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

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# TECHNO-ECONOMIC COMPARISON OF TYPICAL WIRE-ROD MILLS: THE EXPERIENCE OF KOBE STEEL[1]

by

Osamu Miki and Toshiyasu Onishi
Kobe Steel Limited
Japan

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## SUMMARY

This paper presents a comparison of five typical wire-rod mills from both the economic and the technical points of view, and sets out the characteristics of each mill.

The rolling capacity of the five mills ranges from 5,000 to 50,000 tons per month. Some of them can be used for the production of both wire rod and bar products. The diameters that can be rolled range from 5.5 mm to 38 mm for wire rod and from 9.5 mm to 80 mm for straight bar.

The five typical mills are studied for comparative purposes from four main points of view :

1. The quality and quantity of product
2. The productivity of the mill
3. The skills and the number of operators
4. The construction costs.

Some of the figures given in the paper (e.g. the construction costs for building the mills) may vary in accordance with local conditions in different countries. However, the relative evaluation of the different types of mill can be used for the selection of the type of mill to be installed.

The descriptions and conclusions are based on the practical operating experience of Kobe Steel Ltd in the rolling of wire rod and bar over half a century. The company's present capacity for wire rod is about 200,000 tons per month, in seven mills built over the last fifteen years.

## 1. Introduction

Generally speaking, wire-rod mills are classified according to the layout of the roll stands and the quality and quantity of the products rolled. Considerable study and discussion is always needed to determine which type of mill should be adopted for the proposed sales schedule and demands of the market. Capital investment for mill construction and the iron and steel engineers and operators available (including those for electrics and maintenance) must also be investigated thoroughly.

To assist in the selection of such a mill, five typical mill layouts are described in the paper. The most important factor in reaching a decision of this kind is the results of market research on the demand for the product - i.e. the type of steel (low-carbon, high-carton, or alloy), the required seam depth in the product, the permissible depth of decarburisation, and the product finishing method (cold drawing, etc.). In other words, quality requirements must be studied exhaustively. Tonnage and dimensions are shown in Table 1 and rod qualities and tolerances in Table 2. Schematic mill layouts are shown in Fig. 1.

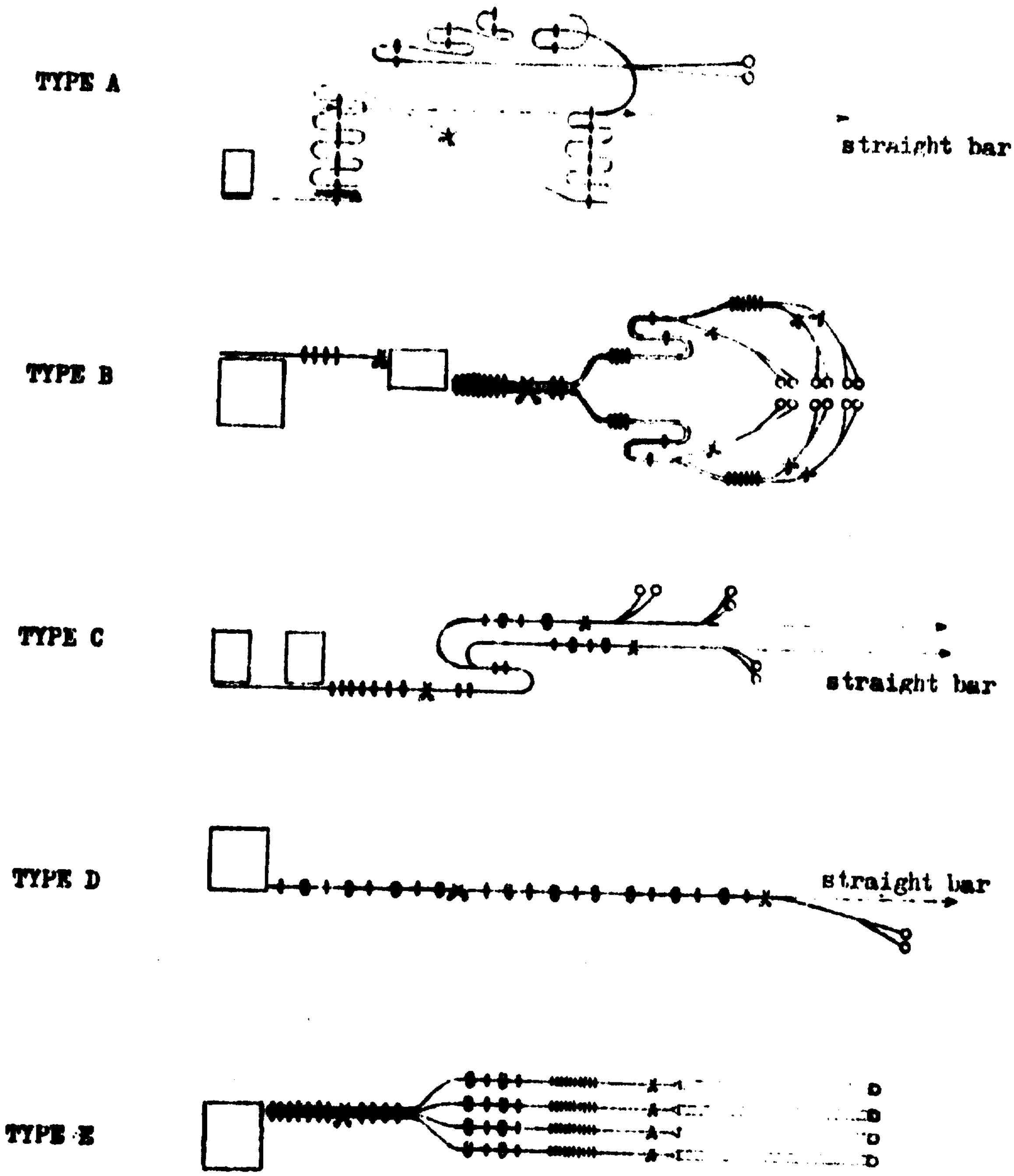



Fig. 1 - Schematic layouts of typical mills

**Table 1 - Characteristics of Mills**

| ITEM | Type A | Type B | Type C | Type D | Type E |
|---|---|---|---|---|---|
| Number of Strand | 1 | 4 | 2 | 1 | 4 |
| Monthly Production Tonnage | 5,000 T/M | 25,000 T/M | 20,000 T/M | 20,000 T/M | 50,000 T/M |
| Sizes of Products | Coil 5.5 - 25 ø<br>Bar 9.5 - 80 ø | 5.5 - 25 ø<br>— | 12 - 38 ø<br>12 - 50 ø | 12 - 38 ø<br>12 - 38 ø | 5.5 - 13 ø<br>— |
| Billet Dimension Standard Size | under 6.4 ø<br>110 sq. x 2.7 m<br>over 7.0 ø<br>110 sq. x 4.0 m | 110 sq. x 4.0 m | under 19 ø<br>85 sq. x 10 m<br>over 19 ø<br>110 sq. x 10 m | 12 - 19 ø<br>110 sq. x 12 m<br>over 19 ø<br>110 sq. x 12 m<br>150 sq. x 12 m | 110 sq. x 20 m |
| Maximum Length | under 6.4 ø<br>3.2 m<br>over 7.0 ø<br>4.3 m | 4.2 m | 10.2 m | 12.3 m | 21 m |
| Coil Weight | under 6.4 ø<br>250 Kg<br>over 7.0 ø<br>370 Kg | 370 Kg | under 19 ø<br>550 Kg<br>over 19 ø<br>900 kg | 12 - 19 ø<br>1,000 Kg<br>over 19 ø<br>1,000 kg<br>2,000 kg | 1,800 Kg |
| Finishing Speed | 6.5 - 22 m/sec | 5 - 30 m/sec | 5 - 18 m/sec | 5 - 20 m/sec | 15 - 50 m/sec |

**NOTE** 6.4 ø = 6.4 mm dia.
110sq.= 110 mm square

Table 2 - Product Quality

| ITEM | Type A | Type B | Type C | Type D | Type E |
|---|---|---|---|---|---|
| Grade of Steel | Carbon steels for industrial, cold heading, valve spring, roping quality. Low-alloy and high-alloy steels. | Carbon steels for industrial, roping quality | Carbon steels for industrial, cold heading, cold drawing quality. Low-alloy steels. | Carbon steels for industrial, cold drawing quality. Low-alloy and high-alloy steels. | Carbon steels for industrial, cold heading, roping quality. |
| Size tolerance | ± 0.40 mm | ± 0.50 mm | ± 0.40 mm | ± 0.40 mm | ± 0.40 mm |
| ovality | 0.50 mm | 0.60 mm | 0.50 mm | 0.50 mm | 0.50 mm |

2. Operating figures of the mills

Short descriptions of each type of mill are given in Tables 3 - 6. The essential features are classified under the following four headings and details are given in the Tables :

1. Quality and quantity of product
2. Mill productivity
3. Labour aspects
4. Construction investment.

2-1 Quality and quantity of product (Tables 1 and 2)

1. Quantity of production
2. Sizes of products
3. Coil weights
4. Size tolerance or roundness.

2-2 Mill productivity (Table 3 and 4)

1. Type of rolling and roll stand arrangement
2. Number of strands
3. Finishing speed
4. Yield ratio
5. Cobble ratio
6. Operating efficiency

Definitions : Yield ratio $= \frac{\text{quantity of product}}{\text{quantity of billet}} \times 100\%$

Cobble ratio $= \frac{\text{number of misrolls}}{\text{number of billets}} \times 100\%$

Operating efficiency $= \frac{\text{monthly rolling hours}}{\text{calendar hours}} \times 100\%$

2-3 Labour (Table 5)

1. Working system (teams and shifts)
2. Composition of labour and duties
3. Morale of operators.

2-4 Construction investment (Table 6)

1. Cost of building and foundation work
2. Cost of billet reheating furnace
3. Cost of mechanical equipment
4. Cost of electrical equipment
5. Operating costs
    1. Roll consumption
    2. Fuel (oil) consumption
    3. Electricity consumption
    4. Quantity of cooling water, compressed air, and steam
6. Quantity of product per working hour of direct labour

Definitions : All costs are based on present-day Japanese wholesale prices.

Operating expenses are given as the amount of each item consumed.

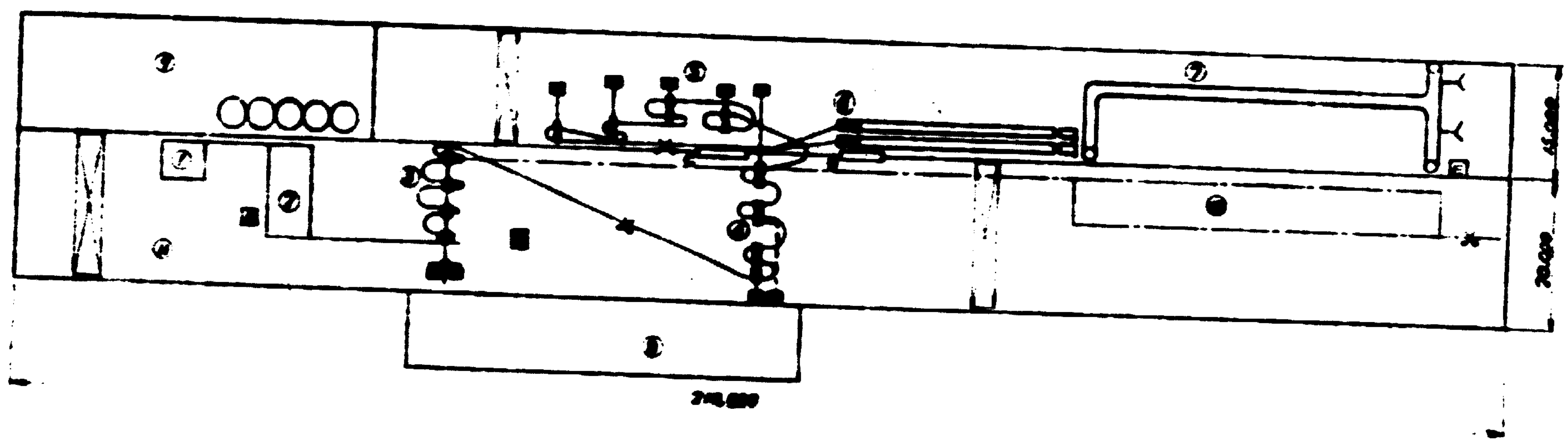
3. Outline of mills

Type A

This mill is designed to roll high-quality wire rod. Wire rod of 5.5 mm to 25 mm can be rolled with a single strand rolling throughout the mill.
As shown in Fig. 2, billets are rolled through 180 degree repeaters between each stand.
Tension-free and twist-free rolling between each stand can produce wire rod with close tolerances and good surface quality.
Rolling speed is comparatively slow for 5.5 mm rod, and so the rolling capacity of this mill is not so large as other rod mills described in this paper; however, the mill is the most suitable one for high-alloy steel product. Bar sizes from 9.5 mm to 30 mm can be rolled by changing rolls of roughing train if cooling bed is installed. The layout has many variations, according to the product.

Type B

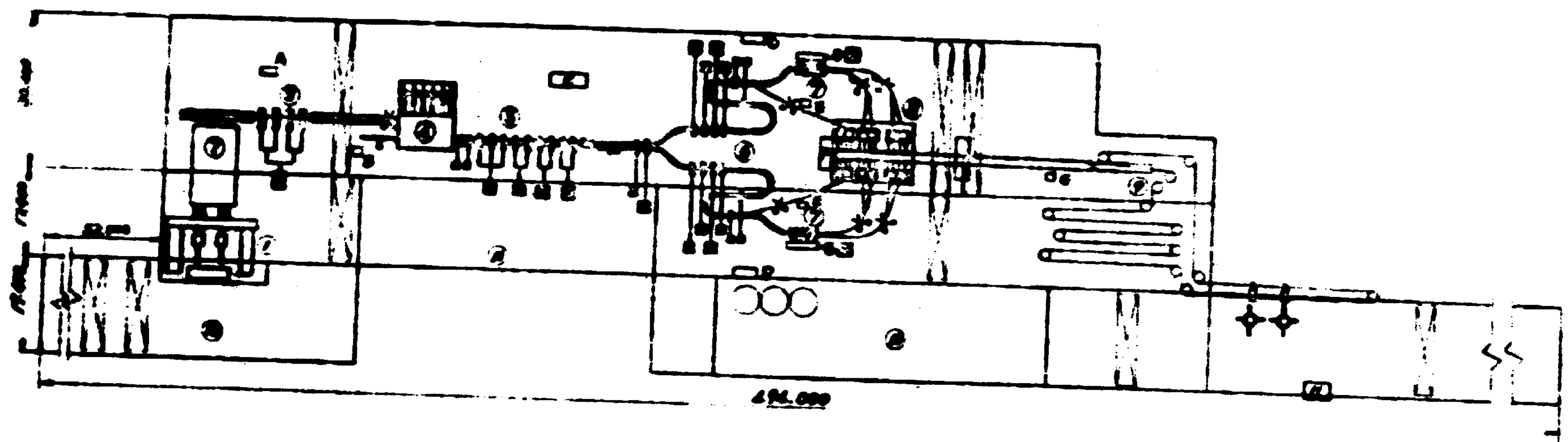
This mill is designed to roll carbon steels with rod diameter of 5.5 mm to 25 mm. As shown in Fig. 3, two 180 degree repeaters and two S-shaped repeaters are adopted to minimize the influence of tension rolling in roughing, intermediate, and finishing tandem mills.
Billet mill is single strand and rod mill is 4 strands, and both consist of horizontal stands.
Rolling speed is comparatively high. As tension and twist exist between each stand, this type of mill is not suitable for rolling the very high-quality wire rod.



1. Billet charging device
2. Billet reheating furnace
3. Roughing train
4. Intermediate train
5. Finishing train
6. Coilers
7. Hook conveyor
8. Electrical control room
9. Water treatment station
10. Cooling bed for straight bar
11. Billet yard

A - E. Pulpits

Fig. 2 - TYPE A MILL LAYOUT




1. Billet charging device
2. Billet reheating furnace
3. Billet mill
4. Holding furnace
5. Roughing train
6. Intermediate train
7. Finishing train
8. Coilers
9. Hook conveyor
10. Water treatment station
11. Electrical control room
12. Billet yard

A - E Pulpits

Fig. 3 - TYPE B MILL LAYOUT

Type C

This mill is designed to roll carbon steels and low-alloy steels. Rod of 12 mm to 38 mm can be rolled.

As shown in Fig. 4, the mill consists of horizontal stands and alternate horizontal and vertical stands in finishing trains.

Larger sizes are rolled in single strand, while smaller sizes are rolled in two strands with 110 mm sq. and 85 mm sq. billet, respectively.

Tension-free and twist-free rolling through H-V finishing trains produce coils with close tolerances.

Bars up to 50 mm can be rolled if cooling bed is installed.

Type D

This mill is designed to roll high-quality wire rod.

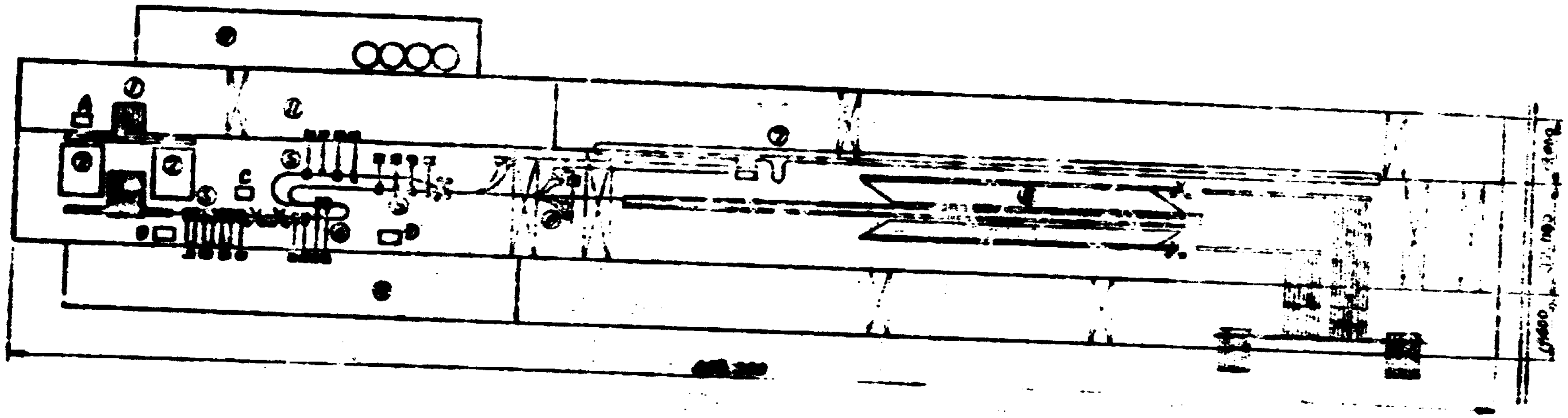
Rod sizes varies from 12 mm to 38 mm.

As shown in Fig. 5, the mill consists of alternate horizontal and vertical stands, arranged in a fully continuous straight line.

Each stand is driven individually and loop control is operated automatically.

Tension-free and twist-free rolling between each stand can produce wire rod with close tolerances and extremely good surface quality.

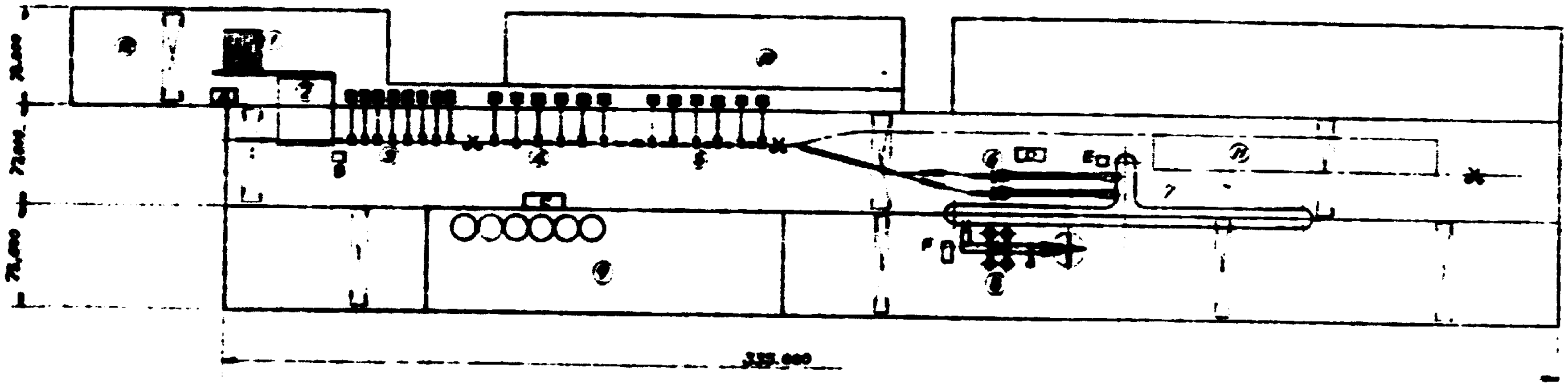
From 12 mm to 38 mm diameter straight bar can be rolled if cooling bed is installed.




1. Billet charging device
2. Billet reheating furnace
3. Roughing train
4. Intermediate train
5. Finishing train
6. Coilers
7. Hook conveyor
8. Cooling bed for straight bar
9. Water treatment station
10. Electrical control room
11. Billet yard

A - E. Pulpits

Fig. 4 -TYPE C MILL LAYOUT



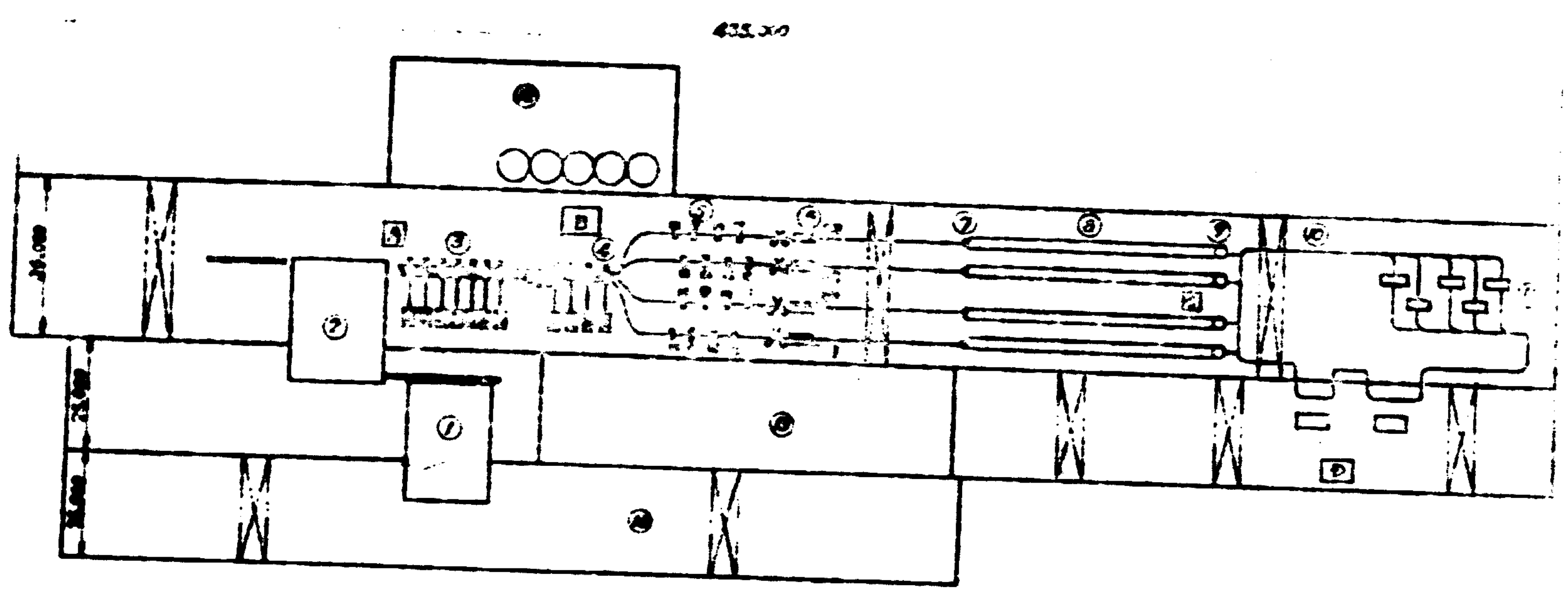
1. Billet charging device
2. Billet reheating furnace
3. Roughing train
4. Intermediate train
5. Finishing train
6. Coilers
7. Hook conveyor
8. Coil binding machine
9. Water treatment station
10. Electrical control room
11. Cooling bed for straight bar
12. Billet yard

A - F. Pulpits

Fig. 5 - TYPE D MILL LAYOUT

Type E

This mill is designed to roll carbon steel rod of 5.5 mm to 13 mm. As shown in Fig. 6, the mill consists of horizontal stands in roughing train, and alternate, twist-free horizontal-vertical stands follow in the intermediate and finishing trains.
This finishing mill consists of compact block with 150 mm and 200 mm tungsten carbide rolls, and controlled cooling devices are provided after the mill.
Finishing speed is very fast with multi-strand roughing train; consequently, the quantity of the product is the highest among these five rod mills.
Applying control cooling facilities after rolling mill, uniform metallurgical micro-structure through the whole length of a coil can be obtained.




1. Billet charging device
2. Billet reheating furnace
3. Roughing train
4. } Intermediate train
5. }
6. Finishing train
7. Loop layer
8. Control cooling equipment
9. Coil collector
10. Hook conveyor
11. Coil binding machine
12. Water treatment station
13. Electrical control room
14. Billet yard

A - D. Pulpits

Fig. 6 - TYPE E MILL LAYOUT

Table 3 - Operating Features (1)

| ITEM | Type A | Type B | Type C | Type D | Type E |
|---|---|---|---|---|---|
| Monthly Production Tonnage | 5,000 T/M | 25,000 T/M | 20,000 T/M | 20,000 T/M | 50,000 T/M |
| Monthly Rolling Hour (Rolling Hour/25 Day x 24 Hour) % | 390 Hr. ( 65 % ) | 450 Hr. ( 75 % ) | 430 Hr. ( 72 % ) | 450 Hr. ( 75 % ) | 450 Hr. ( 75 % ) |
| Production ratio per Hour (Monthly Production Tonnage/Rolling Hour) | 13 T/Hr. | 55 T/Hr. | 44 T/Hr. | 44 T/Hr. | 110 T/Hr. |
| Cobble ratio per month (Obtainable Minimum Cobble Ratio) | 1 - 3 % ( 0.2 % ) | 1 - 2.5 % ( 0.4 % ) | 1.5 % ( 0.05 % ) | 0.5 - 1.5 % ( 0.1 % ) | 1 - 2 % ( 0.3 % ) |
| Yield in Weight | 92 - 94 % | 93 - 95 % | 94 - 95 % | 95 - 96 % | 94 - 96 % |
| Roll Consumption | 1.0 Kg/T | 1.0 Kg/T | 0.7 Kg/T | 0.8 Kg/T | 0.5 Kg/T |
| Electrical Consumption | 125 KWH/T | 200 KWH/T | 105 KWH/T | 130 KWH/T | 170 KWH/T |
| Fuel Oil Consumption | 50 l/T | 57 l/T | 48 l/T | 45 l/T | 47 l/T |
| Quantity of Cooling Water per Hour | 300 T/Hr. | 1,500 T/Hr. | 1,000 T/Hr. | 1,000 T/Hr. | 3,500 T/Hr. |
| Quantity of Steam per Hour ( 7 Kg/cm$^2$ ) | under 1 T/Hr. | under 1.5 T/Hr. | under 1 T/Hr. | under 1 T/Hr. | under 2 T/Hr. |

**Table 4 - Operating Features (2)**

| ITEM | Type A | Type B | Type C | Type D | Type E |
|---|---|---|---|---|---|
| Quantity of Compressed Air per Hour ( 7 $kg/cm^2$) | 1,200 $Nm^3$/Hr. | 700 $Nm^3$/Hr. | 700 $Nm^3$/Hr. | 1,000 $Nm^3$/Hr. | 1,500 $Nm^3$/Hr. |
| Quantity of Product per Working Hour of Direct Labour | 0.3 T/man.Hr. | 0.9 T/man. Hr. | 0.9 T/man.Hr. | 1.2 T/man. Hr. | 3.6 T/man.Hr. |
| Expected Skill* | | | | | |
| Direct Labour | A | A | B | B | B |
| Indirect Labour | B | B | B | A | A |

* NOTE :

A means ; Skilled competent workers are necessary.

B means ; Less skilled workers can be employed.

TABLE 5 defines the ranges for direct labour and indirect labour

Table 5 - Manning of Mills

| ITEM | Type A | Type B | Type C | Type D | Type E |
|---|---|---|---|---|---|
| Working System | Three teams for three shifts | Three teams for three shifts | Three teams for three shifts | Three teams for three shifts | Three teams for three shifts |
| Monthly Operation | 25 D/M | 25 D/M | 25 D/M | 25 D/M | 25 D/M |
| **Direct Labour** | | | | | |
| Foreman | 1 x 3 | 1 x 3 | 1 x 3 | 1 x 3 | 1 x 3 |
| Furnace | 7 x 3 | 8 x 3 | 12 x 3 | 6 x 3 | 4 x 3 |
| Rolling | 6 x 3 | 10 x 3 | 6 x 3 | 6 x 3 | 6 x 3 |
| Pulpit Operator | 6 x 3 | 14 x 3 | 5 x 3 | 4 x 3 | 6 x 3 |
| Coil Handling | 11 x 3 | 18 x 3 | 20 x 3 | 14 x 3 | 11 x 3 |
| Total | 33 x 3 | 51 x 3 | 44 x 3 | 31 x 3 | 28 x 3 |
| **Indirect Labour** | | | | | |
| Foreman | 1 (daytime) | 1 (daytime) | 1 (daytime) | 1 (daytime) | 1 (daytime) |
| Roll Maintenance | 6 x 3 + 2 | 10 x 3 + 2 | 5 x 3 + 10 | 6 x 3 + 9 | 12 (daytime) |
| Roll Lathe | 3 x 3 + 3 | 3 x 3 + 1 | 3 x 3 + 1 | 2 x 3 + 1 | 3 x 3 + 2 |
| Crane Operator | 3 x 3 | 6 x 3 | 5 x 3 | 4 x 3 | 6 x 3 + 1 |
| Utilities Maintenance | 2 x 3 | 2 x 3 | 2 x 3 | 2 x 3 | 2 x 3 |
| Mechanical and Electrical Maintenance | 2 x 3 + 4 | 2 x 3 + 4 | 2 x 3 + 4 | 2 x 3 + 4 | 13 x 3 + 4 |
| Inspection | 5 x 3 | 3 x 3 | 5 x 3 | 5 x 3 | 5 x 3 |
| Crop Handling | 3 x 3 | 4 x 3 | 2 x 3 | 2 x 3 | 2 x 3 |
| Clerk for Spare Stock | 1 (daytime) | 1 (daytime) | 1 (daytime) | 1 (daytime) | 1 (daytime) |
| Delivery | 2 x 3 + 5 | 2 x 3 + 5 | 2 x 3 + 5 | 2 x 3 + 5 | 2 x 3 + 5 |
| Total | 26 x 3 + 16 | 32 x 3 + 14 | 26 x 3 + 22 | 25 x 3 + 21 | 33 x 3 + 26 |

(Shift worker x 3 shifts + daytime worker)

**Table 6 - Construction Costs**

(Estimated costs based on present Japanese wholesale price) x thousand dollars • ¥300 = U.S. $1 FEBRUARY 1973

| ITEM | Type A | Type B | Type C | Type D | Type E |
|---|---|---|---|---|---|
| Mill Building | 1,500<br>(10,000 $m^2$) | 2,200<br>(25,000 $m^2$) | 2,200<br>(23,000 $m^2$) | 2,000<br>(21,000 $m^2$) | 3,000<br>(31,000 $m^2$) |
| Foundation | 1,000<br>(6,000 $m^3$) | 1,900<br>(27,000 $m^3$) | 1,100<br>(16,000 $m^3$) | 1,000<br>(13,000 $m^3$) | 3,200<br>(33,000 $m^3$) |
| Billet Reheating Furnace | 700<br>(Pusher type with ceramic skid) | 1,000<br>(Including holding furnace) | 800<br>(Pusher type with water cooled skid pipe) | 1,100<br>(Walking hearth type) | 2,100<br>(Walking hearth type) |
| Mechanical Equipment | 3,200 | 4,600 | 2,600 | 3,300 | 11,400 |
| Electrical Equipment | 2,600<br>(Main motor 6,800 KW<br>Auxiliary motor 1,900 KW) | 5,500<br>(15,140 KW<br>4,050 KW) | 4,100<br>(9,400 KW<br>4,850 KW) | 4,900<br>(10,600 KW<br>5,660 KW) | 80,000<br>(22,750 KW<br>10,000 KW) |
| Utilities and Others | 500 | 1,400 | 1,600 | 4,600 | 4,300 |
| Coil Handling Equipment | Included under mechanical equipment | Included under mechanical equipment | 500 | 700 | Included under mechanical equipment |
| Cooling Bed | 1,000 | — | 2,000 | 1,300 | — |
| Total | 10,500 | 16,600 | 14,900 | 19,100 | 32,000 |

## 4. Conclusion

Some of the figures given in this paper (e.g. the construction costs for mill building) may differe widely, according to the local conditions prevailing in each country. The descriptions given in the paper are based on our own practical operating data or on our local conditions.

Many modifications of these typical arrangements are possible and various combinations of equipment can be suggested for the individual requirements of different steel companies. It is accepted that this paper does not deal with all the considerations that have to be taken into acount ebfore deciding on the type of mill or the financial background; lengthy and detailed discussions of these topics is necessary. However, it is hoped that this comparative evaluation of several typical mills will be of use in the selection of the type of mill to installed in future steel projects.

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