Study on the Economical Production Scale at Chiba Works*

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I. Introduction

In February 1951, Kawasaki Steel Corporation commenced the construction of the first integrated plant after World War II on a 3,300,000 m² reclaimed land located on the southern seashore of Chiba City.

Initially, a 1,000,000-ton scale plant was intended but afterwards actual production has been raised steadily to the present annual rate of about 4,000,000 tons of ingots, due to the progress in steelmaking techniques. Study on the most suitable production scale for the total of about 4,000,000 m² land, including additional 660,000 m² of reclaimed land in the neighbouring Oiama district, led to the conclusion that production of 5,000,000 tons of ingots is most reasonable, considering the most economical operation of present steelmaking equipment.

Moreover, iron-making and rolling equipment connecting with steel shops, have been found to be roughly balanced with this production level, so that this is regarded as the final production level at Chiba Works. Fig. 1 shows the general view of Chiba Works at its completion. The purpose of this lecture is to explain the details which enabled us to determine the economical production level, and the plan of Chiba Works when it is completed as an annual 5,000,000-ton production scale plant.

II. Steelmaking Equipment

In calculating the economical production scale, it is reasonable to study at first the capacity of the melting shop which is the basic equipment in the plant, and then that of the accessory equipment such as iron-making and rolling.

Steelmaking equipment consists of open hearth and LD converter shops. The open hearth shop has six furnaces each with 150 ton nominal capacity, and the converter shop houses two LD converters of 150 ton nominal capacity, the third one to be installed in July 1965. With its installation there can be introduced the system of operation in which two converters are blowing while the third one is being relined. Table 1 shows the outline of steelmaking equipment.

1. Steelmaking Capacity of O-H Shop

Various inquiries into the utilization of a large quantity of oxygen in O-H shop of this plant have demonstrated that for promoting furnace productivity it was more effective to blow oxygen into the metal bath rather than to use it for accelerating combustion.

Table 1. Outline of steelmaking equipment

Shop	Furnace No.	Normal capacity (t/heat)	Furnace type	Date of constructions	Remarks
O-H	No. 1	150	Basic, stational	Jan. 1954	Remodeled Jun. 1959
	No. 2	„	„	Mar. 1954	Nov. 1959
	No. 3	„	Maerz-Boelens	Jun. 1954	Jan. 1960
	No. 4	„	Basic, stational	Nov. 1959	
	No. 5	„	„	Dec. 1959	
	No. 6	„	„	Apr. 1960	
LD	No. 1	150	Concentric, bot-tom unremovable	Apr. 1962	Inner volume: 242.4 m ³
	No. 2	„	„	Jun. 1962	„
	No. 3	„	„	Jul. 1965	„

This shop has actually attained an annual production of 2,000,000 tons of ingots with an oxygen plant capable of generating 13,400 Nm³/hr.

However, as a result of the development of the oxygen converter process in recent years, it has become clear that the LD converter is superior to the O-H furnace in operation cost even when the latter is operated most efficiently, and the O-H furnaces had to be operated most economically to keep pace with the LD converters. Then the steelmaking capacity of the O-H shop when it was operated with the lowest cost was calculated on the basis of the actual results of economical operation conducted in 1962 in order to cope with the recession at that time.

In the calculation of the various factors determining the production cost of ingot, the main factors varying with production tonnages were summed up and the results were compared with various production levels. For this purpose, a study on several relations described below was conducted. Data adopted here were obtained on the basis of the premises that hot metal rate was 70~75% and amount of good ingots was 158 tons per heat with operation of five furnaces at all times.

Relation between Amount of Oxygen Consumed and Number of Heat

As shown in Fig.2, there exists a close correlation between them, and the amount of heat is in proportion

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Fig. 1. General view of Chiba Works

to the amount of oxygen. From this relation oxygen consumption per ton of ingot for a certain tonnage of production can be calculated.

Fig. 2. Relation between oxygen consumption and number of heat

Relation between Amount of Oxygen Consumed and Steel-making Yield

Fig.3 shows that as the amount of oxygen increases, steelmaking yield decreases. This is because the increase in the amount of oxygen brings the increase in the volumes of flash-slag and metal, while decreasing tonnage of iron ore used.

From the two relations shown above, steelmaking yield and, accordingly, cost of metallic charges for each production level can be calculated.

Fig. 3. Relation between oxygen consumption and steelmaking yield

Relation between Fuel Consumption and Number of Heat

As shown in Fig.4, there is an inverse correlation between fuel consumption and number of heat, and the fuel consumption per ton of ingot lowers with the increase of number of heat. This can be naturally

Fig. 4. Relation between number of heat and fuel consumption

expected from the fact that, with an increasing amount of oxygen consumption, heat time is shortened and in addition fuel input can be regulated.

Relation between Number of Heat and Roof Life

It can be easily presumed that roof life is shortened and brick consumption per ton of ingot will rise on account of the vast splash and overheating of roof lining. The latter is caused by the increase of oxygen consumption which brings an increase in the number of heat. These circumstances can be seen in Fig.5.

Fig. 5. Relation between number of heat and roof life

Relation between Number of Heat and Consumption of Repair Materials

In the O-H shop, dolomite clinker and dolomite stone are used for repairing the furnace bottom and front and back walls. As the amount of oxygen consumption increases, the time for sintering dolomite stone becomes insufficient because of the shortened heat time, and the consumption of dolomite clinker becomes much larger. Figs.6 and 7 show these situations.

Fig. 6. Relation between number of heat and dolomite clinker consumption

Fig. 7. Relation between number of heat and dolomite stone consumption

Relation between Number of Heat and Man-Hour

As shown in Fig. 8 man-hour per ton of ingot decreases with the increase of production, but unusual points representing man-hours for 1959 and 1962 in this figure are due to intentional increases in the labor force.

Cooling Water Consumption and Volume of Waste-Heat Steam Generated

These two factors including cooling water consump-

Fig. 8. Relation between number of heat and man-hour

Fig. 9. Relation between output amount and production cost per ton of steel ingot

tion and volume of waste-heat steam generated per ton of ingot have a tendency to decline when production tonnage increases.

Depreciation and Overhead Cost

With an increase of production, the depreciation and overhead costs per ton of ingot are naturally reduced. Except for those described above, other factors which determine the production cost per ton of ingot remain more or less constant irrespective of the output tonnage, and may be omitted when comparing production cost for each production level. Then the relation between the production cost and amount of production is as shown in Fig.9. In this figure the production cost for 2,000,000 tons per year (roughly 170,000 tons per month) is fixed as 100 per cent, and costs for the other production levels are shown in percentages to this. From the diagram it can be seen that the production cost for about 100,000 tons per month shows the lowest value. Therefore, in order to produce ingots most economically in the O-H shop, the steelmaking capacity must be reduced to 1,200,000 tons annually even if much more ingots can actually be produced.

2. Steelmaking Capacity of LD Shop

The LD shop at Chiba Works has two oxygen converters, each having the inner volume of 242.4 m³ and it is producing now over 2,000,000 tons of ingots annually, and when the third converter is installed in July 1965, the production can be easily increased to max. 3,800,000 tons of ingots.

Moreover, in addition to the fact that the production cost in the LD shop is far cheaper than that of the O-H shop, it declines in proportion to the increase in the ingot production per hour, differing from the case of the O-H shop.

Therefore, when operating both shops, it is appropriate to have the converters operated to the utmost, and so we can regard the annual capacity of the LD shop as 3,800,000 tons of ingots. Consequently, the economical production level at Chiba Works can be considered to be 5,000,000 tons of ingots per year.

On the other hand, the iron-making and rolling facilities relating to the melting shops, when the including ones now being planned, have roughly balancing capacities with 5,000,000 tons of ingot production annually as described below. Then Chiba Works will be well-balanced in capacity, as a whole, when reaching the stage of annual production of 5,000,000 tons.

3. Oxygen Plant

Oxygen generators at Chiba Works are shown in Table 2. Assuming that the total operation time per annum is 8,000 hours, the annual amount of oxygen generated will be :

$$45,400 \text{ Nm}^3/\text{hr} \times 8,000 = 363,200,000 \text{ Nm}^3$$

Table 2. Summary of oxygen generators

Machine No.	Nominal capacity (Nm ³ /hr)	Machine type	Date of construction
No. 1	2,000	High and low pressure regenerative, heat-exchange type	Aug. 1955
No. 2	3,000	Low pressure regenerative, heat-exchange type	Jun. 1958
No. 3	4,200	„	Mar. 1960
No. 4	4,200	„	Jun. 1961
No. 5	6,000	„	May. 1962
No. 6	8,000	„	Dec. 1963
No. 7	8,000	„	Under construction
No. 8	10,000	„	Planned
Total	45,400	—	—

On the other hand, annual oxygen requirement is as shown in Table 3. The surplus oxygen resulting from the above calculation will be used to enrich the blast blown into the blast furnaces, or otherwise Nos.1 and 2 oxygen generators will be shut down. On the other hand, the total capacity of the oxygen plant can meet oxygen requirements of melting shops, even when large-scale generators such as Nos.6, 7 and 8 machines must be stopped for periodical repair.

Table 3. Oxygen requirement

	Production tonnage (t)	Oxygen consumption (Nm ³ /t)	Annual oxygen requirement (Nm ³)
O-H shop	1,200,000	40	48,000,000
LD shop	3,800,000	50	190,000,000
Others	—	—	60,000,000
Total	5,000,000	—	298,000,000

4. Demand and Supply of Scrap

Table 4 shows annual scrap requirement for the production of 5,000,000 tons of ingots.

Since return steel scrap and iron scrap are assumed to be 750,000 and 50,000 tons, respectively, about 500,000 tons of scrap must be purchased annually. As the existing scrap yard at Chiba Works can only handle scraps of about 60,000 tons per month with an area of about 50,000 m², new scrap unloading and stock yards are to be built at Oihama district.

Table 4. Scrap requirements

Type of furnace	Scrap rate (%)	Steelmaking yield (%)	Production tonnage (t)	Annual scrap requirements (t)
O-H	25	92	1,200,000	330,000
LD	23	92	3,800,000	950,000
Total	—	—	5,000,000	1,280,000

III. Iron-Making Equipment

1. Hot Metal Requirements

In the study of steelmaking capacity above-mentioned the economical production scale of annual 5,000,000 tons of ingots takes for granted the self-supply of pig iron. In this case iron requirement will be as shown in Table 5.

Therefore, required daily output of hot metal will be :

$$\frac{4,170,000 \text{ t}}{365} = 11,400 \text{ t/day}$$

Table 5. Iron requirement

Type of furnace	Production tonnage (t)	Steelmaking yield (%)	Standard pig iron rate (%)	Pig iron requirement (t/yr)
O-H	1,200,000	92	75	980,000
LD	3,800,000	92	77	3,190,000
Total	5,000,000	—	—	4,170,000

2. Iron-Making Capacity

There are five furnaces at Chiba Works, as shown in Table 6. At present four blast furnaces are in operation, and in May 1965, No.5 furnace having a working volume of 2,142 m³ is to be erected, and remarkably high productivity will be expected through the employment of the newest techniques such as high top pressure operation, fully automatic charging equipment using belt conveyer system and high temperature hot stoves of side combustion type (Koppers type). No.2 blast furnace, after its relining scheduled in the near future, is also to adopt high top pressure operation.

Table 6. Summary of blast furnaces

Furnace No.	Nominal capacity (t/day)	Working volume (m ³)	Date of construction	Remarks
No. 1	1,000	913	Jun. 1953	Remodeled in Aug. 1963
No. 2	1,000	1,172	Mar. 1958	
No. 3	1,500	1,689	Apr. 1960	High top pressure operation after relining
No. 4	1,500	1,689	Aug. 1961	
No. 5	2,000	2,142	Under construction	High top pressure operation
Total	7,000	7,605		

Except No.2 furnace, the blast furnaces now in operation are producing hot metal at the rate of 1.40 to 1.45 t/m³/day, and when the condition of metallic burdens is improved by importing high-grade iron ores and pellets, it will be easy to raise the rate to 1.50 t/m³/day in the near future with all of five furnaces operated, even at normal top pressure operation. Then tons of hot metal produced per day will amount to :

$$1.50 \text{ t/m}^3/\text{day} \times 7,605 \text{ m}^3 = 11,400 \text{ t/day},$$

and hot metal requirement for steelmaking can be

fulfilled.

On the other hand, as a blast furnace must usually be relined every six years, it is necessary to reline approximately one furnace in a year when five furnaces are in operation. Therefore, it is reasonable to preserve enough capacity of production by adopting high top pressure operation and by oxygen enrichment of blast, in order to cope with the shortage of hot metal and to self-supply the necessary amount of hot metal in the case of relining any blast furnace. Furthermore even when such a large furnace as No. 5 must be relined, it will be possible to cover shortage of pig iron by storing cold metal previously.

3. Iron Ores

As for iron ores, it is necessary to study material-handling capacity in the plant, grades of imported iron ores and the rate of sinter and pellet to the total ore.

Due to the limited area of ore-storage yards, necessarily high grade ores must be selected and their origins must be limited, and plans must be made to import oversea pellets and increase the amount of sized ores, as the ores presently supplied are apt to bring excess fines. When high grade of sized ores and pellets can be imported, the ore rate will decrease to 1.50 to 1.55 (average 1.53) tons per ton of pig iron, and also coke rate to about 450 to 470 kg/t-pig, considering heavy oil injection of 40 to 50 kg/t-pig. With the ore rate of 1.53 t/t-pig, iron ore requirement will amount to 6,400,000 tons for annual hot metal production of 4,170,000 tons. Assuming that the ratio of sinter and pellet to all metallic burdens is 70%, the sinter and pellet requirement is roughly 4,500,000 tons. Since the annual production of sinter and pellet in the plant is about 3,200,000 tons, as shown in Table 7, 1,300,000 tons of pellets have to be purchased from abroad.

Table 7. Pellet and sinter plants

	Plant	Capacity (t/day)	Remarks
Pellet	No. 1 pellet plant	900	Kawasakiseitetsu type
	No. 2 „	„	„
	No. 3 „	2,000	„
Sinter	No. 1 sinter plant	2,400	Dwight Lloyd type
	No. 2 „	„	„ (Under construction)
Total		8,600 t/day=3,200,000 t/year	

4. Ore-Storage Yards and Transportation of Ores

As shown in Table 8, the ore yard consists of ore-storage yard having an area of 81,000 m² and ore bedding yard of 48,000 m² and the former is supposed to be able to store 788,000 tons and the latter, 150,000 tons of ores. Plans are now under way to prepare another ore-storage yard of 20,000 m² to store over 180,000 tons of ores. Thus the total storage capacity for iron ores will become 1,120,000 tons, or equivalent to two months' requirement of total 6,400,000 tons in a year.

Table 8. Ore-storage yards and ore-bedding yards

Yard	Area (m ²)	Maximum storage volume (t)
Lump ore storage yard	43,240	465,000
Fine ore storage yard	37,740	323,000
Ore-bedding yards	48,000	150,000

The ore-conveying system has been found to have sufficient capacity to transport ores, until the production of hot metal amounts to 12,000 t/day.

5. Demand and Supply of Coke and Coal-Storage Yard

As seen in Table 9, five coke ovens can produce a total of 5,480 tons of cokes per day. With the coke rate of 470 kg/t-pig, coke requirement for daily hot metal production of 11,400 tons will be 5,360 t/day, which will be supplied sufficiently from these coke ovens.

Table 9. Outlook of coke ovens

Coke oven No.	No. of chambers	Nominal capacity (t/day)	Type	Date of construction
No. 1 coke oven	54	700	New Otto double block system	Jun. 1953
No. 2 „	60	780	„	Mar. 1959
No. 3 „	74	1,000	„ (remodeled)	Nov. 1960
No. 4 „	74	1,000	„ (remodeled)	Mar. 1962
No. 5 „	92	2,000	Carl-Still	Under construction
Total	—	5,480		

On the other hand, as annual coke requirement is :

$$5,360 \text{ t/day} \times 365 = 1,950,000 \text{ tons}$$

and annual coal requirement in dry state amounts to :

$$\frac{1,950,000 \text{ tons}}{0.67} = 2,900,000 \text{ tons}$$

A coal-storage yard, having an area of 115,000 m², is able to store 370,000 tons of coal, which corresponds to about one and half months' requirement, and this will create no difficulty in operation because the sources of supply are limited.

6. Unloading at the Wharf

The front wharf for unloading coal and iron ore consists of Nos.1 and 2 front wharfs and the coal wharf. Table 10 shows the details. As mentioned above, at the time when 5,000,000 tons of ingots are produced annually, 6,400,000 tons of iron ores and 2,900,000 tons of coal are required, and unloading of these raw materials is found to be possible, as is explained in the following :

Iron Ore

Capacity of unloaders

at No.1 front wharf (4 sets) : 140,000 t/month
at No.2 „ („) : 600,000 „

Table 10. Summary of unloaders

Raw material	Name of wharf	Length of wharf (m)	Depth of water (m)	Unloaders		Remarks
				Capacity (t/hr)	No. of units	
Iron ore	No. 1 front	500	9.5	175 150	3 1	Common berth for ore and coal
	No. 2 front	560	12	500 480	3 1	Exclusive use for ore
Coal	No. 1 front	500	9.5	150	3	Common berth
	Coal	270	12	500	2	Exclusive use for coal

Amount of ores to be unloaded :
$$\frac{6,400,000}{12}=533,000 \text{ t/month}$$

Amount of ores to be unloaded at the peak time (peak rate=1.3) : $533,000 \text{ t} \times 1.3=700,000 \text{ t/month}$
Consequently, the existing unloaders can handle the required amount of ores.

Coal

Unloading capacity
at No.1 front wharf (3 sets) : 145,000 t/month
at the coal wharf,
from coal carriers : 310,000 t/month
from common carriers : 245,000 t/month
Amount of coal to be unloaded :
 $2,900,000 \text{ t}/12=242,000 \text{ t/month}$
Amount of coal to be unloaded at the peak time (peak rate=1.3) : 315,000 t/month.
Assuming that the rate of coal to be unloaded from coal carriers to the total amount is 30 per cent, the amount to be unloaded will be :
from coal carriers : $315,000 \text{ t} \times 0.3=94,500 \text{ t/month}$
from common carriers :
 $315,000 \text{ t} \times 0.7=220,500 \text{ t/month}$

These amounts can be unloaded by the existing unloaders.

IV. Rolling Facilities

Table 11 shows outline of rolling facilities at Chiba Works.

1. Slabbing Mill

No. 1 Slabbing and Blooming Mill

This is a reversing mill of high lift type which came

into operation in September 1954, and its annual rolling capacity was 1,200,000 tons at the start, but with such subsequent improvements as tandem rolling, it can now roll annually 1,800,000 tons of ingots. This plant has AMCO type, bottom fired soaking pits which have been operating satisfactorily since their installment.

No. 2 Slabbing Mill

This is a universal-type mill, which started operation in October 1961 for producing slabs especially for wide plates and wide strips, and its annual rolling capacity is 4,000,000 ton ingots.

Soaking pits in this plant are equipped with apparatus to predict the time required for taking out ingots by the electronic computer, and their operation has been properly carried out.

2. Hot Rolling Mill

No. 1 Hot Strip Mill

This is a 56-in wide semi-continuous hot strip mill, which rolls 1,620,000 tons a year, and produces hot coils of relatively thin gauge by rolling slabs from No.1 slabbing and blooming mill.

No. 2 Hot Strip Mill

This plant contains a 80-in wide fully continuous hot strip mill, which is now on the highest level of this type and was put into operation in October 1963, and is designed to roll annually 3,000,000 tons of slabs. The finishing train consists of five stands, and when seven stands are installed, eventually the maximum coiling speed is 1,000 m/min. This is equipped with A.G.C. system with hydraulically and pneumatically driven loopers for producing coils of little tolerance

Table 11. Outline of rolling facilities

Name of mill	Type	Rolling capacity (t/yr)	Date of construction	Remarks
No. 1 slabbing & blooming mill No. 2 slabbing mill	High lift Universal	1,800,000 (ingot) 4,000,000 (ingot)	Sept. 1954 Oct. 1961	
Total		5,800,000 (ingot)		
No. 1 hot strip mill No. 2 hot strip mill Plate mill	Semi-continuous Fully continuous	1,620,000 (slab) 3,000,000 (slab) 720,000 (slab)	Apr. 1958 Oct. 1963 Apr. 1961	Barrel length 56 in 80 in
Total		5,340,000 (slab)		
No. 1 cold strip mill No. 2 " " No. 3 " " No. 4 " "	5-tandem 6-tandem Reversing 5-tandem	480,000 (hot coil) 600,000 (hot coil) 240,000 (hot coil) 780,000 (hot coil)	Jun. 1958 Apr. 1963 Under construction Planned	Barrel length 56 in 56 in 80 in 68 in
Total		2,100,000 (hot coil)		

in thickness. The computer control system in this mill is now being developed in co-operation with an electric company.

Plate Mill

This mill which started operating in April 1961 can roll 720,000 tons of slabs a year, and can produce plates up to 3.9 m wide by the rolls of 4.2 m long. As the diameter of back-up roll is 1.7 m, plates of little tolerance in thickness can be produced. This plant is equipped with heat treating equipment for producing various kinds of high-tension steel plates.

3. Cold Rolling Mill

Cold Strip Mills

The total output of cold strip mills including those now in the planning stage is 2,100,000 t/yr. Among them, the 56-in wide 6-tandem mill newly erected in April 1963, can produce cold strips of min. 0.1 mm thick with its max. rolling speed of 2,130 m/min.

Secondary Processing Equipment

A continuous galvanizing line capable of producing 80,000 t/yr. is now in operation and another line is being planned. The type of these lines is remodeled from one of those now commonly used throughout the world and can be called Kawasakiseitetsu.

The installation of a continuous tinning line is under consideration, the annual production capacity of which will be 100,000 tons.

The flow diagram of materials at the production level of 5,000,000 tons of ingots from the unloading of the iron ore and coal to rolling is shown in Fig. 10. As seen from the diagram, the rate of operation of each rolling mill is from 80 to 90 per cent. Considering the lowering in capacity due to the rolling various kinds and sizes of products, the rolling capacity of the plant is regarded as adequate.

V. Transportation

The transport route of hot metal and semi-finished products among plants at the time of annual output of 5,000,000 tons of ingots is shown in Fig. 11. The flow from the blast furnace is divided into two main routes : the one is from the O-H shop, via No.1 slabbing and blooming, No.1 hot strip and Nos.1 and 2 cold strip mills to the north wharf and the other is from the LD shop via No.2 slabbing, No.2 hot strip and plate mills to the south wharf. As seen from the diagram, transportation at any point can be conducted very smoothly.

1. Hot Metal

Hot metal is transported from each blast furnace to O-H and LD shops daily in the amount of 11,400 tons on the average, with a maximum of 12,500 tons.

Table 12. Transport of hot metal

	Amounts to be transported		No. of ladles to be required	
	Average (t/day)	Max. (t/day)	Average	Max.
To O-H	2,700	3,000	45	50
To LD	8,700	9,500	145	158
Total	11,400	12,500	190	208

Table 12 shows the transport of hot metal, where the ladle contains 60 tons of hot metal on an average. Judging from the actual results so far obtained, the number of hot metal-carrying trains will be 42 to 47 per day, each train consisting of 4.5 cars and with favorable condition, it is possible to match the train schedule with the tapping time of each blast furnace.

2. Ingots

As a rule, all ingots from the open hearth furnaces are transported to No.1 slabbing and blooming mill, and most of those from the LD converters are hauled to No. 2 slabbing, with the balance going to No. 1 slabbing mill. Since distance between the melting shop and the rolling mill is short in either case, a smooth transport of ingots can be expected.

3. Slabs

Usually, slabs from No.1 slabbing and blooming mill are transported to the neighboring No.1 hot strip mill, and those from No.2 slabbing are hauled to the adjacent No.2 hot strip mill with ease. Even in rare cases where it is necessary to transport slabs from No.1 slabbing to No.2 hot strip and plate mill or from No.2 slabbing to No.1 hot strip mill, there will be no great difficulty.

4. Hot Coil

Hot coils from No.1 hot strip mill are transferred through pickling lines to Nos. 1 and 2 cold strip mill shops, without any obstacle. The major part of hot coils produced by No. 2 hot strip mill will be transferred, with ease, to Nos. 3 and 4 strip mills to be installed at Oihama compound.

5. Shipping of Products

All products are shipped from three shipping yards, two of which are situated at the north and south ends of Chiba compound and the other is located at Oihama compound, as shown in Fig. 11.

VI. Energy Balance

1. Electric Power

Annual requirement of electric power for the output of 5,000,000 tons of ingots is 1,600 million kWH as seen in Fig. 12 which shows power balance. Of this amount 500 million kWH is supplied by the home power plant and 1,100 million kWH is to be purchased, as shown in Table 13.

The total generating capacity of the power plant in the plant is 80,000 kW per hour, and when the power plant's availability is about 75 per cent, the actual generated power will be 58,000 kW in average and even in the maximum.

Table 13. Demand and supply of electric power

	Power required (kW/hr)	Home generated power (kW/hr)	Power purchased (kW/hr)
Average	183,000	58,000	125,000
Maximum	232,000	58,000	174,000

2. Steam

The steam balance is shown in Fig. 13. The total

- Notes: 1) Unit: 1,000 tons
 2) Figures in the brackets show mill capacity
 3) Figures in percentage in the brackets show the rate of operation

Fig. 10. Flow diagram of iron and steel raw materials

output of steam is supposed to be about 2,200,000 tons a year, of which 1,900,000 tons are used in each plant, the balance being in the power plant. It should be noticed that at Chiba Works over 75 per cent of the steam output is generated from waste heat boilers.

3. Heat Quantities

The total quantity of heat in the plant is 14×10^{14}

kcal as shown in Fig. 14. Blast furnace gas is reserved in the 150,000 m³ gas holder, coke oven gas in the 30,000 and 40,000 m³ gas holders. Gases are supplied to each plant solely or as mixed gas.

In Chiba Works there is used heavy oil of high sulphur content for general use, low sulphur for the blast furnace and very low sulphur oil for the open hearth furnace, which are pumped from the front wharf to

Fig. 11. Transport routes of hot metal and semi-finished products

Fig. 12. Electric power balance

Fig. 13. Steam balance

6000-t, 2500-t, 5000-t and 1500-t oil storage tanks, respectively.

4. Cooling Water

Seawater

Seawater is taken in through two pipelines from the front wharf to Nos.1 and 2 seawater pump station, which in turn supplies to each plant using seawater. The breakdown of seawater consumption at the

time of annual output of 5,000,000 tons of ingots is shown in Fig. 15, and daily consumption will amount to about 1,200,000 m³, which is equivalent to about 88 m³ per ton of ingot.

Fresh Water

In the early period of the operation of Chiba Works, fresh water was supplied from deep wells drilled in the site, but as a shortage was estimated with the increase of steel output, the equipment for drawing fresh water of max. 77,500 m³/day from Imba Lake was completed in April 1963.

Fig. 14. Heat balance

The daily use of fresh water for the annual output of 5,000,000 tons of ingots will be approximately 650,000 m³, or equal to 48 m³ per ton of ingot, 80 per cent of which is recirculated. Fresh water consumption comes to about 7 m³ per ton of ingot, which corresponds to 98,000 m³ per day. Of this amount, 63,000 m³ is supplied from Imba Lake.

Fig. 15. Consumption of sea water

VII. Conclusions

The annual steel output at Chiba Works has been raised from the initial 1,000,000 tons of ingots to the present 4,000,000 tons. But judging from the economy at the stage of steelmaking it is found reasonable to set annual production at 5,000,000 tons, other equipment being nearly balanced with the steelmaking capacity, even though these have some surplus capacities. At the completion of Chiba Works, annual production will amount to 5,000,000 tons of ingots to total about 4,000,000 m² land and about 14,000 employees. Thus, the productivity of the Works will be 1.25 tons per m² of land and 360 tons per man, and these represent satisfactory productivity as an integrated plant.

After the completion of Chiba Works in this scale, the Company will launch into the construction of Mizushima Works which will be the newest and largest plant in Japan.