On the Construction and Operation of Mizushima Iron Works*

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I. Introduction

The trend to construct a large integrated iron and steel plant at an entirely new site, which has proved to be the decisive factor in raising rapidly the international position of Japanese iron and steel industry high in the world's top level in these years, was first set model for by Kawasaki Steel Corporation in the Chiba Iron Works soon after the War in 1951.

This works, the construction of which was started in many public opinions, both pro and con, was able to achieve the scale of one million ton of crude steel annual, with two blast furnaces, one open-hearth shop, one slabbing and blooming mill, and one hot and cold strip mill, only as late as in 1956 owing to the great depression that hit this country in the course of its construction. In this year, the late Yataro Nishiyama, the first president of the company, recognized the necessity of constructing another iron works in order to match the expansion of Japanese iron and steel industry that he foresaw in the near future; he started to seek for a suitable plant site, on one hand, and to enlarge the capacity of the Chiba Works, on the other.

Although this inquiry for new site was conducted all over this country, places farther west than Osaka, especially those districts that are along the coasts of the Seto Inland Sea, were considered preferable, because the construction of the modern Chiba Works was then still in progress in the eastern Japan. After careful inspections of several promising candidates, the Mizushima district was finally decided on as the new site. It was 1961.

Photo. 1. Whole view of Mizushima Iron Works

II. Reasons of Selecting Mizushima as the New Site

1. Land Area Requirements

At the time when construction of the Chiba Works was in planning, one million ton of steel ingot in its 3.3 million square meter campus was thought to be the eventual scale of the then new iron and steel plant; the subsequent addition of new equipments and facilities, however, has made the site rather small in several years.

As a general tendency, owing to the technical innovations that often necessitate the use of ever greater equipments, the economically adequate scale of an iron works has become larger and larger; it shifted from one or two million tons annual to four or five in 1950's and to eight or ten in 1960's, so much so that the iron works now in construction or in planning in Japan are all aimed at the scale of over 10 million tons annual.

When the possibility of future expansion in iron and steel industry is taken into consideration, furthermore, a plant site in which 15 or 16 million tons of steel can be produced must then be secured.

The Mizushima district is situated at the mouth of the Takahashi River, and the shoal extends to some distance, so that a large land area can be reclaimed easily to accomodate such an iron works.

After several studies on the scale of iron works, it was decided that in the first stage of construction the new iron and steel plant to be built would have the capacity of 11 million tons of crude steel in an area of about 8.35 million square meters; this includes that already reclaimed and the 4.3 million square meters to be reclaimed of the sea in the future.

2. Natural Conditions

At the Mizushima district, that faces the calm Seto Inland Sea, it is so mild that typhoon, flood, and even earthquake are the seldom occurrences.

The site is composed of a land already reclaimed on the sand bank with sand and soil that the Takahashi River had brought over and a land to be newly reclaimed from the sea; at 12-16 m under the sea level there is a sand and gravel layer of about 30-m thick having *N* values of over 50, which is perfectly suitable for the installation of heavy structures of iron and steel plant.

Generally, the iron and steel industry consumes a large quantity of industrial water. This is met by the

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neighbouring Takahashi River, the greatest in Chugoku provinces, which can supply easily about 300 000 m³ of water daily, the quantity that is to be required eventually in this works.

3. Economical Conditions

As the sea to be reclaimed in the first period of construction is shallow, the maximum depth being 3.5 m, and the soil volume required for making land is small, the estimated cost for reclamation was very low, of the order of 4 U. S. dollars per square meter. In addition, the dredging for sea route was to bring forth a great volume of good sand and pebbles, that can be utilized as the raw materials for concrete blocks.

Moreover, this district, being situated in the middle of the Inland Sea, is convenient on both sea and land; especially, as large carriers can enter into the Mizushima Route (depth 16 m) from the mains of the Seto Inland Sea, the new iron works that is to depend solely upon marine transportation can enjoy a low cost freight.

The Mizushima district had then been opened just recently as a new industrial region by the local government, and an ample labour was still available in the hinterland for the new iron works to tap on.

This district is neighbouring on the Osaka-Kobe Industrial Region, and also there are many industries such as automobile and ship-building along the Inland Sea. The new works will meet demands from these industries most readily.

It was on these advantages described above that the company had chosen the Mizushima district as the plant site of its second iron and steel plant in western Japan; it was to complement each other with the Chiba Iron Works in the eastern Japan.

III. Layout of the Works

The extent of the area, which the company selected

as the new plant site, was to be bounded by the following three lines as shown in Fig. 1, the Mizushima sea route, the Tamashima sea route to be excavated, and the line parallel to the western bank of Takahashi River, the peculiar shape of the land being the main factor in deciding the layout of the works.

When considering the layout of a large-scale iron works that produces 11 million tons of ingots annual as the first goal of construction, it is essential that each shop must reasonably be arranged with regard to the transportation of raw materials and products, both semi- and finished, within the works.

As the raw materials and products were to be transported by sea into or from the works, it was desirable to provide the plant with a long seashore. The land transportation within the campus, on the other hand, had to rely on the railway, for not only all the materials except those for the blast furnace are heavy and massive but the transfer of them very frequent. In this case the primary requisite is that the railroads must not get tangled up, lest the transporting time will be prolonged by increase of stoppages of trains, the arrangement of equipments be restricted on account of the layout, and any modification of arrangement conceivable in the future innovation be, if not entirely denied, hindered. From these reasons, the layout was studied so that the raw materials and the semi-and finished products would flow without stagnation in one direction down to the final stage, and after many trials, the one shown in Fig. 2 was finally decided.

In this layout, the entire area projected for the new works is divided into two zones: one that is for the first stage of construction is of boot-like shape covering about 8.45 million square meters, and the other is for the future expansion.

In order for the large carriers of over 150 000 DWT to approach easily the ore or coal wharf, an inland sea route connecting to the Mizushima route (16 m deep)

Fig. 1. Plant site of Mizushima Iron Works

Fig. 2. Layout of Mizushima Iron Works

was made in the site. Along this inner route was constructed a long wharf (—16 to —17 m deep) for unloading ores, whereas the coal wharf was to be constructed along the Mizushima route.* Behind and in parallel to these wharfs laid were the ore and coal yards, and about the same distance farther from these yards, blast furnaces were to be installed.

It was very difficult to decide how to arrange four mammoth blast furnaces. There are two ways in the arrangement of blast furnaces with hot metal railways running beside them; the first is the parallel disposition, and other the recession. There was, however, no space for arranging four big blast furnaces in a line, and moreover this arrangement would result in an extension of the hot metal railroad. As a compromise of the two ways, therefore, twin furnaces were arranged along the branches of hot metal railroad as shown in Fig. 3. With this disposition it was expected that in the rotation of hot metal cars, the criss-crossing of railroads can be minimized. It was this way that the iron-making facilities were snugly accommodated within the peninsula part of the site.

A main broad way called "Green Belt," passing through the remaining campus of rectangular shape, was laid down, in the middle of which ran electric cables of high voltage and main pipes for water supply, waste water, and other utilities; in the western area of the Green Belt the steelmaking and rolling equipments were arranged in good order; LD shops that consume almost all of the hot metal from blast furnaces were located in the southern part nearest to the group of blast furnaces; and several kinds of rolling mills were arranged in the order of the process towards north from the steelmaking shops.

At the time when annual 11 million tons of ingots are being produced, the finished-products in this works are to amount to approximately 9 million tons; as almost of them are to be transported on ship, two ports of shipment were provided for: wide flange beams and bars and rods are to be shipped off the berths along the inner sea-route, while plates, sheets, and coils the berths on the bank of Takahashi River.

The steel casting and forging facilities, the ferro-alloy shop, and other equipments of the 2nd and 3rd products, which are not directly related to the integrated plant, were placed at the northern part of the site.

It was true that in a peninsularly long and slender site, the transport of materials from its top to bottom was naturally disadvantageous at the initial stage of construction because the distance of transportation was long, but the reasonable layout gradually turned out to be profitable as the construction progressed.

IV. Construction Processes until the Establishment of Integrated Operation

When the Mizushima district was selected as the new plant site, the Chiba Iron works was still in the stage of enlargement, and it was not necessary to establish immediately the integrated operation in this

Fig. 3. Layout of No. 1 and No. 2 blast furnaces

district; besides there was little margin in the capital fund. In these circumstances the reclamation of sea was conducted only at a moderate pace.

On the other hand, in the manufacture of rods, out of which this company has been turning out wires and welding rods, the company had then to depend upon other firms for some of the intermediate steps of the process. This and the fact that the manufacture of bars was being done with outmoded machines had made the production unprofitable. In order to give a clear-cut solution to this problem, at first a modern bar & rod mill was installed in October, 1965 in the old reclaimed land. Next, as it became evident that the rolling capacity of mills of the company as a whole would become short for demands in the last stage of enlargement of the Chiba Iron Works, the No. 1 slabbing and blooming mill was scheduled so as to commence the operation in August 1966. It was after this that any attempt at the integration of operation was done. However, even at this stage the rolling facilities to be constructed next in the Mizushima Works was the plate mill, not the hot strip mill as might ordinarily be. This was because the capacity of plate mills of the company was not sufficient for demands.

In such a manner, the Mizushima Iron Works was at first given a character subsidiary to other plants of the company; the construction of the strip mill was postponed, and even now, in spite of having two mammoth blast furnaces, it is to remain for some time to come to be a plant that supplies semi-products to other plants.

In the mean time, the Chiba Iron Works had attained the scale of about 6 million tons of steel annual with the completion of No. 5 blast furnace in April, 1965; it has no more place to install any more supplementary equipments. Fortunately, at that time the reclamation of sea at the Mizushima district had been in progress as expected, and the integration schedule could be put into practice.

However, another difficulty was in waiting: owing to the depression the fund for construction became insufficient just when the schedule was going to be put into effect. It was considered then too much a burden for the company to complete in one stroke the whole one set of equipments having the production capacity of 2 million tons of steel; it could not be helped but to do with equipments having only one-

* At this moment, however, as the ore wharf has a surplus length, coals are also being unloaded there together with ores. When the third blast furnace is erected, the ore wharf will be prolonged and made deeper to —18 m.

half the capacity as the first step. This meant that even though the blast furnace or LD vessel themselves might have the capacity that would correspond to the 2 million tons of steel, but the accompanying facilities were limited to match the production of one million ton of ingots.

The saving of the capital fund was encouraged, sought, and achieved in every quarter. For example, in the iron-making department, as it was relatively easy, under the then existing materials situation of the company, to purchase fine iron ores for sintering, the burden for blast furnace was made mainly from sintered ore and partially purchased pellet and sized ore; this made it possible to postpone the construction of the sizing and screening facilities. Also only three out of the proper four hot stoves and one out of the original two casting floors to be arranged at the each side of furnace, were installed. In the steelmaking department, too, the berth for unloading the purchased scrap, unloader, and accompanying scrap yard were eliminated from the first step of construction by using only the return scrap as the charge for the converter.

Thus the construction of the new iron and steel integrated plant struggled under such an extremely restricting condition. Fortunately, however, the market situation turned favourable soon after the start of construction, and equipments at first postponed or eliminated were reclaimed one by one to the goal of annual 2 million tons of steel.

Later several new equipments were added, and the works is now able to boast the production capacity of annual 4.5 million tons of ingots by blowing in No. 2 blast furnace in January and No. 3 LD vessel in April, 1969. The eagerly wanted strip mills, hot and cold, are to be completed in January, 1970 and October, 1969, respectively, completing the formation of the modern iron and steel integrated plant.

The construction process of each equipment, details of facility, and its operational results are reviewed in the following sections.

V. Iron-Making Equipments

1. Iron-Making Capacity

Each of four large blast furnaces has adopted or will adopt the newest technical means as well as the experiences gained through the construction of No. 5 blast furnace in Chiba Works to decrease the production cost and to improve the productivity. They will be able to produce hot metal at the rate of 2.1 to 2.2 t/m³·day, and the total production will amount to 26 000 t/day, or 9.5 million t/yr as shown in Table 1.

2. Iron Ores

When the ratio of charged ore volume to the total burden of the blast furnace is 1.6, the annual requirement of the iron ore to be charged will amount to approximately 15.2 million tons, 70 to 80% of which is composed of sinter and partially imported pellet. Then the fine ore required for sinter will come to 9.6 million tons annually. On the other hand, the

Table 1. Iron-making capacity

Furnace number	Inner volume (m ³)	Production (t/day)	Date of completion
1	2 156	4 600	Apr., 1967
2	2 857	6 300	Jan., 1969
3	ca. 3 300	7 300	Sept., 1970 (planned)
4	ca. 3 500	7 800	Mar., 1972 („)
Total		26 000	

Table 2. Review of sintering machines

Machine No.	Grate area (m ²)	Production (t/day)	Date of completion
1	183	5 600	Mar., 1967
2	250	7 700	Jan., 1969
3	ca. 300	8 800	Sept., 1970 (planned)
4	ca. 300	8 800	Mar., 1972 („)
Total		30 900	

volume of sized lump ores to be charged amounts to about 3.8 million tons, and if 40% of the total unscreened ore volume becomes the fine ore through the process of screening:

the unscreened ore to be required: 6.36 million tons ($=3.8 \div 0.6$), and

the fine ore generated through the process of screening: 2.55 million tons ($=6.35 \times 0.4$).

Therefore, total iron ore requirements will be 13.4 million tons, *i.e.*, 6.35 million tons of lump ore and 7.05 million tons of fine ore.

There will be installed four lines of crushing and screening facilities, each having the treating capacity of one thousand tons per hour, in which the ore is to be crushed four times, and the sized ore will range 9 to 25 mm in size.

Sintering machines shown in Table 2 will be erected successively in order to secure the amount of sinter required; the machines are all the over-size Lurgi, and its total production will be about 11.3 million tons of sinter annually, capable of supplying the required sinter ore volume.

3. Iron Ore Yard

Figure 4 shows the arrangement of iron ore yards. Iron ores unloaded at the ore wharf are stored temporarily in the crude ore yard, in separate piles, according to their origin, then are divided into sized lump ore and fine ore through the crushing and screening facilities. The former is stored again in the sized ore yard in separate piles according to its origin to be conveyed to the sized ore bed when called for, whereas the latter is directly conveyed to the fine ore bed. At the beds they are blended repeatedly, and conveyed to the ore bins or the sintering machine. The ore transportation is conducted by the remote controlled belt-conveyers.

Table 3 shows the total area and storing capacity of all the ore yards and beds for imported ore that amounts to approximately 36 700 t per day; the beds

Fig. 4.
Arrangement of iron ore yards

Table 3. Area and storing capacity of ore yards

Name of yard	No. of yard	Total area (m ²)	Storing capacity (1 000 t)
Crude-ore yard	6	124 300	1 178
Sized-ore yard	5	26 300	696
Ore bed	10	72 000	600
Total	24	222 600	2 474

can store more than 65 day's provision of ore, which represents the sufficient storing capacity.

Miscellaneous raw materials such as manganese ore, limestone, and others, except iron ore, are unloaded by 500-t unloader at the ore wharf and stored in the auxiliary yards. These yards can also be used as the storage yard of sintered ore to a moderate quantity in order that the operational conditions of the sintering machine may not influence adversely the operation of the blast furnace.

4. Coal and Coke

When the coke ratio is fixed at 470 to 480 kg per ton of iron at the iron production of 26 000 t/day, the lump coke requirement amounts to about 12 400 t/day. In order to meet this requirement, coke ovens shown in Table 4 were planned to be installed; designed by the Carl Still Co., they are the largest oven in Japan the height of No. 1 and No. 2 coke ovens being 6 550 mm and that of No. 3 and No. 4, 6 800 mm. These coke ovens can not only supply the total coke required by all the blast furnaces, but also the fine coke for sintering machines.

Coals are unloaded presently at the ore wharf, but they will be unloaded at the coal wharf in the future; they are stored in the coal yards in separate piles according to their origins, and then conveyed through the crushing and screening facilities to the blending yard, where they are blended in the same way as for iron ores, a method unique to the Mizushima Works.

Table 5 shows the outlook of coal yards. As the coke production equivalent to tonnage in the coke bin near the blast furnace is about 12 740 t/day, the coal requirement amounts to 19 600 t/day and, as shown in Table 5, the total coal yards can store about 42 day's provision of coal; as this is somewhat insufficient, the coal yards will be supplemented by reclaiming sea if necessary. There is also a coke storage yard accomodating about 50 000 t of coke in order to damper out the effect of variation of operational conditions of the coke oven. Also, there are several chemical facilities for refining such by-products as tar. Coke ovens and other facilities are owned by the Kawatetsu Chemical Co., a subsidiary of this company.

5. Blast Furnaces and Their Operational Results

At present two furnaces are in operation, whose principal specifications are shown in Table 6.

The No. 1 blast furnace is almost the same as the No. 5 blast furnace of the Chiba Iron Works, only somewhat better. For instances, for the high top pressure operation the valve-seal type, rather than the

three bell type of the Chiba No. 5, has been adopted; it has taller hot stoves for better heat efficiency and bigger volume. Moreover, for transportation of hot metal torpedo cars of 250-t capacity are used; the liquid slag is cooled and solidified in the dry pits ad-

jacent to the blast furnace, so that the facilities for transfer of liquid slag pots might be safely disregarded.

The No. 2 blast furnace, blown in on January 13th of this year, is the most modern in that it was designed and fabricated taking the experiences in the No. 1 blast furnace and the newest technical means with zeal. The principal differences in the No. 2 blast furnace with No. 1 are as follows:

- (1) The furnace itself and its accompanying facilities are larger.
- (2) Instead of supporting furnace weight with six steel pipes as in the Chiba No. 5 and the No. 1, four steel pipes support the weight of the upper part of the furnace, while four shaft columns support the weight of shaft.
- (3) The bosh and belly are cooled by staves, while the shaft by cooling boxes of closed type.
- (4) In the facilities for high top pressure operation, the pressure equalizing is by the crude gas instead of the secondary equalizing by gas compressor.

Figure 5 (p. 55) shows the section of No. 2 blast furnace. These two furnaces are operating successfully as shown in Tables 7 and 8.

Each of the two furnaces has four hot stoves in contrast with the three that is common in this country,

Photo. 2. No. 1 and No. 2 blast furnaces (right, No. 2 blast furnace)

Table 5. Review of coal yards

Name of yard	No. of yard	Dimension of each yard (m)	Total area (m ²)	Storing capacity (t)
Coal yard	A	6	460×36	705 200
	B	6	530×36	
Blending yard	A	2	150×25.7	12 500
	B	2	287×25.7	
	C	4	255×25.7	
Total	20		262 384	825 700

Table 6. Principal specifications of No. 1 and No. 2 blast furnaces

	No. 1 blast furnace	No. 2 blast furnace
Hearth diameter	10.0 m	11.5 m
Inner volume	2 156 m ³	2 857 m ³
No. of tuyere	28	34
No. of tap hole	2	2
Charging method	Belt conveyor	Belt conveyor
Top pressure	1.5 kg/cm ² max.	1.5 kg/cm ² max.
Hot stove ;		
Type	Koppers, side combustion type	Koppers, side combustion type
Heating area	36 800 m ² ×4	51 800 m ² ×4
Blast :		
Temperature	1 350°C max.	1 350°C max.
Volume	4 500 Nm ³ /min	6 300 Nm ³ /min
Pressure	3.5 kg/cm ² max.	4.7 kg/cm ² max.

Table 4. Review of coke ovens

Coke oven number	No. of ovens	Oven dimension (mm)	Production (t/day)*	Date of completion
1	39×2	420×15 950 ×6 550	2 290	A group Mar., 1967
				B " Dec., 1967
2	43×2	"	2 530	A " Dec., 1968
				B " May, 1969
3	43×2	420×15 950 ×6 800	2 640	A " Jan., 1970 (planned)
				B " Sept., 1970 (")
4	43×2	"	2 640	A " Mar., 1971 (")
				B " Mar., 1972 (")
5	43×2	"	2 640	A " Sept., 1972 (")
				B " Mar., 1973 (")
Total	—	—	12 740	—

* In tons equivalent to that in the coke-bin near the blast furnace

because it was proved earlier that four hot stoves improved the heat efficiency better than three, and the increased capital expenditure was recoverable in a short period of time; this company will adopt this arrangement hereafter. Each furnace makes use of a process computer for collecting operational data and controlling furnace conditions.

VI. Steelmaking Equipments

As shown in Table 9, there will be two LD shops and an electric arc shop, and at the completion of the first period construction the total steelmaking capacity will amount to 12 million tons annual with some surplus.

1. The LD Converter Shop

The No. 1 and No. 2 LD shops have respectively three over-size vessels of inner volume of 331 m³ and

more than 400 m³; they are equipped with a gas recovery system of the IRSID-CAFL type for the mass production of plain carbon steel. The feature here is that, along with conventional casting facilities, continuous casting machines are installed in the LD shop. Moreover, in order to meet the customer specifications for steel qualities that are getting the severer of late, facilities of desulphurizing the hot metal, of vacuum-degassing the liquid steel, etc. are installed.

The No. 1 LD shop, with the addition of the third vessel in April 1969, has begun the normal operation of blowing two converters continuously while one converter is in repair; further, it has a vacuum degassing equipment of R-H type capable of treating a 200-t heat, a continuous casting machine that is among the world's greatest, and hot metal desulphurization facilities that are under construction. This shop will

Table 7. Operational results of No. 1 blast furnace

Date	Production		Coke ratio (kg/t)	Treated ore (%)	Blast temperature (°C)	Oxygen enrichment (%)	Top pressure (g/cm ²)
	(t/day)	(t/m ³ , day)					
Apr. 1967	(1 250) 542	0.58	662	88.4	724	—	71.8
May	2 238	1.04	550	92.9	911	—	122.0
Jun.	2 916	1.35	518	90.3	1 065	—	142.0
Jul.	3 019	1.40	510	87.3	973	—	143.0
Aug.	3 327	1.54	506	86.7	945	—	140.5
Sept.	3 713	1.72	492	83.2	976	—	141.7
Oct.	3 761	1.74	483	80.2	990	—	138.1
Nov.	3 583	1.66	483	82.2	988	0.4	137.3
Dec.	4 043	1.88	474	81.1	1 004	1.5	166.0
Jan. 1968	4 237	1.97	468	79.1	1 054	1.2	267.2
Feb.	4 587	2.13	475	73.3	1 064	1.4	599.0
Mar.	4 425	2.05	482	70.4	1 053	1.3	649.0
Apr.	4 370	2.03	478	71.3	1 033	1.3	801.0
May	4 669	2.17	477	70.3	1 049	1.4	1 088.0
Jun.	4 747	2.20	476	67.1	1 062	1.2	1 192
Jul.	4 311	2.00	488	73.9	1 084	1.5	979
Aug.	4 720	2.19	482	70.9	1 085	1.4	1 160
Sept.	4 210	1.95	494	67.2	1 057	1.5	1 043
Oct.	4 920	2.28	485	67.3	1 095	1.5	1 256
Nov.	4 669	2.17	489	71.6	1 083	1.4	1 098
Dec.	4 706	2.18	490	70.5	1 078	1.6	1 213
Jan. 1969	4 688	2.17	488	70.1	1 073	1.7	1 260
Feb.	4 296	1.99	494	72.2	1 045	2.0	1 165
Mar.	4 434	2.06	491	73.0	1 060	1.4	1 210
Apr.	4 373	1.98	478	76.4	1 069	1.2	1 104
May	4 386	2.04	499	70.0	1 036	1.2	1 055

Table 8. Operational results of No. 2 blast furnace

Date	Production		Coke ratio (kg/t)	Treated ore (%)	Blast temperature (°C)	Oxygen enrichment (%)	Top pressure (g/cm ²)
	(t/day)	(t/m ³ , day)					
Jan. 1969	(2 569) 1 574	0.90	588	59.1	884	—	154
Feb.	3 684	1.29	532	64.2	985	—	296
Mar.	4 026	1.41	506	67.8	1 003	—	514
Apr.	4 386	1.54	486	75.4	1 008	—	674
May	5 187	1.82	496	70.1	1 025	—	1 013

Fig. 5. Profile of No. 2 blast furnace

eventually produce, when provided with three continuous casting machines, the 2nd machine being scheduled to be put into construction in this autumn, mainly semi-products for plate, wide flange beam, and bar & rod. Figure 6 shows the layout of the No. 1 LD shop, which is now steadily increasing the production, together with the No. 2 blast furnace.

The No. 2 LD shop, on the other hand, is scheduled to start the operation when the 3rd blast furnace is blown in; it will contain three converters, each having an inner volume of more than 400 m³, and produce mainly ingots for the hot strip mill.

2. Electric Arc Furnace Shop

The equipments and machines of the Hyogo plant in Kobe, that is producing mainly steel castings and forgings, are getting old and inadequate in the capacity; an extensive renewal has since some time been contemplated. It has now been decided that the whole plant be removed to the campus of the Mizushima Iron Works and doing so revitalized. The new shop, as a part of this schedule, is now under construction; a ladle-refining furnace of the ASEA-SKF system will

Table 9. Outlook of steelmaking shops

Name of shop	No. of furnaces	Production capacity (1 000 t/yr)	Steels to be produced	Date of completion
No. 1 LD shop	200 t × 3	5 500	Carbon steel	No. 1 & No. 2, Apr., 1967 No. 3, Apr., 1969
No. 2 LD shop	250 t × 3	6 500	Carbon steel	No. 4 & No. 5, Sept., 1970 (planned) No. 6, Mar., 1972 (")
Electric arc shop	30 t × 1 100 t × 1	300	Special steel Carbon steel	In planning
Total		12 300		

Photo. 3. No. 1 LD shop

be completed in March, 1970 in its casting yard, and in the near future one 30-t and one 100-t electric arc furnaces will be installed to produce steels for casting and forging as well as some special steels. In the ladle furnace, which is capable of treating one 100-t heat, the liquid steel is vacuum-degassed, and the temperature and chemical composition controlled, so that from the plain carbon steel blown in an LD converter at low production cost are refined into those that are of clean and high quality enough for forgings.

3. Continuous Casting Machine

Since the beginning of the Mizushima project, the continuous casting has been the subject of intensive study and investigation. Table 10 shows the continuous casting machines now in operation and planning. As the production capacity of a continuous casting machine is expected to increase with the progress of its operational techniques, the future number of machines cannot be fixed now, but the total capacity of continuous machines will have to be at least 4.5 million tons considering the rolling capacity of two slabbing mills in this works. Then the continuously cast steel will occupy 40% of the total steel production, an important contribution to the saving of the overall

Fig. 6. Layout of No. 1 steelmaking plant

Table 10. Outlook of continuous casting machines

Ma- chine number	Casting	Working at	Heat size (t)	Annual capacity (1 000 t)	Serving for
1	Bloom	No. 1 LD shop	200	1 000	Medium flange beam mill, Bar & rod mill, Billet mill
2	Slab	„	200	1 000	Hot strip mill, Plate mill
3	Bloom	„	200	1 200	Medium flange beam mill, Bar & rod mill
4	Slab	No. 2 LD shop	250	1 500	Hot strip mill, Plate mill
Total	—	—	—	4 700	—

Table 11. Details of the No. 1 continuous casting machine

Type	All-curved type for bloom
No. of strands	8
Tundish	2, for 4 strands (inner volume 12 to 14 m ³)
Structure : Level of working floor	13 500 mm above the floor level
Radius of curvature (mm)	12 500
Ladle capacity	200 t (2 nozzles)
Bloom size (mm)	4 sizes : $\left. \begin{matrix} 200 \times 220 \\ 200 \times 300 \\ 250 \times 250 \\ 250 \times 300 \end{matrix} \right\} \times 3\,000 \text{ to } 10\,500$ (length)
Kinds of steel	Plain carbon steels (0.07 to 0.85%C)
Cutter	Torch cutter of Messer type
Hot-scarfer	Scarable size : 150×150 to 300×300 mm Scarf depth : below 5 mm Scarling speed : 5 to 70 m/min

production cost.

In the No. 1 LD shop, which has a production capacity of 5.5 million tons of steel annual, a total of three continuous casting machines are to be installed, of which the No. 1 machine for bloom is now in operation. The reasons why the machine for bloom was selected at first are as follows.

(1) The continuous casting of bloom or billet has since some time been put into stable practice everywhere in the world, and continuously cast blooms purchased from other companies have proved to be of excellent qualities.

(2) The rolling capacity of the No. 1 slabbing and blooming mill in the works can be raised markedly by substituting the rolled bloom by the continuously cast one.

(3) Bloom demand in the company exceeds the production capacity of the No. 1 machine.

(4) At the time when the No. 1 machine was being planned only a few and small slab casting machines were in operation, and further casting of the rimmed steel had never been successful.

Table 11 shows details of the No. 1 continuous casting machine. This machine has succeeded in casting one heat into 8 strands within one month since the commencement of operation, and by increasing production every month it is now producing about 40 000 t of blooms for bar & rod and junior H beam, and further experiments for casting steels of higher

carbon are in progress.

Table 12 shows operational results since its start. This machine was originally installed to augment the rolling capacity of the No. 1 slabbing and blooming mill, and it now plays an important role to contribute not only to the program of enlarging the continuous casting facilities in the Mizushima Works, but also to the schedule of installing newly the continuous casting machines in the Chiba Works.

As it is still now difficult to cast continuously the rimmed steels, which occupy a great part of the carbon steels now produced, especially those for the hot strip mill, however, this sort of steels will continue to be treated in conventional method, while as many of other kinds of steel as possible is going to be continuously cast.

4. Pig Iron Balance

The 9.5 million tons annual of pig iron the four blast furnaces are producing are to be distributed as follows.

1. Pig Iron Requirements for Ingot Mould Shop

Ingot moulds and stools used in the company have been produced by using a hot cupola in the Chita plant, near Nagoya. In order to decrease the production cost, however, a new mould casting shop was constructed, which produces ingot moulds by using hot metal from the blast furnace. The production capacity is to be brought eventually to the scale of 20 000 t per month of ingot moulds and stools, thence the annual hot metal requirement will be about 270 000 t for a production yield of 90%.

2. Pig Iron Requirements for Electric Arc Furnace Shop

When the production capacity of this shop comes to be 200 000 t of ingots, the annual hot metal requirement amounts to be approximately 55 000 t for a hot metal ratio of 25%.

3. Pig Iron for the LD Shop

The remaining quantity of pig iron is supplied to the LD shop, which is about 9.185 million tons annual. When the annual steel production is 11 million tons, the pig iron ratio will be about 77% for a steelmaking yield of 92%, figures that are proper for the LD operation.

5. Scrap Balance

Scrap requirement at the production rate of 11 million tons of steel annual amounts to about 2.9 million tons. Since the return steel and mould scrap are estimated to be 1.75 million tons, about 1.15 million tons of scrap must be purchased annually. At the existing scrap wharf, 500 m long and —7.5 to —11.5 m deep, this amount of purchased scrap can be unloaded without any difficulty, and there are about 500 000-m² wide scrap storage yards behind the wharf and around the LD shop. The scrap is transferred by dump trucks into the melt shop.

VII. Rolling Mill Equipments

The Mizushima Iron Works at its eventual scale of 11 million tons of steel annual will have following rolling mills in addition to the slabbing mills: one hot strip mill now under construction, two cold strip mills, one plate mill to meet the demands of shipbuilding in-

dustries on the coasts of Seto Inland Sea, two wide flange beam mills to supply all sizes of beam products, two bar mills, and one rod mills.

1. Slabbing and Blooming Mills

As shown in Table 13 three slabbing mills are to be installed, the total rolling capacity of which will be 8.7 million tons annual; since the No. 3 blooming mill will mainly roll the continuously cast blooms into billets, however, the actual rolling capacity is 7.4 million tons of ingots.

1. The No. 1 Slabbing and Blooming Mill

This mill was completed in August, 1966 to supplement the rolling capacity of slabbing mills of the company.

The soaking pits are of the top one-way firing type, using metallic recuperator of the Schack type; they are composed of four holes per pit, each of which can hold 200 t of ingots, equivalent to one heat from the No. 1 LD shop. Initially the operation was begun with eight holes firing the heavy oil, and now 16 holes are in full operation firing the mix gas.

The two-high reverse rolling mill of high-lift type can roll an ingot of up to 25 t into slab for the plate mill, into beam blank of up to 1 010 × 450 mm for the wide flange beam mill, and into bloom for the bar & rod mill. It is now tandem-rolling slabs and is also designed to roll blooms in parallel. Having two sets of 4 000-kW driving motors, the greatest in the motor power class in Japan, it can roll very efficiently.

Behind this rolling shop arranged are three spans of slab yards, and from there the plate mill shop and the wide flange beam mill shop stretch to the north.

2. The No. 2 Slabbing Mill

This shop, completed towards the end of this May, is to supply slabs for the hot strip mill now under construction, and is now producing slabs for the plate mill of this works and for the hot strip mills of the Chiba Works. Figure 7 (p. 59) shows the layout of this shop.

The soaking pits are of the one-way firing type, using twin recuperator of the Schack type; they can hold 250 t of ingots, equivalent to one heat from the No. 2 LD converter shop. Now eight holes are in operation, and eventually 32 holes will be installed.

The universal rolling mill can take an ingot of up to 40 t, and is in the greatest class in Japan.

Of the many features of this shop the following means that are being taken for improvement of efficiency to roll more than 5 million tons of ingots eventually are noteworthy:

Table 13. Outlook of slabbing and blooming mills

Name of mill	Rolling capacity (1 000 t/yr)	Product
No. 1 slabbing & blooming mill	2 400 (ingot)	Slab, bloom
No. 2 slabbing mill	5 000 (ingot)	Slab
No. 3 blooming mill	1 300 (ingot & con'cast bloom)	Billet, bar
Total	8 700	

Table 12. Operational results of the No. 1 c. c. machine

	Jul., 1968		Aug.		Sept.		Oct.		Nov.		Dec.		Jan., 1969	
No. of heats cast	24	%	49	%	56	%	96	%	112	%	86	%	142	%
No. of heats completely cast	20	83.3	43	87.8	55	98.2	92	95.8	103	92.3	82	95.4	133	93.8
No. of heats incompletely cast	4	16.7	6	12.2	1	1.8	4	4.2	9	7.7	4	4.6	9	6.2
Trouble ;														
by ladle stopper	0	0	2	4.1	0	0	1	1.0	4	3.6	1	1.1	2	1.4
by nozzle stoppage	0	0	4	8.1	0	0	2	2.1	1	0.5	2	2.3	4	2.8
others (including experiments)	4	16.7			1	1.8	1	1.0	4(2)	3.6	1(0)	1.1	3(0)	2.0
No. of strands cast	191	%	390	%	429	%	730	%	847	%	653	%	1 097	%
No. of strands completely cast	127	66.1	335	86.0	408	95.6	678	92.9	765	90.3	606	92.8	1 012	92.2
No. of strands incompletely cast	64	33.9	55	14.0	21	4.4	52	7.1	82	9.7	47	7.2	85	7.8
Trouble ;														
by ladle stopper	10	5.2	12	3.0	0	0	9	1.3	44	5.2	15	2.3	19	1.7
by nozzle stoppage	41	21.8	26	6.7	9	1.6	28	3.8	26	3.1	23	3.5	42	3.8
break out	3	1.6	5	1.3	1	0.2	7	0.9	6	0.7	5	0.9	9	0.8
electric	1	0.5	2	0.5	1	0.2	2	0.3	1	0.1	1	0.1	0	0
mechanical	1	0.5	2	0.5	3	0.7	4	0.5	2	0.2	1	0.1	6	0.6
overflow	4	2.1	6	1.5	7	1.7	2	0.3	3	0.4	2	0.3	3	0.3
others	4	2.1	2	0.5	0	0	0	0	0	0	0	0	6	0.6

Table 14. Details of the No. 1 and No. 2 mills

	No. 1 slabbing & blooming mill				No. 2 slabbing mill	
Type	High lift				Universal	
Roll dimensions (mm)	1 350×3 400				1 300×2 800	
Horizontal roll					1 050×2 280	
Vertical roll						
Roll lift (mm)	2 100				2 500	
Ingot weight (t)	25, max.				20 to 40, max.	
Product dimensions (mm)	Bloom	Beam blank	Slab		Slab	
	180×200	70×250×500	Thickness	100 to 300	110 to 305	
			Width	1 000 to 1 900	600 to 2 200	
	200×300	150×500×11 300	Length	1 500 to 9 200	12 200 max.	
Manufacturer	Hitachi Co.				Mitsubishi Heavy Ind. Co. —Mesta Co.	
Main motors	4 000 kW×2				5 000 kW×2, 3 500 kW×2	
Rolling capacity	2.4 million t/yr				Initial 1.5 million Final 5.0 „	

- (1) In order to shorten the time for transfer from the soaking pits to the mill, two ingot buggies and two lines of ingot-receiving tables are to be provided.
- (2) As torque of the main motor, being in the greatest class, is ample, the mill can roll two ingots in tandem or execute all types of flat rolling.
- (3) This shop is equipped with two sets (eventually

- four) of hydraulically driven slab coolers having four rows of spokes each, with which connected are two slab-conditioning lines, an autoweigher, and belt conveyors to hot strip mill shop in that order.
- (4) By resorting to various automation devices such as APC (automatic pass control), CPC (card programming control), etc., not only the saving of labour and

Feb.		Mar.		Apr.		May	
175	%	192	%	197	%	238	%
163	92.8	183	95.3	191	97.0	229	96.2
12	7.2	9	4.7	6	3.0	9	3.8
2	0.9	3	1.6	2	1.0	5	2.1
6	3.4	3	1.6	4	2.0	3	1.3
5(2)	2.9	3(3)	1.6	0	0	1(1)	0.4
1 367	%	1 478	%	1 545	%	1 866	%
1 253	91.6	1 333	90.0	1 438	93.1	1 753	93.8
114	8.4	145	10.0	107	6.9	113	6.2
31	2.3	24	1.6	15	1.0	32	1.7
58	4.2	69	4.7	36	2.3	32	1.7
13	0.9	15	1.0	12	0.8	11	0.6
2	0.2	1	0.1	0	0	4	0.2
1	0.1						
2	0.2	1	0.1	2	0.1	4	0.2
7	0.5	35	2.4	42	2.7	30	1.6

the stabilization of operation are simultaneously achieved, but transfer of many kinds of information and directions of operations are automated.

Details of the No. 1 and No. 2 mills are shown in Table 14.

3. The No. 3 Blooming Mill

This mill is planned to stand in front of the existing billet mill; its rolling capacity will be 1.3 million tons. With this mill completed, the rolling rate will be raised enormously because the bloom fed to the billet mill will then be larger, besides it rolls ingots into round bar by one heating for the seamless pipe mill now under construction in other plant. Blooms to be rolled in this mill will be the continuously cast ones in the future.

2. The Plate Mill Shop

This shop was completed in April, 1967 to replace the old three-high plate mill in the Fukiai Works, Kobe. Initially it started operation at a rolling capacity of 70 000 t monthly with one continuous reheating furnace and one finishing stand, then the capacity has been enlarged successively; it will be 160 000 t in July, 1970, when one roughing stand is completed. This shop extends from the western

Fig. 7. Layout of No. 2 slabbing mill

part of the slab yard of the No. 1 slabbing and blooming mill shop to the north. The layout of this shop is shown in Fig. 8.

1. The Slab-Reheating Furnace

There are two continuous and one batch-type reheating furnaces; their principal details are shown in Table 15. Now the third furnace is under construction.

The following are the features of the continuous reheating furnace.

(1) In order to eliminate surface defects of slabs, hot skids made from heat-resistant alloy are used in the No. 1 and No. 2 furnaces, whereas the walking-beam is to be adopted in the No. 3 furnace.

(2) Each furnace is equipped with a slab extractor instead of commoner slab pusher.

(3) Having no soaking zone, the furnace has a heating capacity that is much greater than that of other furnaces of the same length.

2. Plate Mill

Principal specifications of the finishing mill stand of the plate mill are shown in Table 16.

The features of the mill are as follows.

(1) The back-up roll diameter is 1 900 mm, which is among the largest in the world, and the mill housing weighs more than 260 t, whose great mill rigidity is responsible for an improved accuracy of the product thickness.

(2) The mill is equipped with an *AGC* (automatic gauge control) system for the first time in Japan; this automatic controller secures uniformity of the plate thickness longitudinally.

(3) Being designed primarily for ship-hull plates, the body length of the work roll on the finishing mill was decided to be 160 inch; however, that of the roughing mill is 180 inch, making the rolling of plates of more than 4 up to 4.3 m wide possible.

(4) The quick roll changing device cuts down the time required for changing rolls to the minimum.

(5) The scale removal is effectively done by a high pressure descaling water of 150 kg/cm².

3. Finishing Facilities

In anticipation of the future rolling capacity, two cooling beds of the walking beam type are so arranged that the products may be treated in two directions after cooling. There is a side shear of the down-cut twin type, which is unprecedented in that it is capable of cutting plates of thicknesses up to 40 mm with ease. In addition to these, facilities for shot blasting, heat treating, and others are being constructed as dictated by the demand. The use of computer on the plate mill is the first in Japan; it has proved, as expected, to be effective for minimizing the deviation of the plate thickness in the same lot, reducing the number of operators, preventing the miss operations, and rationalizing the rolling schedules by process computer control application.

3. Wide Flange Beam Mill Shop

This company has been producing Junior H beam at the Fukiai Works, but on account of the increasing demand and in order to produce larger size structural

Table 15. Principal details of reheating furnaces

	The continuous furnace	The batch type furnace
Type	6-zone hot skid	Top one-way firing
No. of furnaces	2	1 (2 holes)
Heating capacity	150 t/hr	8 t/hr×2
Slab dimensions (mm)		
Thickness	100 to 300	80 to 500
Width	1 000 to 1 900	1 000 to 1 900
Length	1 900 to 3 200	1 500 to 4 000
Weight (t)	14.1, max.	25, max.
Fuel	Heavy oil or mix gas	Heavy oil or mix gas

Table 16. Principal specifications of the plate mill

Type	Four-high reversible
Roll dimensions (mm)	
Back-up roll	1 900 to 4 000 (75×157)
Work roll	1 100 to 4 100 (39×160)
Roll lift	550
Manufacturer	Ishikawajima-Harima Heavy Industries Co.
Main motors	3 750 kW×2 (Mitsubishi Electric Co.)
Product dimensions (mm)	
Thickness	4.5 to 200
Width	3 850 max.
Length	40 000 max.

Photo. 4. Finishing mill stand of the plate mill

shape, this new mill has been put into operation in July, 1968. With this mill in active operation, the company is now able to manufacture all the H shape steels in sizes of 100/50 mm to 1 010/450 mm. Further, the plan of producing sheet piles is steadily in progress.

Fig. 8. Layout of slabbing & blooming mill, plate mill, and wide flange beam mill

This shop consists of one break-down, one roughing, and one finishing mill, the latter two being of the universal type.

The layout of this shop is shown in Fig. 8.

The features of this shop are as follows.

(1) In order to prevent surface defects of materials, the walking beam type reheating furnace equipped with one extractor is used.

(2) In order to produce long size products and to improve the production yield, the mill stands are

Photo. 5. Wide flange beam mill shop

arranged to be capable of rolling products as much as 100 m long.

(3) Two different sizes of stands and rolls are used separately according to the dimensions of rolled products and also in order to improve the accuracy of the product's dimension; means to minimize the roll deflection and mill housing strain during rolling operations are incorporated.

(4) To adapt to the variations in production schedule, the stand-changing system for changing rolls is used; this system cuts the mill stop time for roll changing and roll adjustment down to the minimum.

(5) In order to eliminate scratching defects of the products, the walking beam type cooling bed is used for the first time in Japan as for the structural steel mill.

(6) Finishing facilities are designed so that all the works from inspection to shipping including classification, handling, and marking for customer can be done on a line in the shop.

Initially this shop started the operation at a rolling capacity of 480 000 t annual, and enlarging the capacity successively, it will finally be one million tons. The outline of the existing principal facilities are shown in Table 17.

4. Billet Mill and Bar & Rod Mill Shop

As mentioned earlier, this shop, which is consisting of one billet mill and one bar & rod mill, is the very first ever constructed at the Mizushima Works. Although the billet mill is the one that used to be the hoop mill that had then been left idle in the Nishinomiya Works, near Kobe, the bar & rod mill is the then latest model when it was constructed. The layout of this shop is shown in Fig. 9.

Table 17. Outline of the principal facilities of wide flange beam mill shop

Equipment	Type	Number	Specification	Manufacturer
Reheating furnace	Continuous walking-beam type	1 (No. 2, under construction)	Heating capacity: 150 t/hr Heating materials: bloom, beam blank Fuel: heavy oil or mix gas	Chugai-Ro Industry Co.
Breakdown mill	2-high reversible (Mill edger in the future)	1	Roll dimension: 1 100×2 800 mm Roll lift: top roll, 1 420 mm bottom roll, 380 mm	Ishikawajima-Harima Heavy Industries Co. —SACK Co.
Roughing mill	Universal type roughing	1 (No. 2, to be installed in the future)	Small stand Horizontal roll: 1 320×226 to 557 mm Vertical roll: 880×410 mm	Hitachi Ship Building Co. —DEMAG Co.
	2-high edging	1 (No. 2, to be installed in the future)	Large stand Horizontal roll: 1 500×364 to 856 mm Vertical roll: 1 000×520 mm Main motor: 6 200 kW×1 Edger roll: 1 500×364 to 856 mm Roll for shape steel: 1 050×2 500 mm	
Finishing mill	Universal type finising	1	Horizontal roll: 1 320×225 to 856 mm Vertical roll: 880×410 mm 880×480 mm	
	2-high finishing		Main motor: 3 100 kW×1 Roll for shape steel: 1 050×2 500 mm	

1. Billet Mill

From the rolled blooms at first, and almost entirely the continuously cast ones at present, this mill has been producing billets for the bar & rod mill, medium bars, and flat bars. The facilities consist of one continuous reheating furnace of three-zone type, one two-high reversing roughing mill stand, one non-reversing stand, and six two-high continuous finishing mill stands; the mill has a rolling capacity of 600 000 t annual.

When the No. 3 blooming mill is installed to serve as the breakdown mill, the mill capacity will have been enlarged to 1.3 million tons because then large size blooms will be used.

2. Bar & Rod Mill

Although this mill at present is a combination mill, rolling bars & rods as shown in Table 18, it is to become the exclusive rod mill in the future, when an independent bar mill is constructed.

The mill is the fully continuous type with a total of 25 stands; it is the most modern in that it can produce 5–10 mm diameter bars & rods at a speed up to 40 mm/sec. Initially this mill was operating in a two-strand rolling for 5–10 mm diameter rods, but presently it is capable of a four-strand rolling, and the annual capacity has been enlarged from 360 to 420 000 t by adding one finishing mill train in last September.

As mentioned above, although the rolling is basically the H-H type, the specially constructed Wilson type housings, in which the rolls are directly connected by link and the variation in the parting of rolls is very little, are adopted in the No. 1 intermediate mill and in the finishing mill train; this has not only made the high speed rolling possible but the accuracy of products has become very high. The vertical rolls incorporated in the No. 13 and No. 15 stands in last September have helped to raise the accuracy of the rolling dimension even more.

Furthermore, the Stelmor process has been adopted in two of the rod strands since last September. In this process the rods are distributed so as to form rings on the mill delivery conveyor and heat-treated by controlling the cooling of the heat that is held by the rod itself. By this the heat treatment of the following process has been eliminated, and also the production of

Table 18. Constitution of the bar & rod mill

Type	Morgan-Siemag, horizontal fully continuous type
Roughing mill	2-high continuous type, 7 stands
No. 1 intermediate mill	2-high continuous type, 8 stands
No. 2 intermediate mill	2-high continuous type, 2 stands-2 lines
Finishing mill	2-high continuous type, 8 stands-2 lines

the homogeneous high quality rod has become possible. In the near future, two more strands of Stelmor process will be installed. Although this is presently a combination mill, rolling bars & rods, for which purpose it is equipped with a cooling table for straight rods besides the reels, this mill will become exclusive for rod when the new bar mill is installed in the future.

5. Hot Strip Mill Shop

The construction of the long awaited hot strip mill was started in June, 1968; it will be completed in January, 1970. It will be a 90-inch fully continuous mill, among the largest in the world, and it is planned that the annual capacity is to be enlarged by and by from the initial 1.5 million tons to finally 5 million tons. The shop will consist of four roughing mills (five in the future) and six finishing mills (eight in the future). In order to improve the quality of the product in the accuracy of the strip thickness and strip shape, an AGC system is provided on the finishing mill, and the work roll bending devices are installed on all the stands.

The strip mill yard starts from the slab yard of No. 2 slabbing mill, and the mill line is extended to the north. The hot strip coils are transferred by coil car or coil conveyor to the coil storage yard in separate buildings. The mill is capable of producing coils of up to 40 t from slabs from the No. 2 slabbing mill, or up to 45 t when the continuously cast slabs become available.

6. Cold Strip Mill Shop

It is planned to have ultimately two cold strip mills,

but in the first stage a 68-inch five-stand tandem mill is to be installed. Since, in the cold rolling facilities of the company, the capacity of annealing or skin-passing had then been inadequate compared with the rolling capacity, the cleaning line, annealing equipments, skin pass mill, and other accompanying facilities were put to operation in March this year without waiting for the completion of the tandem mill, to take care of a part of the coils cold rolled in the Chiba Works. The tandem mill is scheduled to be completed in this September, and the annual capacity will be increased from the initial 360 000 t to about one million tons finally.

The special feature of this mill is the all-out adoption of hydraulic system instead of ordinary screw-down mechanism to make the high speed reduction, correction of the roll centre variation, *etc.* possible. Together with the AGC system and the roll crown control, this system will help greatly the manufacture of accurate and good shape products. Moreover, mechanization and automation, such as automatic coil handling or automatic threading of the strip, are extensively adopted. The No. 2 mill now being planned will be of a capacity of about 1 million tons annual, similar to the No. 1.

7. Other Rolling Mill Equipments

Besides those stated above, the rolling mill equipments whose installation before the completion of the first period construction is now intended are:

- a bar mill (with an annual capacity of 600 000 t),
- a bar & rod mill (500 000 t), and
- a medium flange beam mill (600 000 t).

The annual capacity of each mill is only tentative at present, however.

8. Flow Diagram

When all the rolling mills are in operation at the production scale of 11 million tons annual of ingots total, all of the equipments from the blast furnace down to the final products lines will be balanced with some to spare capacity-wise. Then the flow diagram of the entire process, from the steelmaking shops to the rolling mill, will be as shown in Fig. 10 with values of rough estimates.

Generally speaking, the two strip mills and the plate mill will be almost in full operation, whereas the mills for shape steel, bar, *etc.*, will be working at 80 to 85% of the capacity.

VIII. Casting and Forging Plant

As mentioned before, the history of production of steel castings and forgings in the Hyogo Works, Kobe, is long, and its facilities have become rather outmoded. However its campus and buildings, being limited in size, do not permit of a ready installation of new equipments, so much so that only partial improvements have been done. Meanwhile the ships, the shipbuilding industry, the main customer of steel castings and forgings, built those days, are rapidly becoming ever larger, so that the existing facilities of the Hyogo Works, which are incapable of producing the parts for

Photo. 6. Skin pass mill

ships of over 100 000 t, cannot follow the trend. It was decided, therefore, that a modernest plant for castings and forgings was to be constructed in the northern area of the Mizushima Works, and the Hyogo Works would be eventually closed.

This casting and forging plant consists of facilities of steelmaking, machining, and assemblage, but the equipments now under construction to be completed in July this year, except the electric furnace stated previously, are as follows:

- (1) Casting shop

Casting equipments,	300 t per month capacity	1 set
- (2) Forging shop

6 000 t hydraulic press	1 set
Car bottom type heating furnaces and heat treating furnaces	5 sets each
Oil quench tanks	2 sets
- (3) Machining and assemblage shop

Large size lathe	1 set
Machine tool for rudder stock	1 set
Horizontal boring machine	1 set
Centering surface machine	1 set
Assemblage floor	2 sets
1 000 t press for plate working	1 set.

The 6 000 t press, the main equipment in the forging shop, is the latest innovation whose specifications are shown in Table 19.

With completion of these facilities, the weight of the steel castings is increased from 45 to 120 t maximum, while that of the steel forgings from 26 to 120 t maximum, both by using the ingot of 200 t. The maximum weight of products, on the other hand, is enlarged to 270 t (320 t in the future) from 75 t now current in the Hyogo Works. Not only any parts of ships of 200 000 to 300 000 DWT class are readily producible by those facilities, for example, rudder stocks of more than 62 t finished and shafts of 70 t finished are easy targets, but also any demands for yet larger vessels soon expected will be comfortably met.

IX. Computer System

Since information in an enormous quantity and a

Fig. 10. Flow diagram from steelmaking shops to rolling mills

Table 19. Principal specifications of 6 000-t press

Type	Four columns, push-down type
Capacity (t)	2 100 / 4 200 / 6 300 / 7 500 four stages pressure control
Drive system	Pressurized water accumulator drive
Daylight	6 000 mm
Clear distances between the columns	4 900×2 200 mm
Size of shifting table	3 400×8 000 mm
Number of strokes	Cogging 18 to 19/min Planishing 50 to 60/min
Manufacture	Hydraulik Co. (West Germany)

multitude kinds will be required to manage and control such a large works as producing 11 million tons annual for its efficient production, it is essential to institute a centerized control system. The entire system may become gigantic, but its response must be very fast. In this respect, the computer system will become the center of management and control.

In the Mizushima Iron Works, an unparalleled system is now being constituted steadily for the goal of

producing 11 million tons of steel.

The following are the features of this works.

- (1) The control centre, placed in the middle of the works, has two large central computers, which are connected with their counterparts at the head office, Kobe, on the on-line sales-information system basis.
  - (2) The central computers in this works, besides doing the conventional business calculations, operate mainly in the important fields of the production control such as production scheduling and automation of production directions.
  - (3) The production directions compiled by the central computers are fed to the operation control subcenters of pertinent plants, where details of operation directives are drawn so as to attain the proper quality, high efficiency, and as low a production cost as possible and given out to the operators or to the automatic controlles of each process.
  - (4) For each unit process, there is a process computer that controls its most suitable operation; also in the sub-systems, such as sequence control, DDC, etc., computers are introduced extensively.
- In other words, the computer system in this works operates in a two-way cascade: at the top is the central computer, and information of production cotrol flows from the top to bottom and also back from the bottom to top, all in the real time basis.

X. Transportation

The transport routes of the hot metal and the semi- and finished products among various plants and shops at the time the output of 11 million tons of steel annual is realized is shown in Fig. 11. The railroad is of the narrow gauge, and that for torpedo car serving between the blast furnace and the LD shop in particular has reinforced bed to forestall any trouble.

The total iron production will amount to 26 000 t daily on the average, with a maximum of 28 500 t that corresponds to 52–57 tappings at the rate of 500 t per tap. With those figures in mind, it will be appreciated that the hot metal transfer by means of ladle cars as being done in the Chiba Works will be hazardous because not only the diagramming of so many hot metal-carrying trains will become prohibitively difficult, but also any accident in the melt shop will cause stagnation of long trains on the railroad between the blast furnace and LD shop. On the contrary, if 250-t torpedo cars are to be used, three cars will suffice for one tap, and their handling will be many times easier. This is the principal reason why torpedo cars come to be used in this works.

The flow of material from the melt shop is divided into two routes: the plate and sheet, as produced from slabs, flow to the wharf that is along the Takahashi River, whereas the flange beam, and bar & rod, as produced from blooms, flow to the wharf along the inner sea. On the other hand, the castings and forgings *via* electric arc furnace are shipped off at an independent wharf that is on the bank of Takahashi River, unrelated to the transport of products from the integrated processes.

XI. Handling of Discards

1. Blast Furnace Slag

At the hot metal production of 26 000 t/day, about 8 000 t of blast furnace slag is generated. After cooled and solidified in dry-pits placed around the blast furnace, it is transferred by dump-trucks to the cinder-ballast plant, situated in the north part of this works, and crushed there into several sizes. The pulverized slag is used right in the works or sold as ballast for road or railway, while that of size under 5 mm is sold as fertilizer.

2. Converter Slag

After cooled and solidified in the slag bed placed at the southern part of the melt shop, the converter slag is crushed and screened, and the metal entrapped in the slag recovered. It is then sold or used in land reclamation.

3. Dust

Dusts from the blast furnace, the sintering machine, and the converter are transferred through pipes in the form of slurry to the dust-treating plant, where they are dried and calcined to semi-pellet, which is fed back to the sintering plant.

4. Sulphur Dioxide in Waste Gas

The Mizushima district is a man-made coastal industrial area that houses various industries such as petroleum, chemistry, iron and steel, and electric power. Behind this district lies from east to north a range of hills up to 200 m high, to the west of which and across the Takahashi River opens a broad agricultural field; there are farms of about 200 ha. in the plain, orchards on the hills, and a population of about 400 000 in this area. In short, any public nuisance due to sulphur dioxide in the waste gas cannot be tolerated.

The concentration of sulphur dioxide in the waste gas from this works at its first stage of construction was assumed to be 387 ppm according to the preliminary investigation conducted by the Ministry of International Trading and Industry. However, it was subsequently found that the concentration of SO₂ can be and has actually been reduced to 263 ppm by cutting the ratio of the heavy oil down to about 30% of the total fuel and by using as much B and C gases and low sulphur oils as possible.

Fig. 11. The transport route of hot metal and semi- and finished products

Further, by assembling several stacks of small scale furnaces into one large chimney, and collecting those of furnaces exhausting large volume in one large and tall chimney, the pollution of air by the waste gas over the non-industrial area is now being kept to a level that is yet lower than that specified by the government.

XII. Energy Balance

1. Electric Power

At the same time as the completion of No. 1 blast furnace, the Mizushima Electric Power Corporation, a subsidiary of this company, has started. It generates electricity by using B gas and heavy oil, and eventually will install 2 sets of 75 kW and 2 sets of 156 kW generators.

The power balance in this works at its production level of 11 million tons annual, including power consumption of the Mizushima Ferroalloy Co. and the Kawatetsu Chemical Co., both the subsidiary of this company, is shown in Fig. 12. The annual requirement of electric power is 3 630 million kWh, of which about 3 200 million kWh is to be purchased from the Chugoku Power Co. However, at the peak load of rolling equipments, especially of the hot strip mill, and during the periodic inspection or unexpected failure of generators, considerably more amount of powers will have to be purchased. There are now three sets of transformers, 60 MVA each, are working and two more sets, 200 MVA each will be installed for such contingencies.

Figure 13 shows the arrangement of the electric sub-stations in the campus as related to the Chugoku Power Co. and the Mizushima Electric Power Corporation.

2. Steam

The steam balance is shown in Fig. 14; the annual requirement is estimated to be about 3.1 million tons, of which over one-third will be consumed by the Kawatetsu Chemical Co. The peak consumption per hour amounts to approximately 660 t, which is to be supplied by boilers placed near the consuming plants.

3. Heat

Fuels used in the campus are blast furnace gas, coke oven gas, LD gas, and supplemental heavy oil. At the production scale of 11 million tons annual, the works will have one B gas-holder of 200 000 m³, two C gas-holders of 70 000 m³ each, and two LD gas-holder of 50 000 and 80 000 m³. Gases are used either singly or as mixed. Also the works will have heavy oil storage tanks of 8 000 and 2 500 t in the iron-making district and of 5 000 and 2 500 t in the rolling district. The heavy oil of low sulphur content is to be used.

The heat balance is shown in Fig. 15, and the total quantity of heat required annually in the works will amount to 28×10^{14} kcal.

4. Industrial Water and Clear Water

Figure 16 shows the fresh water conditions at the production of 11 million tons of steel annual: the

Fig. 12. Electric power balance

Fig. 13. Schematic circuit diagram of electric power

Fig. 14. Steam balance

daily use of fresh water will be about 2.24 million tons, equivalent to 74 m³ per ton of steel, of which 88% is circulated. The fresh water consumption

Fig. 15. Heat balance

comes to approximately 275 000 m³ daily, or equal to 8.9 per ton of ingot. The total quantity of the industrial water required is supplied by the Takahashi River. The long term programme of fresh water supply projected by the Okayama Prefecture is now steadily in progress, and in the future 1 million tons daily of water will be supplied to the Mizushima industrial area, which will cover the water requirement of this works.

XIII. Summary

The Mizushima Iron Works, whose site was decided in 1961, has started the iron and steel integration system by the completion of the No. 1 blast furnace in the spring of 1967; the production scale of 4.5 million tons annual, the next target, was attained with the blow-in of the No. 2 blast furnace in January, 1969, and by constructing successively the No. 3 and No. 4 blast furnaces, it will become truly the greatest modern iron and steel integrated plant in the world: with four mam-

Fig. 16. Consumption of fresh water (unit: m³/day)

moth blast furnaces, six LD converters, four continuous casting machines, a number of rolling equipments, and several steel casting and forging facilities, it will be turning out 11 million tons of steel annual a few years hence.

In constructing the Mizushima Works, as much the most advanced technical means and ideas as deemed necessary has been adopted: automated fast-action machines, equipment, and facilities of great productional capacity that are integrated in the computer-controlled information network on one hand, and the facilities that minimize the public nuisance for the local society on the other. The works shall be the ideal iron works blessed with “green and sunshine.”

With the Mizushima Iron Works in the west and the Chiba Iron Works in the east, this company will not only meet the mounting demands of varied customers, but also contribute to the national economy by winning in the international competition that will become the severer.