Since the oxygen top-blowing process by means of a two-ton test converter was first tried at the steelmaking plant in Linz, Austria, on 25 June 1949, the BOF process has made a spectacular advance in various countries of the world both technologically and quantitatively. Especially in Japan, where scrap metal prices are not cheap, the merits of the BOF have been found to exceed expectations.

Fuji Iron & Steel Co. Ltd. too, began research in the turbo-hearth process at its Muroran Works in 1952, and started the study of the BOF process by means of a three-ton test converter in 1954. In 1960, it built two 100-ton BOF at its Hirohata Works and in 1961, two 110-ton BOF at its Muroran Works. In 1965, it installed an additional 100-ton vessel at the BOF plant in its Hirohata Works. All these converters are now operating satisfactorily.

These operational experiences and the rapid technical advance of the BOF process have brought home to steelmakers the superiority of the process over the open-hearth process in points of the quality of products and costs. Thus has come to the fore the problem of remodelling open-hearth plants into converter plants.

In the first stage of this investigation, the No. 1 open-hearth furnace (200-ton tilting-type) at the open-hearth plant of the Muroran Works was dismantled and a 50-ton test converter was installed in its place. This was done with a view to ascertaining whether any problems would arise as to the grade of steel or specifications and production when an open-hearth shop was completely eliminated; to see what the relations would be among remodelling costs, work costs and operational efficiency; and to find out whether actual comparable values could be obtained between a remodelled and an entirely new converter plants.

First, the equipment remodelling to be described later was carried out experimentally, and operation thereof was started in April 1964. As a result, we decided that it was fully possible as well as feasible to make use of the existing open-hearth plant equipment as much as possible when turning the plant into a converter plant and that this arrangement had many merits. It was also found that all steels that an open-hearth plant could produce could also be turned out by such a remodelled plant.

Accordingly, in 1965 we went a step further and built inside the existing open-hearth plant of the Kamaishi Works, two operational 90-ton converters. These converters had as much productivity as that of any newly-built converter plant.

The success at Kamaishi led to the replacement of open-hearth furnaces at Hirohata with BOF.

At Hirohata, two 100-ton BOF - larger than those at Kamaishi - were installed to supplement the production capacity of its open-hearth furnace plant, and as a result, the Hirohata Works succeeded in promoting its productivity higher than Kamaishi.

2. PURPOSE OF CONVERSION

In Japan it is thought that for some time to come the advantages of the BOF process in point of costs and grade of products will remain unshaken and that, sooner or later, the open-hearth plants are destined to be replaced by converter plants. That being so, it is an important problem in the rationalization of steelmaking processes just what to do with the existing open-hearth plants. The simplest formula would be to build new converter plants and abandon the existing open-hearth ones - a scrap-and-build proposition - but, from the following points of view, we have adopted the course of making use of the existing open-hearth plants in installing converters:

1) By using the sites of the open-hearth plants and the existing facilities, construction costs can be reduced and building time shortened.

Especially in the case of the Kamaishi Works, its site is smaller than that of the Muroran or Hirohata Works and there is hardly any space on it available for a new converter plant. Its present ingot production amount is just about adequate to go with its ironmaking and rolling equipment, and there is no need to effect a major increase in its ingot production, so that if a new converter plant were built, the existing open-hearth shop would have to be completely abandoned.

We would add that at the Kamaishi Works, there is sufficient space still left in its open-hearth plant space for the installation of a continuous casting machine after two converters have been installed. A continuous casting machine is now being installed there.

At Hirohata, it was difficult to find space for the construction of a new converter plant. It was believed more advantageous economically to demolish the existing open-hearth furnaces and to replace them with converters, in view of the availability of the existing buildings and other related facilities at the plant site.

At Hirohata, too, there is a possibility of a continuous casting machine being installed in the near future. It will then be possible for the Works to mass produce high grade steel using a continuous casting machine with the existing R-H degassing equipment.

The construction work at Muroran and Kamaishi took about six months - much shorter than the construction of a new plant would have taken. Hirohata required about a year for the conversion work, but it was still far shorter than the construction period for a new converter plant. At Muroran and Kamaishi, production was not affected by the conversion work. This is because at Muroran, the existing 110-ton converters were more efficient than expected, and at Kamaishi, the productivity of the remaining open-hearth furnaces was raised to maximum. At Hirohata, where the project took about a year, a certain degree of production shrinkage was unavoidable.

2) A complete operational plant should be built, instead of merely experimental equipment.

For instance, in the case of the Muroran Works, a plant was provided that could produce 25,000 tons a month, besides fully covering to decrease in production, due to the withdrawal of a 200 ton open-hearth furnace. In addition to the existing six 200 ton open-hearth furnaces, the Muroran Works has two large converters of 110 tons. Muroran produces, besides hot and cold rolled coils, various types of shapes, wire rods and bars. Accordingly the Works adaptability to orders for small quantities of many varieties of such bars and shaped products was low. In order to remedy this shortcoming, a 50 tonner was chosen for the newly installed converter. In the case of the Kamaishi Works, full use was made of the experience at Muroran and two 90 ton converters, capable of fully replacing the entire open-hearth plant, were installed for operation on a commercial scale. The plant thus could produce the maximum amount of 85,000 tons a month.

At Hirohata, two 100 ton converters, with higher productivity than those at Kamaishi, were built, as mentioned before, for the expansion of its production capacity and the improvement of productivity in the future. Although the converters have not been operating too long as yet, a production output of 120,000 tons per month - the output by the old open-hearth furnaces - can be well expected.

3) The major objective of efforts to develop the BOF process hereafter would probably be the production of high carbon steel, alloy steels and other high grade steels that have heretofore been produced by the open-hearth furnace or electric furnace.

First, therefore, the technique for producing such steels by means of the 50 ton converter at Muroran was developed, and the possibility and feasibility of abolishing its open-hearth furnaces altogether in favour of converters was technically examined.

Now, the main products at the Muroran and Hirohata Works are plates and/or sheets and most of the ingot steels turned out there are low-carbon steels, while the main products of the Kamaishi Works are shapes, bars, rails and wire rods, ranging from low carbon to high carbon steels. Through test after test with the 50 ton converter at Muroran, we gained confidence in its capacity to produce all such kinds of steel materials, and thus, we decided to convert the open-hearth plant at Kamaishi and Hirohata also into a converter plant.

4) Maximum advantages of the continuous casting process must be effected. It is believed possible for Kamaishi to produce blooms for large shapes, high carbon wire rods, etc., employing the continuous casting process, by replacing its open-hearth furnaces with converters, and the necessary construction work is now in progress. When the construction work is completed, the new facilities are expected to contribute to the improvement of quality as well as to cost reduction.

3. FEATURES OF THE REMODELING AND OUTLINE OF THE EQUIPMENT

The main features of the remodeling process are the effective use of the existing open-hearth facilities, including buildings, cranes, dust collectors, stacks, and the like, and the removal only of the open-hearth furnaces themselves, replacing them with the converters.

The auxiliary equipment for the 50 ton converter at Muroran, the 90 ton converter at Kamaishi and the 100 ton converter at Hirohata grew larger and its productivity also rose in keeping with the capability of the converter. However, the costs involved in the replacement work were considerably lower compared with the construction of a new plant.

1. Layout of converters

In the case of the Muroran Works, the open-hearth shop consisted of a 700 ton mixer and six open-hearth furnaces, as shown in Figure 1. Of the six furnaces, No. 1 was removed and a 50 ton test converter was installed in its place. Later in December 1966, No. 2 open-hearth furnace was replaced by No. 2 50 ton converter. Thus, at present, all grades of steel at Muroran are being produced by means of BOF. The centre of the converter was placed directly below the girder between the open-hearth aisle and the teeming aisle and made the lance-lifting operation free from interference by the existing cranes. (See Figures 4 and 5.)

In the case of Kamaishi, there has been a 1,000 ton and a 400 ton mixer and five 150 ton open-hearth furnaces in the open-hearth shop, as partly shown in Figure 2. Of these existing units, the 400 ton mixer and No. 1 and No. 2 open-hearth furnaces were removed and two 90 ton converters were put in their places. The flow of hot metal and molten steel was left unchanged, so that the production work by the remaining open-hearth furnaces, which went on simultaneously with the conversion work, would not be affected. The centres of the converters were located similarly to those in the Muroran Works, as shown in Figures 4 and 5.

At Hirohata, there were seven open-hearth furnaces in the open-hearth furnace plant. Their layout is shown in Figure 3. There was a 700 ton open-hearth furnace mixer in a separate building outside the open-hearth furnace plant. However, its capacity being insufficient considering the pig ratio of a 100 ton converter, we decided in the current equipment replacement programme to abolish an open-hearth furnace in the open-hearth furnace plant and install a new 1,300 ton mixer in its place.

The No. 5 and No. 6 open-hearth furnaces were also replaced by two 100 ton converters. The layout differed from Muroran and Kamaishi, where the centre of the converter was placed between the charging floor and the casting floor. In Hirohata part of the charging floor was made into a converter floor, and the converter was placed there. This was because a converter capacity of 100 tons per charge was necessary to make up for the entire steel production at the open-hearth furnace plant, which was 120,000 tons per month. If a converter of this capacity was placed between the charging floor and the casting floor, the level of the ladle car and slag car tracks would be lower than ground level and this would make withdrawal of the slag car difficult, in view of the relation between converter height and the hood height. The vertical section of the hood for waste gas, situated directly above the converter, has been made longer than at Muroran and Kamaishi, which resulted in an increase in the oxygen flow rate. (Compare Figures 3 and 8.)

2. Converter aisle and lance-lifting equipment

In what position and in what way the lance is to be lifted are extremely important questions. In the case of Muroran, a simple converter aisle was provided. The girders and beams were left almost wholly unchanged. As a result, there is very little space available for operations above the converter. There is only one lance in operation, without any spare. Consequently, in case of a lance failure, it would take 40-50 minutes to install a new one.

In the case of Kamaishi, however, the girders and beams were partly rebuilt and reinforced and a converter aisle provided so that the space above the converters could be fully used, as shown in Figure 7. As a result, there is a lance in operation with another to spare, and in the event of a lance failure there is no delay in replacing it.

In the case of Hirohata, since, as mentioned before, a converter floor was newly provided in the open-hearth furnace charging floor, two lances can be used as in the case of Kamaishi.

The maximum oxygen flow rate in the Muroran lance is 6,000 Nm^3/hr., that in the Kamaishi lance is 12,000 Nm^3/hr., and that in the Hirohata lance is 20,000 Nm^3/hr.

In the case of Muroran, almost no change was made in the operating floor in front of the converter, so that the floor is a bit high and awkward to work on; but, in the case of Kamaishi, the floor was brought down from 7.5m. to 6.8m. above ground level to make it easy to work on. At Hirohata, the operating floor was 7 metres from ground level and, therefore, no trouble was encountered as it was.

3. Converter vessel

The converter vessels at both Muroran and Kamaishi are of the concentric type and those at Hirohata are of the eccentric type. The shell inner volume is 85 m^3 at Muroran, 133 m^3 at Kamaishi and 178 m^3 at Hirohata. The height of the converters at Muroran is 6.5m., Kamaishi 7.9m. and Hirohata 8.5m.

4. Hot metal and scrap handling equipment

a) Scrap charging

At Muroran, the existing scrap handling crane and scrap charging crane were used as they were without any alterations. For this reason, since the crane is provided with numerous charging boxes, longer hours are required to charge scrap than in the case of an ordinary converter plant.

In the case of Kamaishi, however, the scrap handling crane was provided with a lifting magnet to charge the chute with scrap in the stock yard, and weighing was also performed there, with the scrap subsequently being sent to the converters by means of the traversing scrap transfer car set up on the former site of the No. 2 open-hearth furnace. A 30 ton/ 30 ton crane remodeled from the existing 60 ton crane was used to charge the converters with scrap.

In case of Hirohata, the chute specially made for the converter is charged with the scrap at the present stock yard using the existing scrap handling crane. The chute is then sent to the converter on a carrier, weighing is conducted during transit and the amount of scrap is adjusted.

The charging of the converter with scrap is conducted by two newly installed 20T x 2 charging cranes.

b) Hot metal charging

At Muroran, the existing ladle crane was used to charge from the pit side, and only the hot metal ladle between mixer and converter was remodeled. As a result, it turned out that even if scrap charging was finished early, hot metal charging was somewhat delayed while removing the teeming ladle previously used for tapping.

At Kamaishi, since, unlike at Muroran, hot metal charging and tapping are conducted from different sides, it was desirable to keep the flow of hot metal and molten steel unchanged, so that the work flow would be the same as in the operation of open-hearth furnaces. As the existing hot metal crane could be used in charging the converters with hot metal, it was only necessary to remodel the hot metal ladle in order to obtain an efficiency comparable to that seen at an ordinary converter plant.

The flow of work at Hirohata is as shown in Figure 3, and the layout is a desirable one in consideration of the work flow. Only those hot metal ladles used between the mixer and the converter were remodelled.

5. Flux-handling equipment

The general method for handling flux, in the case of a newly installed converter plant, is to send the flux from the main hoppers on the ground to the overhead hopper by means of a belt conveyor, suitably weigh it and then charge it into the converter. In the case of using an already existing open-hearth plant, however, there are limitations of space, and it is difficult to provide a large-capacity hopper above the converter from the point of equipment planning.

At Muroran, the space left after the slag pocket and the regenerator on one side of the open-hearth were removed, was used to set up a storage hopper and bucket elevator. The overhead hopper, located below the crane girder, was rather small, and the bucket elevator capacity was also small, making for a somewhat long addition time.

In the case of Kamaishi, the equipment was laid out as shown in Figure 9 so that the work efficiency of the converters would not be impaired by the flux-handling equipment. In other words, the main hoppers on the ground were limited to a minimum of six (40 m^3 x 2, 30 m^3 x 1, 20 m^3 x 3) and placed in front of the middle point between No. 1 and No. 2 converters. The flux is received in the stock yard and carried to the front of the converters by means of a conveyor belt and a bucket elevator.

Two overhead hoppers are provided for each converter (5 m^3 x 1, 2 m^3 x 1) and the flux is carried between the crane girders by means of a belt conveyor and a bucket elevator into the converters from the overhead hoppers.

The flux handling equipment at Hirohata is identical to the equipment commonly used at a newly constructed converter plant. Since Hirohata, unlike Kamaishi, plans to install a third 100 ton converter in the future, it has flux handling equipment with high productivity, sufficient to keep two of the three converters in operation; that is, twelve main hoppers (47.5m^3 x 8, 26m^3 x 4) are installed on the ground, and the flux supplied from these hoppers can be carried on a belt conveyor to be stored in the twelve overhead hoppers (41 m^3 x 1, 16 m^3 x 1, 9 m^3 x 4 for each converter), whose installation became possible with the building of the converter floor, and from there, the flux is charged into the converter.

6. Cooling equipment

In the case of Muroran, steam recovery is unnecessary and cooling water is abundant. Accordingly, the waste-gas-boiler system was dispensed with and the hood flue system, the simplestwater-cooled system, was adopted. The structure chosen was one in which a horizontal flue directly linked with the converter is connected with the uptake of the dismantled open-hearth furnace. This system was found all the more desirable in that the existing building could be used without alteration. Also for the dust collection, the electrostatic precipitator of the dismantled open-hearth furnace was used as it was.

At Kamaishi, too, steam recovery was practically unnecessary. And to save water, the low pressure forced circulating type heat exchanger system was employed. Furthermore, to have sufficient furnace height and hood capacity, the conventional Warren type crane travelling girder was remodelled into a plate girder, and the girder depth was thus decreased.

The route of waste gas flow is as follows:

Low pressure boiler - connecting flue (vertical duct) - underground flue - wet type venturi scrubber - induced draft fan (IDF) - stack.

Waste gas is cooled by spraying water in the vertical duct and by heat exchanger at the low pressure boiler section. The underground flue was connected to the two converters. The capacity of the induced fan is 120,000 Nm^3/hr (dry). This corresponds with the oxygen flow rate of 12,000 Nm^3/hr and the blowing time of the converters of eighteen minutes.

At Hirohata also, steam recovery is not specially necessary, but a heat exchanger system using a low pressure boiler is employed for the saving of water, so that when steam recovery should become necessary in the future, recovery of low pressure steam will be possible. The waste gas cooling system is basically the same as at Kamaishi. Dust collection is conducted by a wet type multi-venturi device. The exhaust gas pipe, IDF, thickener, etc., for the existing open-hearth furnaces are used without any alteration.

7. Ladle transfer car

For the ladle transfer car at Muroran, the wire-pulling system was adopted, while at Kamaishi the self-running system was used.

8. Pit equipment

In the case of Muroran, the ladle crane and teeming pit equipment already in use at the plant were used, and only the teeming ladle was slightly remodelled.

In the case of Kamaishi, a teeming platform and two ladle repairing platforms were newly provided, and, for the rest, the already existing equipment was used.

At Hirohata, they planned to increase the production of killed steel after replacing open-hearth furnaces with converters, and therefore, employed the buggy teeming system with a high rate of rotation. The winching speed of the teeming crane was raised in keeping with the tapppng cycle of the converter.

9. Apparatus for analysis

In the refining process for medium and high carbon steels in a converter, the time required for analysis is a very important matter.

In the case of Muroran, the equipment already there was used, and the sample was sent pneumatically over a distance of 350 metres; but in the case of Kamaishi and Hirohata, a quant-vac analyzer was provided under the converters in order to shorten the time for analysis.

4. REMODELLING PROCESS

At Muroran, the dismantling of No. 1 open-hearth furnace was started on 19 October 1963, and the test operation of the converter began on 17 April 1964. In the case of Kamaishi, the breakup work was launched 1 February 1965, and the test operation was commenced on 1 August of the same year. In both cases, the plant conversion work was completed within the short period of about six months. It is one of the features of the present method that the conversion period is short.

At Hirohata, the breakup work of the open-hearth furnace was begun in January 1967, and operations were resumed on 5 January 1968. The plant conversion work required about one year longer than at Muroran and Kamaishi, which was because the dismantling of the open-hearth furnaces was divided into several stages to minimize the decrease of production during the conversion period. The remodelling work was completed six months after completion of the dismantling of No. 7 open-hearth furnace which was conducted last.

The remodelling work processes are shown in Figures 10 and 11.

5. OPERATIONAL RESULTS

The operational results of the 50 ton test converter at Muroran and those of the 90 ton converters at Kamaishi since the start of their operations are as shown in Figures 12 and 13. Even better results should be obtained at Hirohata, although it has not been long since BOF operations were started at that Works.

In Figure 12, with regard to the operational results at Muroran, the steelmaking time is long and productivity not too good; but these things have apparently resulted from long charging and blowing times, the time required for the analysis of medium and high carbon steels and other various tests.

These, moreover, are not problems which arise necessarily when an open-hearth furnace is turned into a converter plant. In other words, they are those which can be fully solved technically. As a matter of fact, these problems have been fully solved at Kamaishi and Hirohata.

Next comes the problem whether all the steels produced by the open-hearth furnace can also be turned out by the converter. This can be boiled down to the following two points:

1) Can "catch carbon" be performed well within the whole carbon content range?

2) Can dephosphorization be carried out fully within the high carbon range?

The catch carbon situation is now in a satisfactory state, on the whole, through the adoption of the "double catch carbon" method and slag control. As regards dephosphorization within the high carbon range, generally satisfactory results have been obtained by adopting a slag control system, as shown in Figure 15.

As a result, we have been able to ascertain that we can turn out by converters all the varieties of steels that open-hearth furnaces produced, without lowering the grade of the products. This is in a large measure due to the facility of temperature control in the converter method. It has also been demonstrated that converters are superior to open-hearth furnaces in points of productivity and cost. From these results, we have concluded that technically we can afford to abolish all open-hearth furnaces any time.

Although we are still experimenting in the field of all alloy steels, we can go a step further and say that converters are far more efficient than open-hearth furnaces. There is no question about such varieties as C 1.1%, Si 1.8%, Mn 1.7%, Cr 1.2% steels, and work has already been started in actual production of them by the converter. As far as these steels are concerned, the remodelled plants can fully compete with electric furnaces as to grade and cost.

Kamaishi converters are already operating on a par with ordinary newly-installed converters, and are producing medium and high carbon steels to the proportion of 70 per cent of the Works' total steel production. The medium carbon steels they are producing are steels for the production of structurals, sheet piling and shipbuilding materials and the high carbon steels are for that of machine structurals, wire rods, rails and the like. Very satisfactory results are being obtained in the production of all these items, proving the superiority of the converters over the open-hearth furnaces in point of cost and productivity and also in point of grade.

In the case of Hirohata, too, steels for R-H vacuum degassing which requires high temperature tapping, are easier to blow in a converter than in an open-hearth furnace.

6. COMPARISON BETWEEN THE REMODELLED CONVERTER PLANTS AND NEWLY BUILT CONVERTER PLANTS

As already stated, there are various restrictions involved in setting up BOF in already existing open-hearth plants, but these are of a nature to be completely settled technically. It has been proved that it is possible to remodel open-hearth plants into converter plants without any loss in operational efficiency or productivity.

The effects of the remodelled plants will be great. Table 1 gives a comparison between the establishment of a new converter plant and the conversion of an existing plant, which shows that in case of plant conversion, a large portion of the existing facilities such as buildings and various other types of equipment can be used without any alteration. The advantages of such plant conversion, thus, are quite obvious.

In the following circumstances, the proposed remodelling method is far more advantageous than newly erecting a converter plant:

1) In the case of building a steelmaking plant whose production capacity is not to be very large, say, from 80,000 tons to 120,000 tons a month. This method provides maximum economy in construction, and yet ensures a more than sufficient steelmaking output to make up for the original open-hearth furnace output.

2) In case there is no need to vastly increase the ingot production of the steelworks as a whole.

3) In case continuous casting equipment and degassing equipment are rationally combined for production work.

4) In case the plant site is small and it is difficult to obtain an

additional site for a new plant.

5) In case the steels to be produced are very varied and orders come in small lots.

6) In the case of aiming at quick results from investment, the short period of construction required and the small amount of investment are just the features desired.

In Table 2 we have shown how the present remodelling possesses a merit far beyond anything obtainable by installing an additional open-hearth furnace. Comparisons were made between the No. 6 open-hearth furnace which started operation in January 1960 at the Muroran Works and the present 50 ton test converter installed there.

7. CONCLUSION

In order to effect rationalization of open-hearth plants, or, more broadly speaking, to rationalize the whole steelmaking processes, we have built a 50 ton test converter in the open-hearth shop of the Muroran Works and have investigated the technical problems related to the steelmaking efficiency of such a plant, and the equipment problems such a conversion entails.

As a result, we have ascertained that in spite of the savings in cost and shortening of the period of construction made possible by this remodelling method, the productivity resulting from the conversion is such as to be fully equal to any newly-built converter plant.

Accordingly, we have built two converters to be operated on really commercial scales in the open-hearth shop of the Kamaishi Works, and have been able to obtain satisfactory results. We may safely assert that this method of conversion yields far greater advantages than newly installing a converter shop.

It is also expected that converters operated in combination with continuous casting facilities, now under construction, will greatly contribute to cost reduction.

Hirohata successfully rationalized its steel production work as scheduled, and also succeeded in the operation of 100 ton converters with a relatively high efficiency. We are confident that these achievements are no less important than the construction of new converter plants.

The foregoing has been a report on the conversion of open-hearth furnace plants into converter plants. We succeeded in blowing all types of steels in converters which were previously made in open-hearth furnaces, and we are satisfied that almost 100% of our crude steel is now produced in converters.

References

1) M. H. Trenkler — Ein Jahrzehnt LD-Verfahren (1961).

2) C. Maeda et al. — Tetsu-To-Hagane (Journal of the Iron & Steel Institute of Japan), 43 (1957) p. 221; 44 (1958) 7, p. 733; 47 (1961) 3, p. 335; 48 (1962) 11, p.1354.

3) R. P. Krause — Iron & Steel Engineer, 41 (1964) 7, p. 121.

4) Pannel Discussion — Tetsu-To-Hagane, 50 (1964) 2, p. 217.

Photo 1

50 Ton Test BOF of Muroran Works

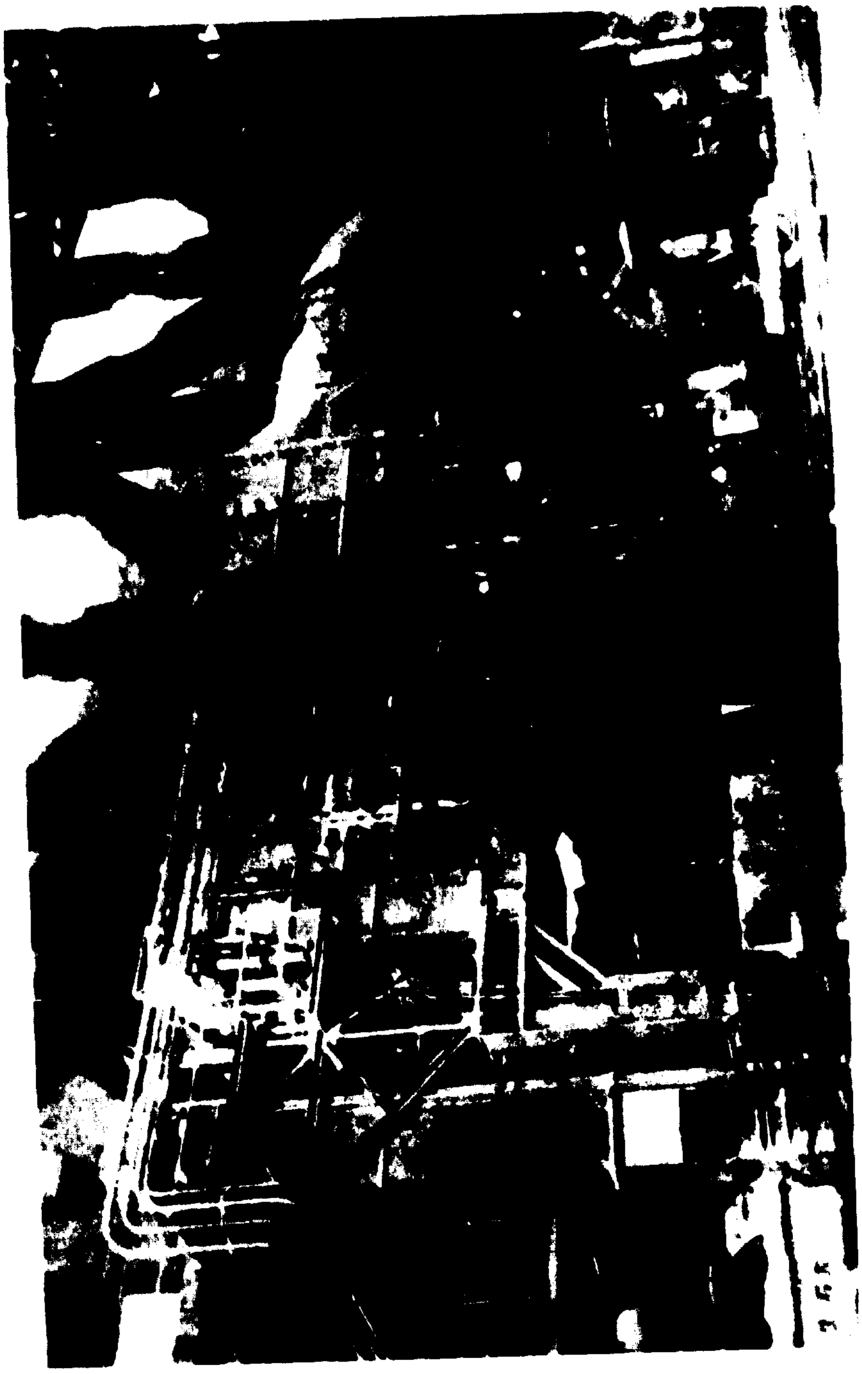


Photo 2

90 Ton BOF of Kamaishi Works

Photo 3

100 Ton BOF of Hirohata Works

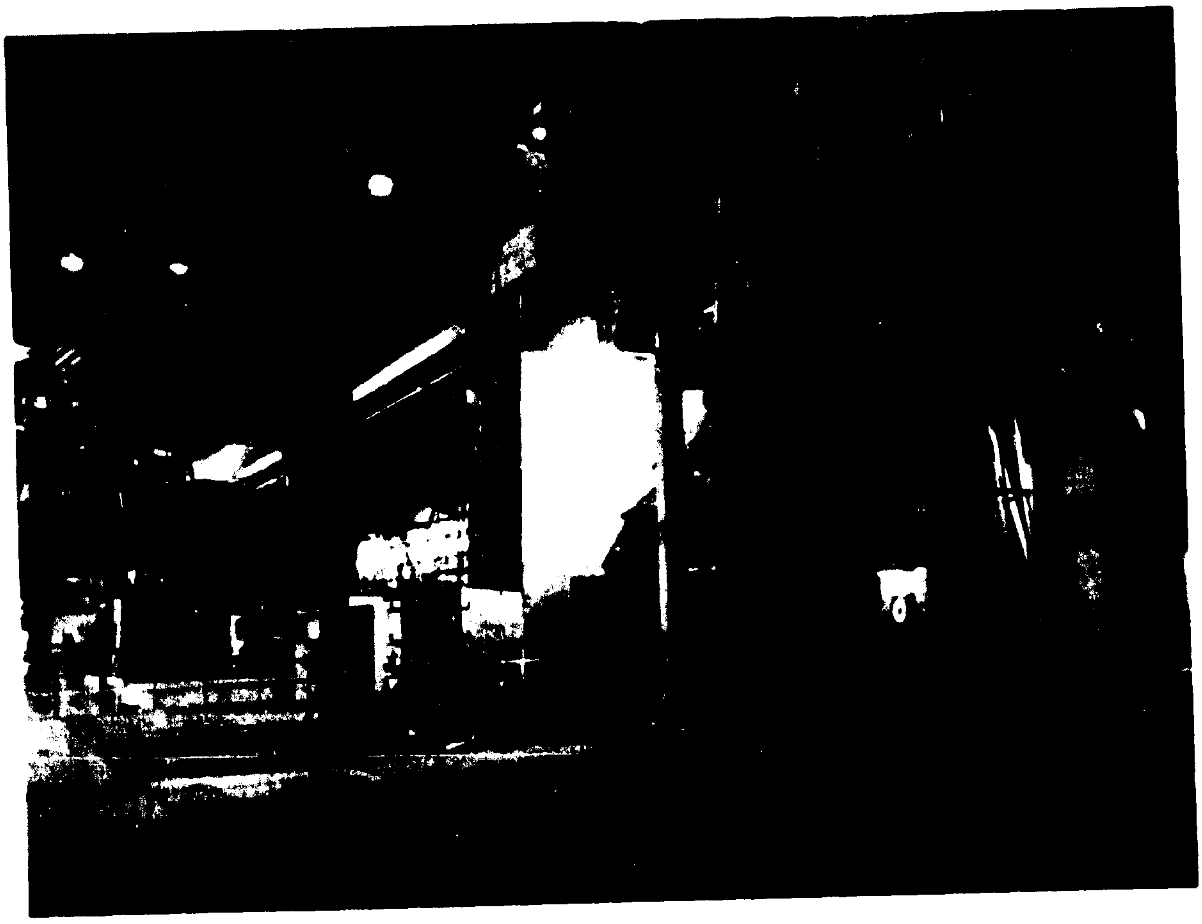
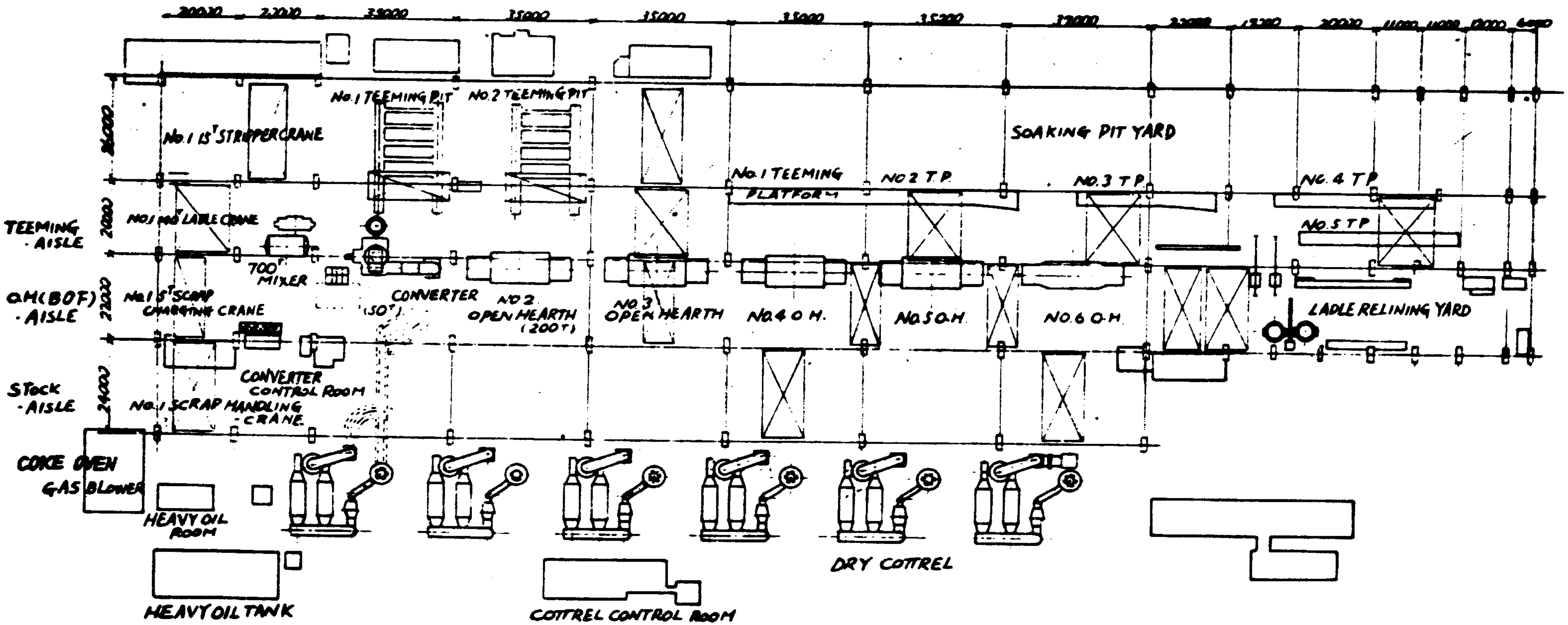


Figure 1

Layout of Open Hearth Shop of Muroran Works



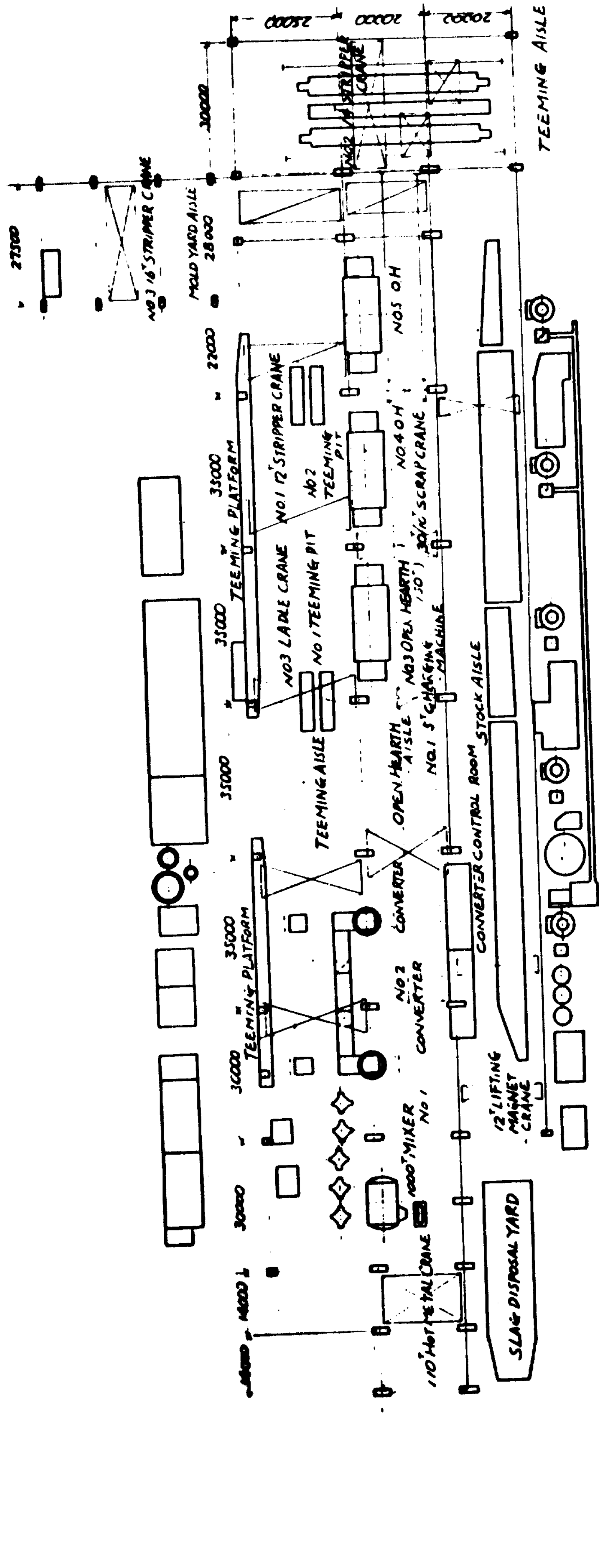


Figure 2

Layout of Open Hearth and BOF Shop of Kamaishi Works

Figure 3

Layout of Open Hearth Shop of Hirohata Works

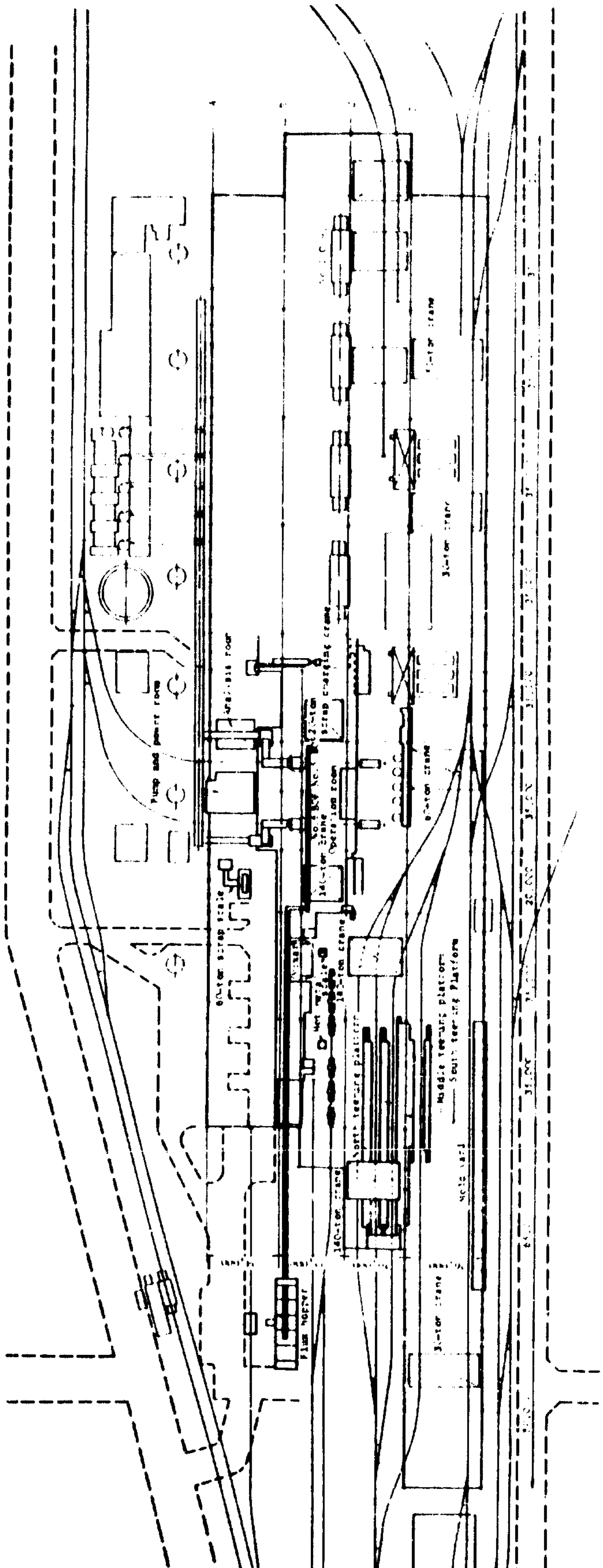


Figure 4

Plan View of 50 Ton Test BOF (Muroran)

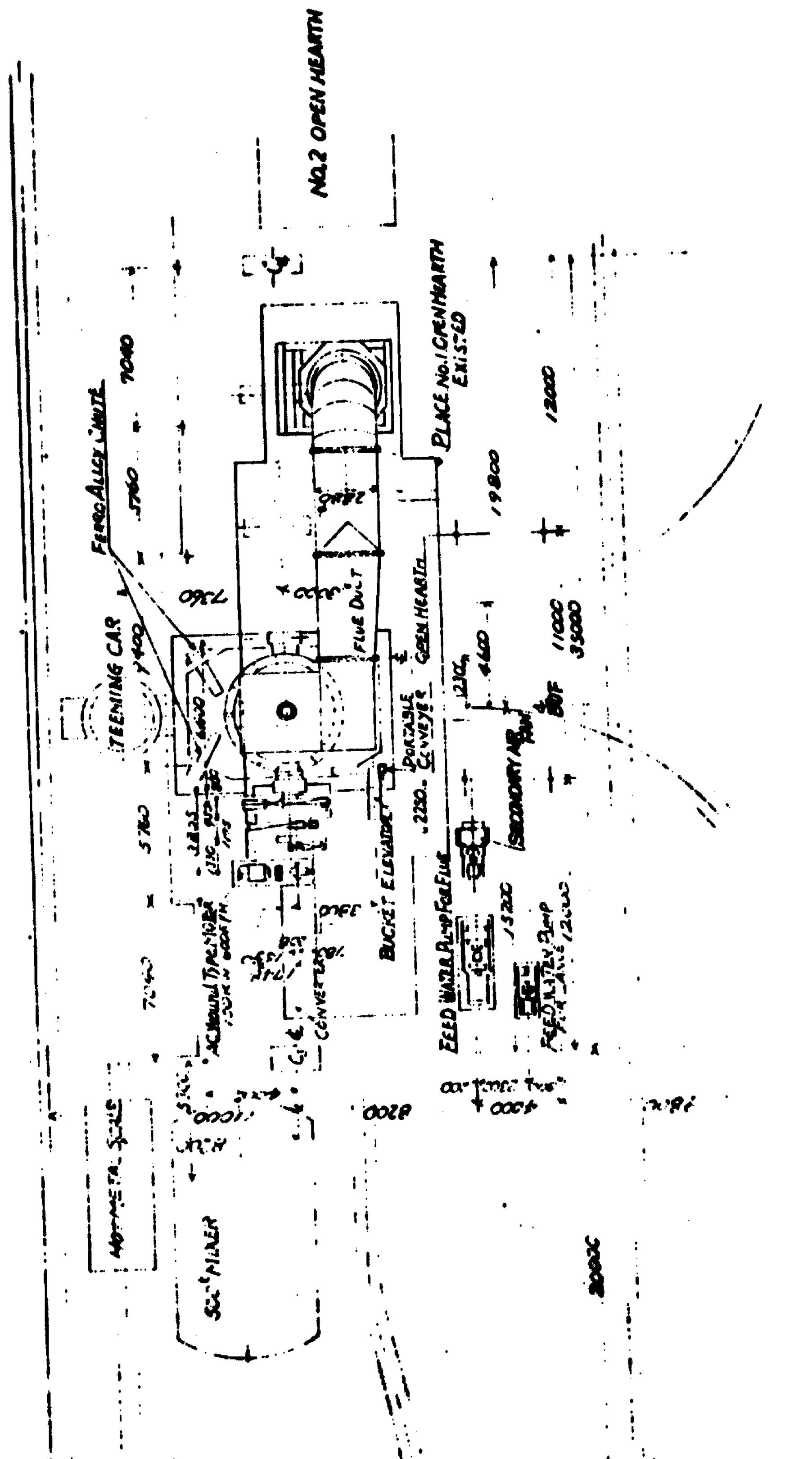


Figure 5

Cross Section of 50 Ton Test BOF (Muroran)

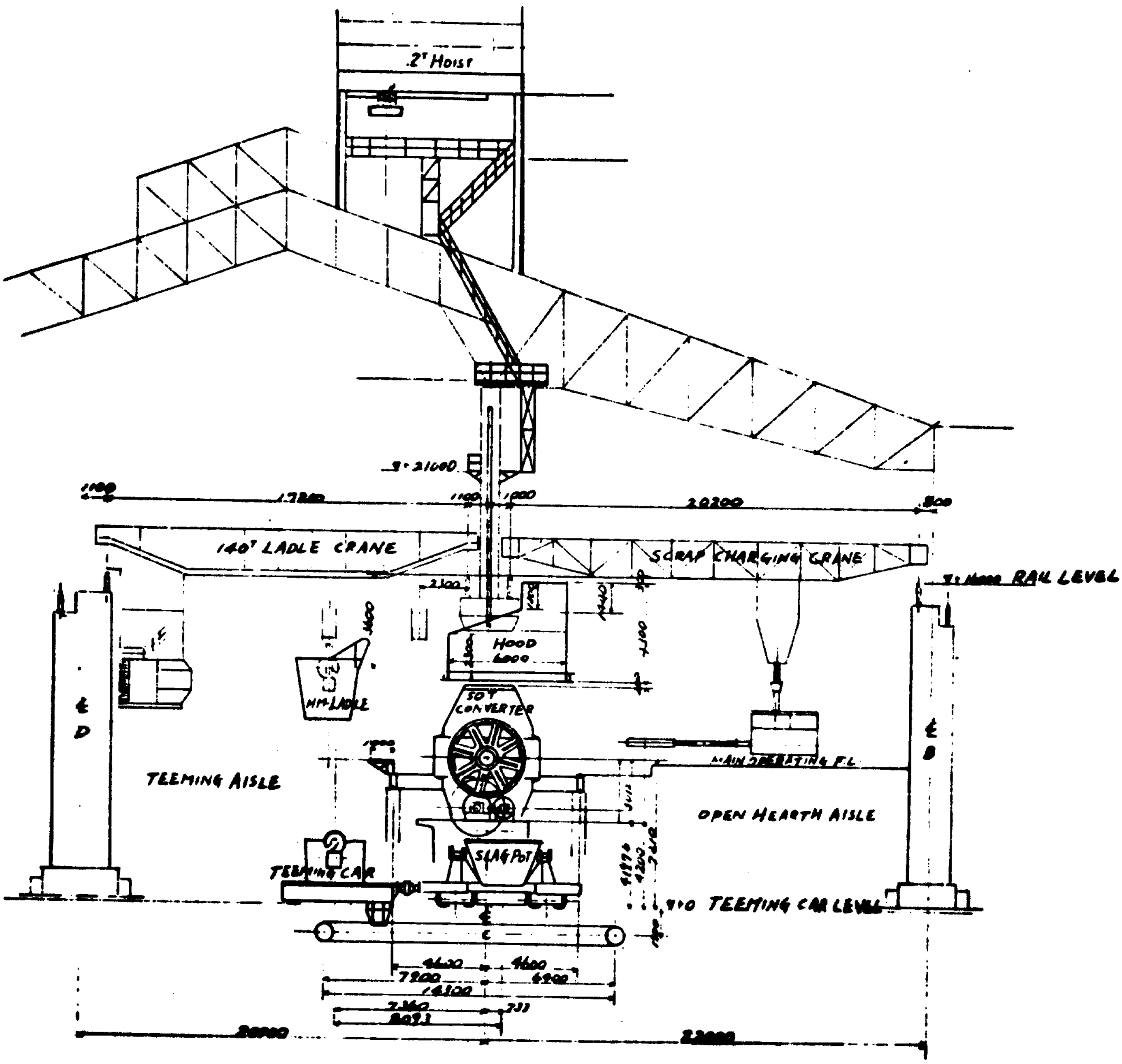


Figure 6

Plan View of 90 Ton BOF (Kamaishi)

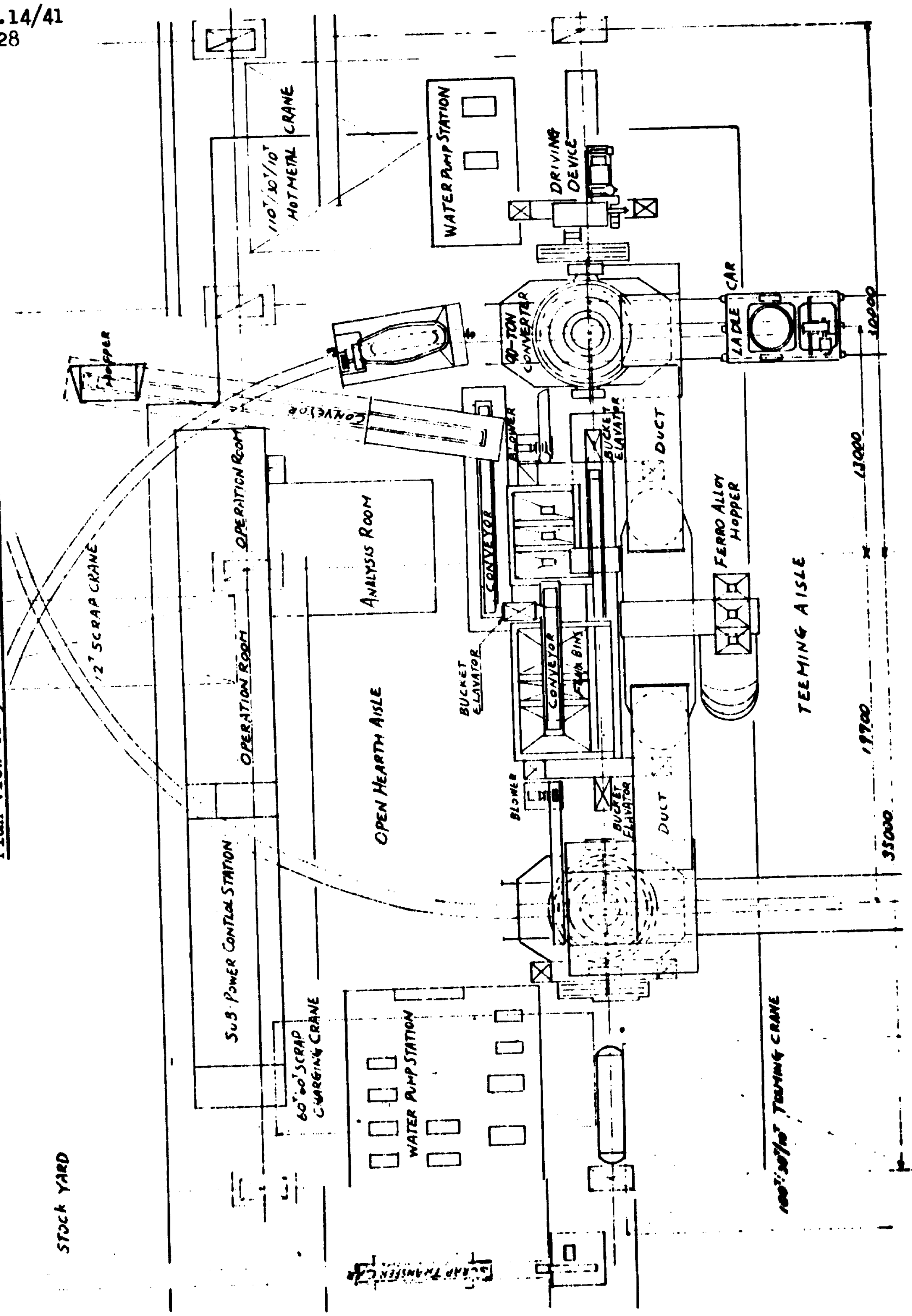


Figure 7

Cross Section of 90 Ton BOF (Kamaishi)

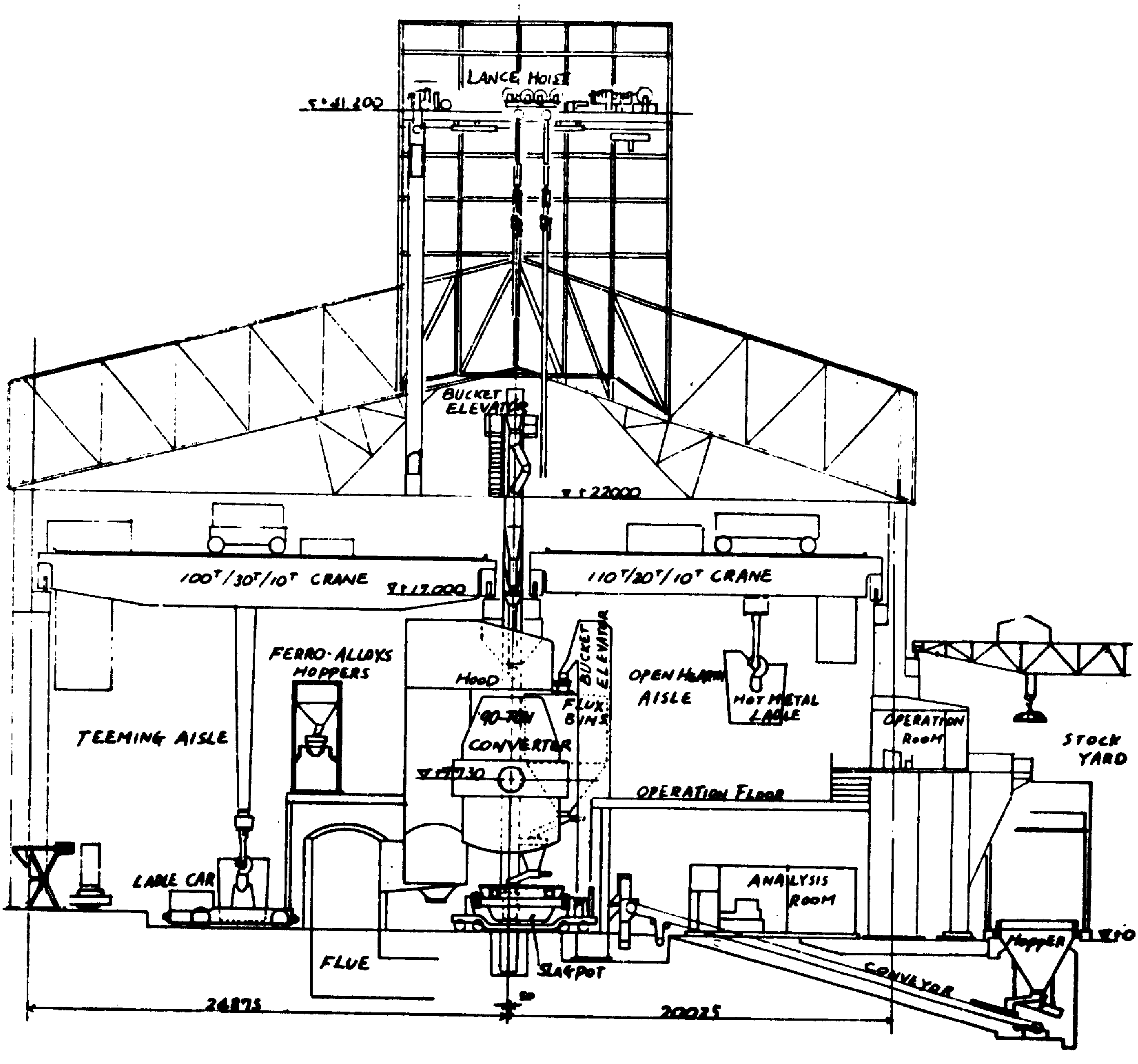


Figure [illegible] Cross Section of 100 Ton BOF (Hirohata)

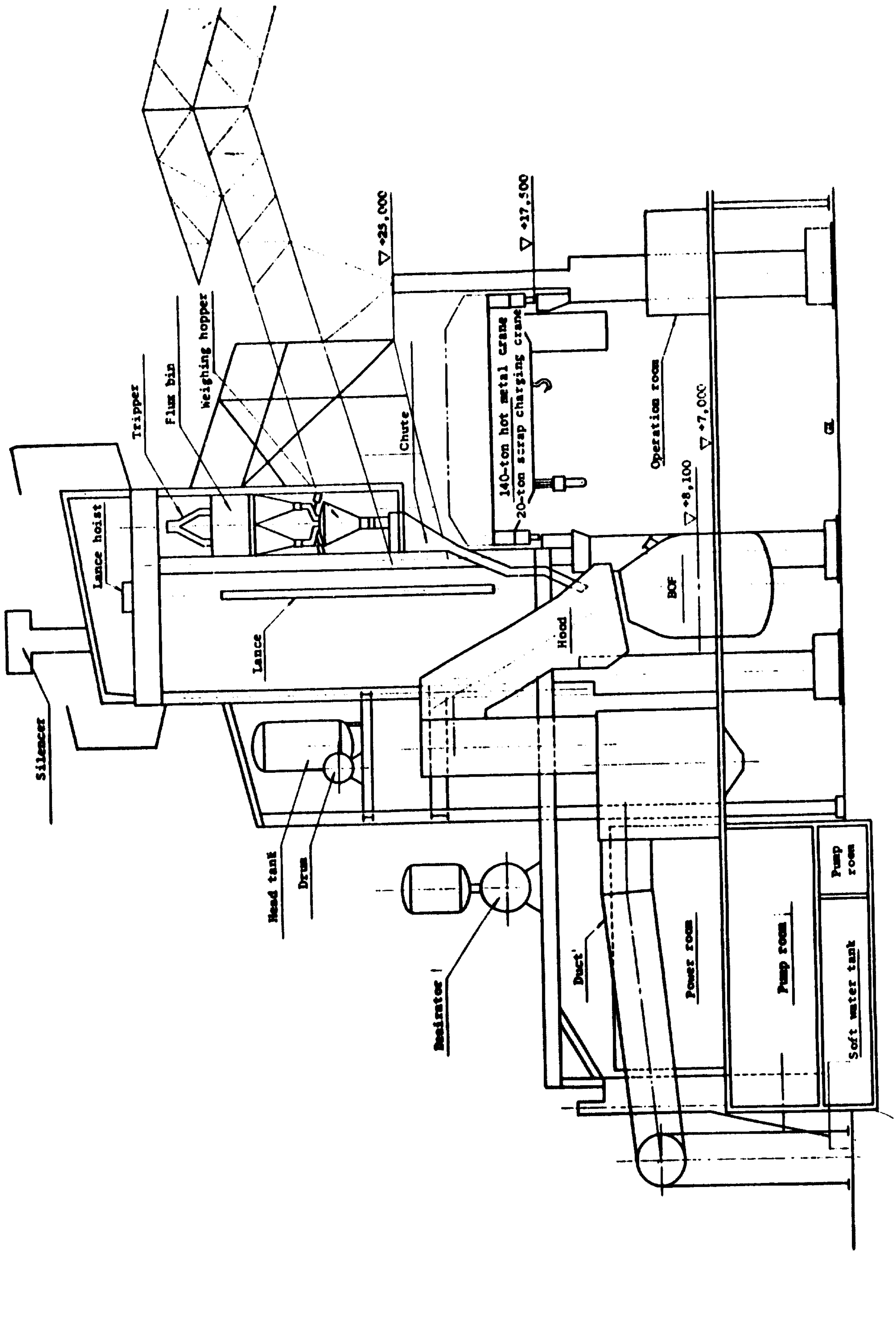


Figure 9

Flux Equipment of 90 Ton BOF (Kamaishi)

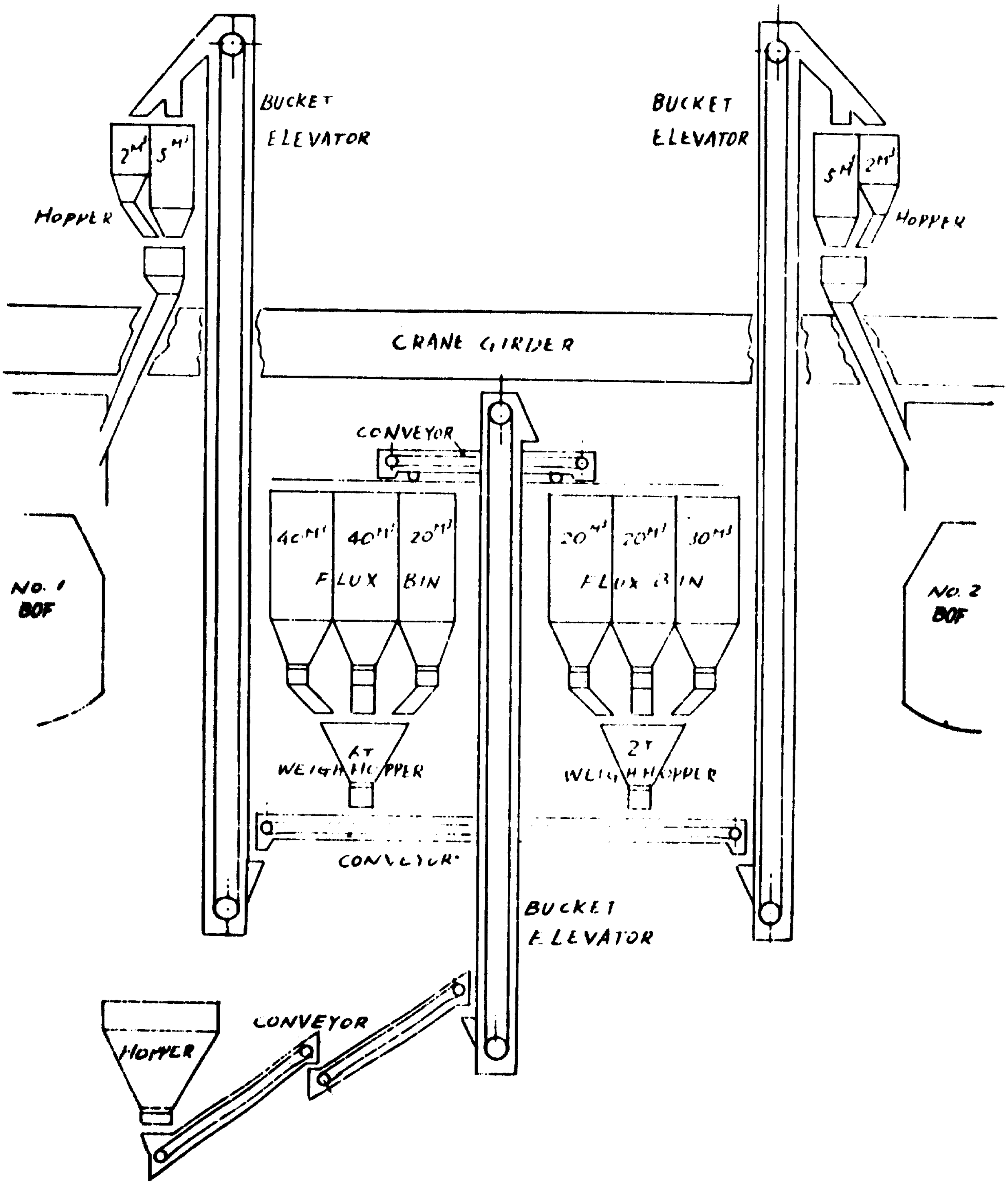


Figure 10

Construction Schedule of 50 Ton Test BOF

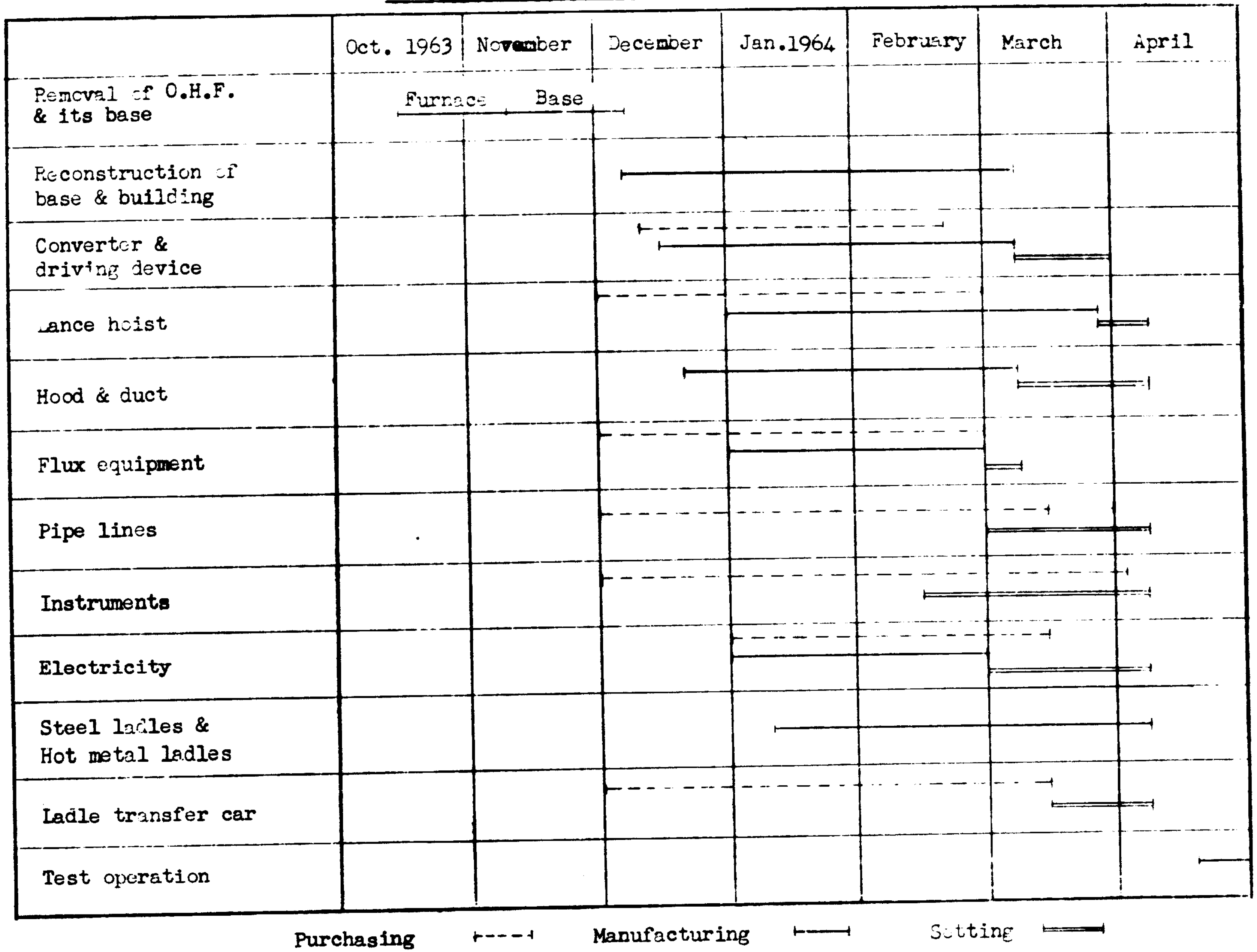


Figure 11

Construction Schedule of 90 Ton BOF

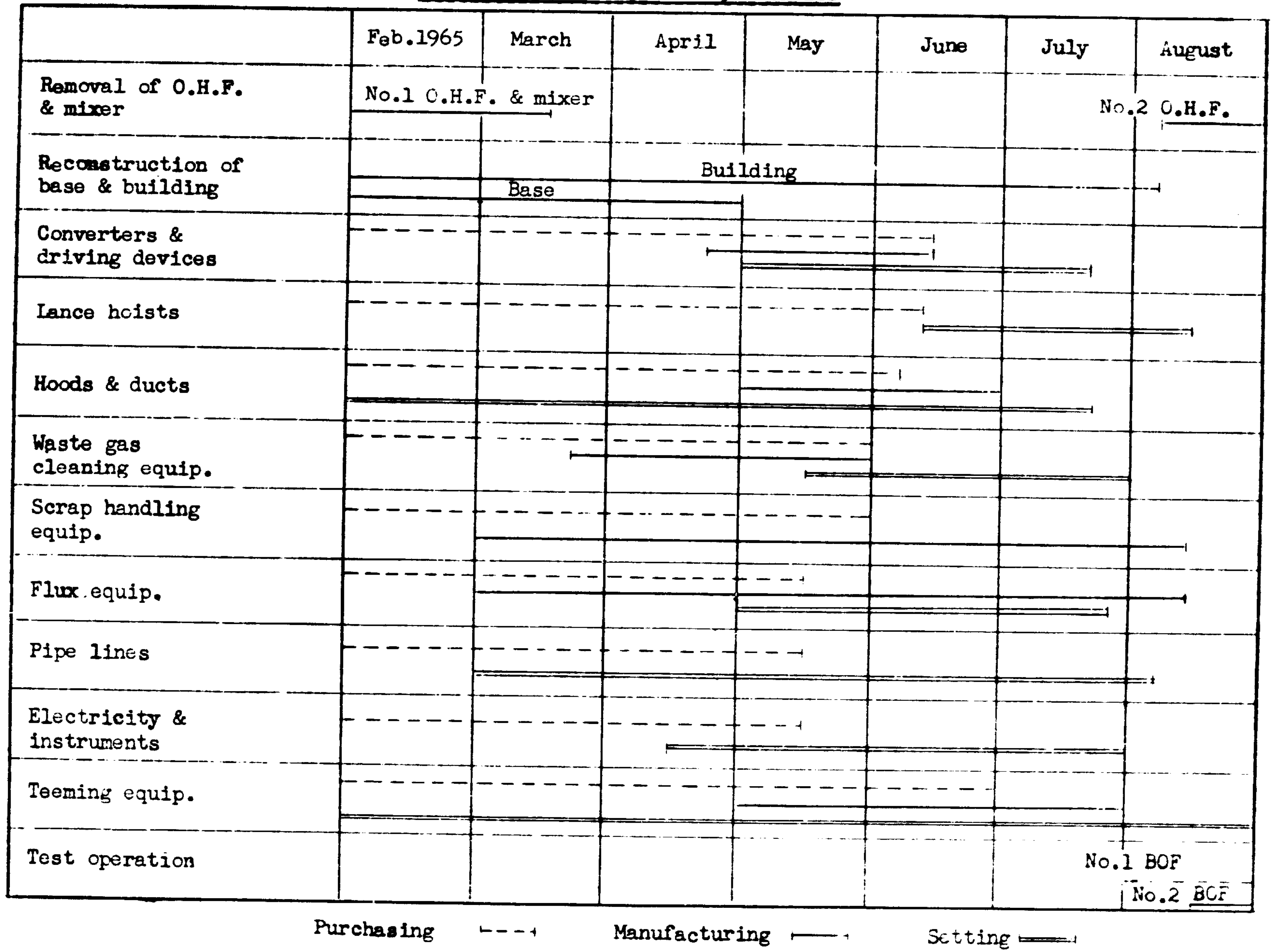


Figure 12

Operation Results of 50 Ton Test BOF

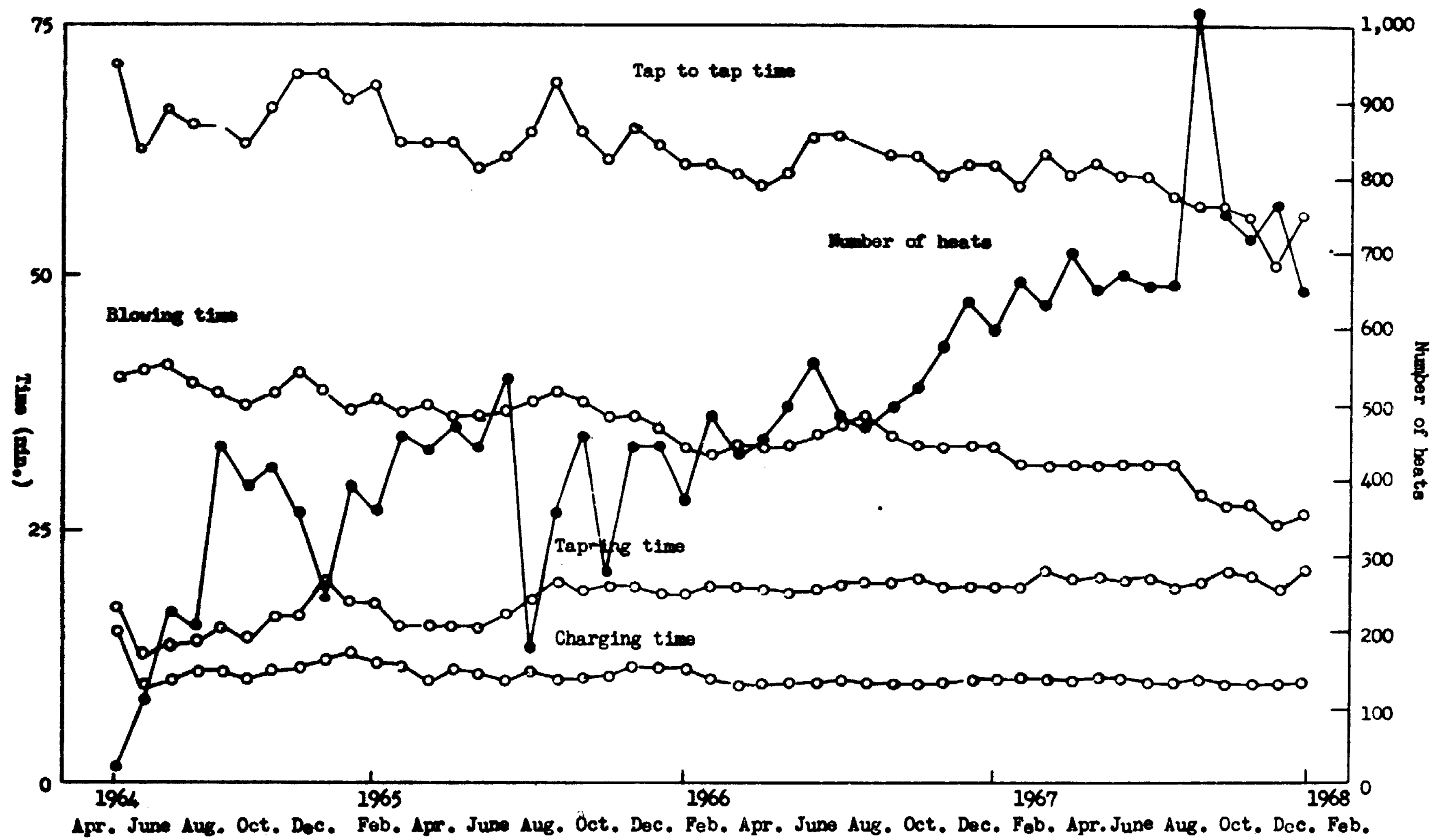


Figure 13

Operation Results of 90 Ton BOF

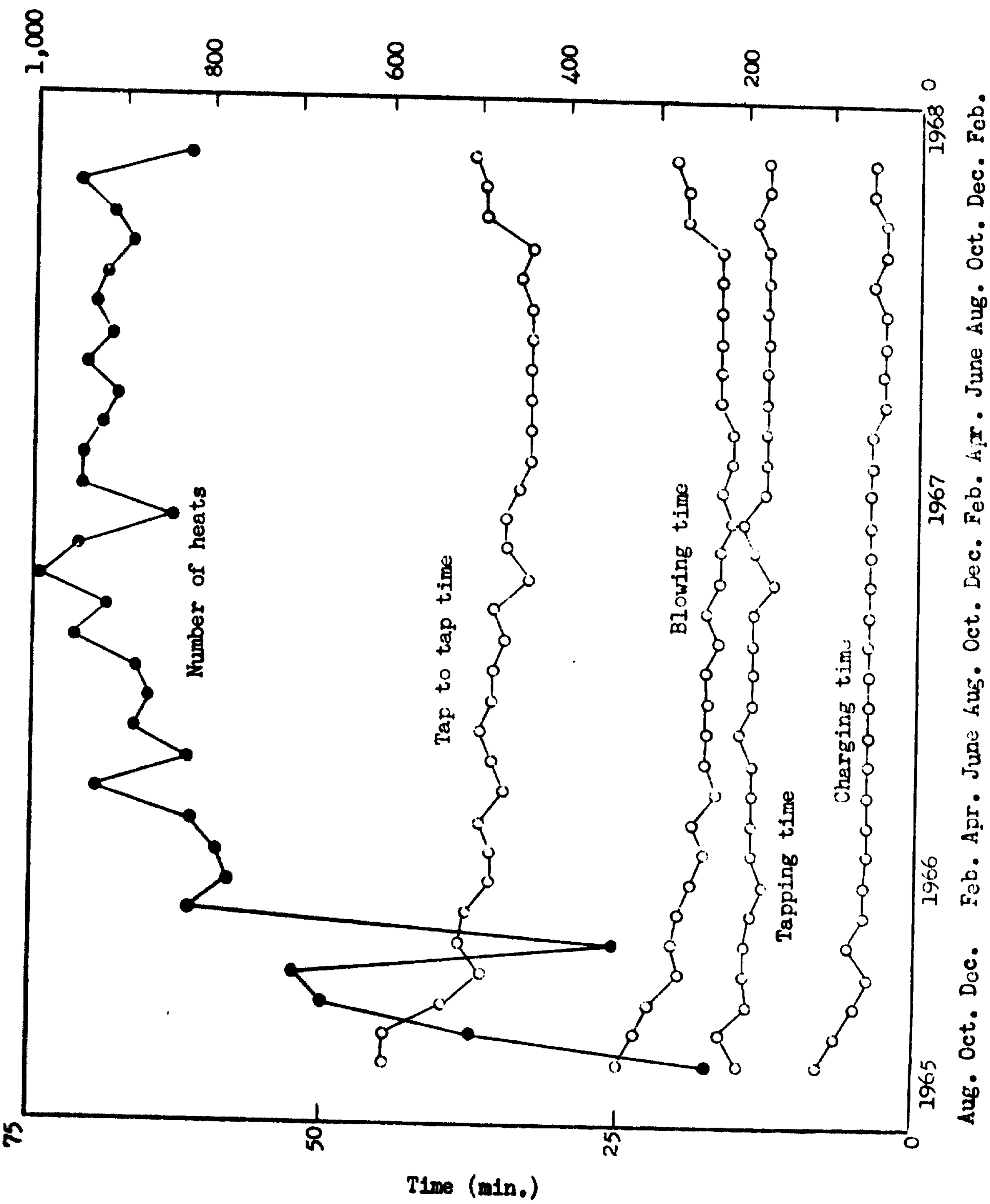


Figure 14

Operation Results of 100 Ton BOF

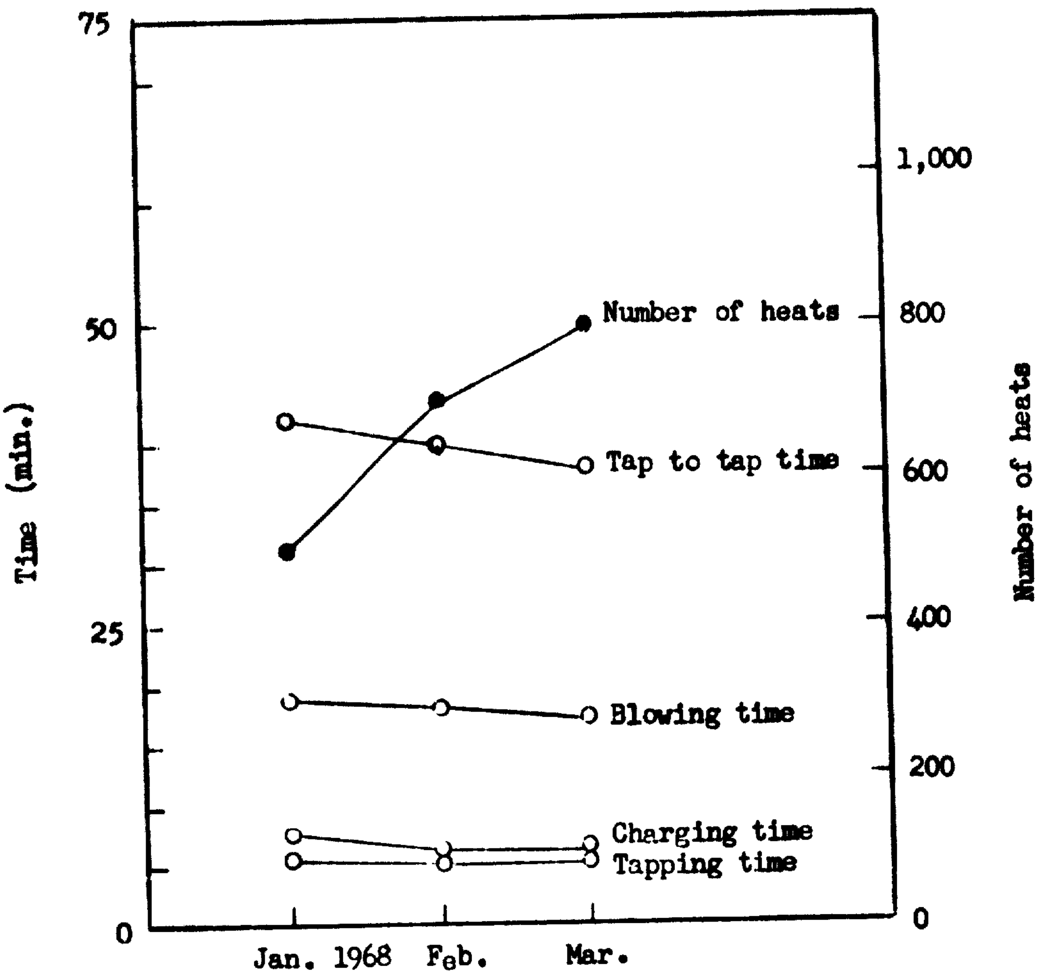


Figure 15

Relation between %(C) and %(P) at end points

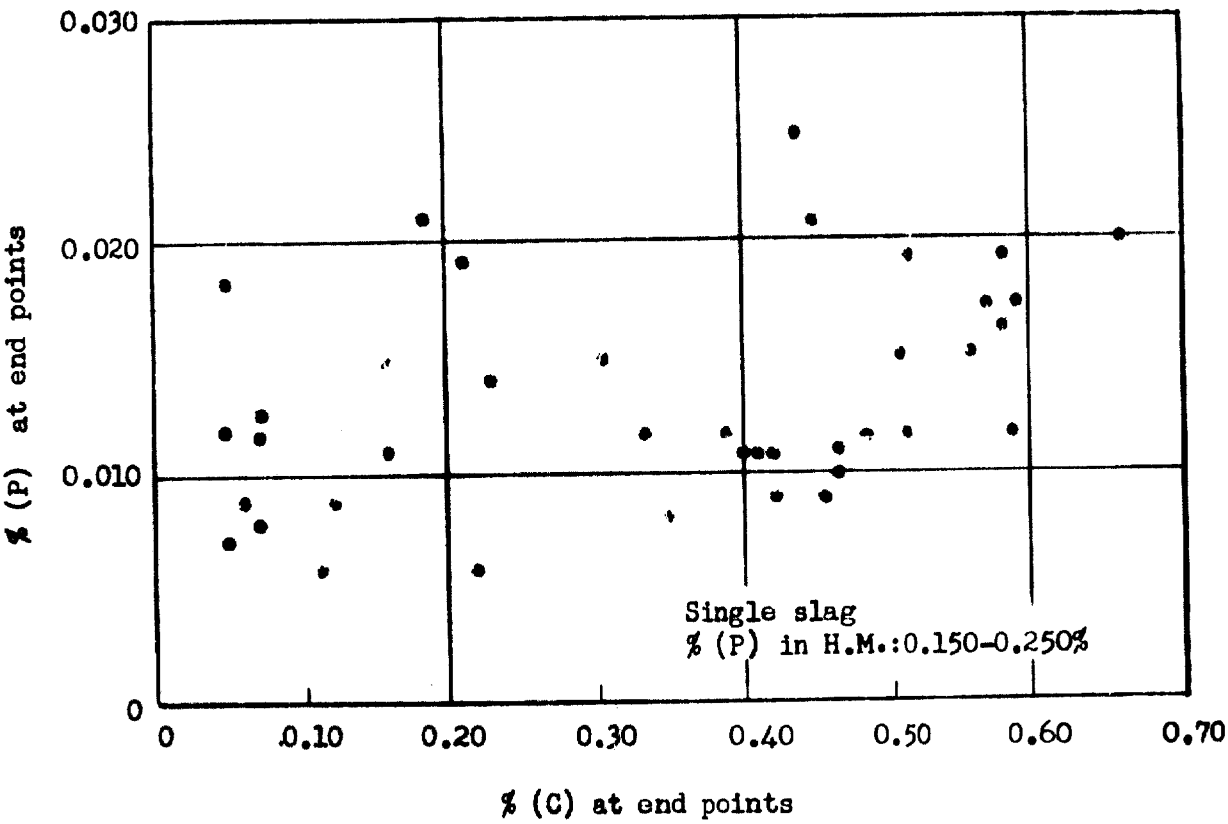


Table 1

New BOF or Conversion of Open Hearth?

	Converted BOF in existing O.H. mill	New BOF mill
Base	△	×
Building	△	×
BOF converter & driving device	×	×
Lance hoist	×	×
Hood & duct	×	×
Waste gas cleaning equip.	△	×
Hot metal handling equip.	△	×
Scrap handling equip.	△	×
Flux equip.	×	×
Teeming equip.	△	×
Ladle repairing equip.	○	×
Ingot & mold handling equip.	○	×
Removal of O.H.F.	×	×
Site for plant	○	×
Installation cost (ratio)	1	2.5
Installation time (months)	6	12
Furnace capacity	60T x 2	60T x 2
Ingot output (tons per month)	70,000	70,000

Remark:

Mark ○ can be fully used.

Mark △ can be almost fully used.

Mark × needs new installation.

Kinds of steel and their ratio

Rimmed steel, top pouring:	20%
Rimmed steel, bottom pouring:	11%
Semi-killed steel, top pouring:	54%
Killed steel, bottom pouring:	15%

Table 2

Comparison: BOF with O.H. Furnace

	O.H. furnace	BOF
Furnace capacity (tons per charge)	200 (stationary)	50
Ingot output	20,000	25,000
Installation time (months)	10	6
Installation cost (ratio)	4	1

74. 10. 17