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Revamping of Billet Mill for a Continuous and Synchronized Operation*


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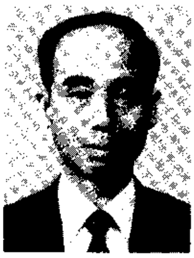
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Synopsis

A modernization program for billet, bloom and shape products was established at Mizushima Works generally aiming at streamlining the complicated crisscrossing of inprocesses from the two continuous bloom casters to the succeeding rolling mills. A new billet mill, which was a significant part of this modernization, was brought into operation in February, 1984. The billet rolling facility has the "roll-chance-free" function in order to realize continuous and synchronized production between the continuous casters and the new billet mill. This new factory has realized drastically labor-saving and rationalization of handling and transporting by several new techniques, such as the highly computer controlled vehicle (HCCV) system, quick roll changing system, and automatic shipment system for round billets. Operation and information processing are fully computerized over the entire process from steelmaking to billet shipping. Operation of the new billet factory has brought much benefit in energy and labor-saving, high yield, higher productivity, and so on.

1 Introduction

Manufacturing processes for slabs, blooms, and billets at integrated steelworks have changed greatly in recent years, from the conventional slabbing and blooming methods to continuous casting. Furthermore, steel companies are presently competing in their efforts to streamline processes by instituting continuous operation between continuous casters and rolling mills (direct rolling and hot charge rolling) against the background of increasing quality improvements in continuously cast semiproducts[1-4].

Taking this trend to be agreeable, Kawasaki Steel's Mizushima Works has examined various plans for drastic rationalization of the entire manufacturing process for various materials, such as square billets for shapes, bars, and wires; as well as round billets for seamless pipe for Chita Works. As a result, the Works instituted a modernization program, a significant part of which is the construction of a new billet mill for the continuous and synchronized operation ranging from continuous casting to rolling.

Planning was started early in 1981, the construction of the equipment and systems was begun in July 1982, and the new billet mill was brought into operation in February 1984. The new mill has since been operating very smoothly in terms of equipment, system, and product quality.

This paper presents an outline of equipment and operation of the new billet mill.

2 Basic Concept of Revamping of the New Billet Mill

Based on a product mix forecast for the future, the new billet mill was planned to produce both round and square billets as its main products while retaining the conventional blooming function for producing large section round bar, square section, and shape (beam blank). In line with the foregoing, the basic concepts of the revamping program was set up as follows:

(1) Rationalization of the manufacture of semiproducts for bar steels to achieve the maximum cost reduction through continuous and automatic operations
(2) Improvement in areas of non-cost competitiveness, such as delivery time, quality assurance systems,

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Table 1 Product specifications

Materials	C.C. blooms	Thickness Width Length 270 mm × 340 mm × 4 500～12 600 mm 300 mm × 400 mm × 4 500～12 600 mm 400 mm × 560 mm × 4 500～12 600 mm
	Ingot	5～25 t
Product dimensions	Round billet Square billet Beam brank	110～450 mm 82～500 mm
Capacity	First stage Second stage	120 000 t/month (at 270 t/h) 150 000 t/month (at 310 t/h)

* Mill capacity depends upon continuous casting capacity

and ability to meet diverse customer requirements (higher quality, smaller lot sizes, product mix, etc.)

(3) Increase in the production capacity for semiproducts for seamless pipe

(4) Total revamping of the production control system for the entire semiproduct lines to achieve the abovementioned targets

In approaching the foregoing targets, it was decided that problems will be solved by coordinated efforts involving equipment, procedures, and systems[5]. Furthermore, a total cost minimum production ranging from steelmaking to rolling must be aimed at, while the latest technologies must actively developed or introduced, along with an active utilization of existing facilities and idle equipment.

To be more specific, the means of achieving continuous and synchronized operation was sought in establishing the roll-chance-free function of the rolling mill, with quality assurance facilities adopted for on-line quality judgment. In terms of productivity, the elimination of material handling manpower and the automation of operation were actively pursued. Furthermore, utmost efforts have been made in bringing up operators into multiskilled from single-skilled by studying equipment and its layout as exemplified in the total elimination of exclusive crane operators. In this manner, productivity has been achieved.

2.1 Types of Product, Producible Dimensions, and Capacity

Types of product, producible dimensions, and capacity are shown in **Table 1**. The production capacity of the new billet mill basically depends on the hourly tonnage (t/h) of the continuous casting plant and varies slightly depending on the amount of cold materials to be treated.

2.2 Basic Functions of Equipment

The basic functions of equipment for achieving the purposes of the program are described in the following:

(1) A good balance of production capacity (t/h) is kept among all units of equipment on the basis of "CC(t/h) < rolling (t/h)."

(2) The material transportation from the continuous casting plant to the rolling mill is performed by the highly computer controlled vehicle (HCCV) system, so that hot materials can be transported according to the order of torch cuting at the continuous casters.

(3) The walking beams of the reheating furnace are divided into two sections to balance a capacity between the charging and the discharging sides.

(4) The accuracy of the No. 1 two-high slabbing mill which serves as rougher has been improved. At the same time, the mill has been remodeled to finish roll large-section round bars with diameters of 230 mm or more.

(5) The roll-chance-free function of the finishing mill is realized by a rapid on-line stand change requiring less than five minutes and off-line roll and guide setups of under 60 min.

(6) In view of the product mix of round billets, the inspection and conditioning line has been given a capacity corresponding to 2/3 of the rolling capacity. This line is provided with various kinds of automated equipment to perform on-line inspection and conditioning. At the same time, this line can ship materials classified according to the lot unit required by the succeeding process.

(7) The organization of the entire billet mill information and control system is as follows: A central computer, an on-line computer, and process computers control production, quality and operation, as well as actual processes. In the lower level are arranged DDC (direct digital control) for regulating electrical equipment, automated equipment, and quality assurance equipment. In this way, data highways are formed to cover the entire process from steelmaking to material transportation, reheating, rolling, conditioning, and shipment.

2.3 Determination of Layout and Its Features

The layout of the entire billet mill is shown in **Fig. 1**. This layout has the following features:

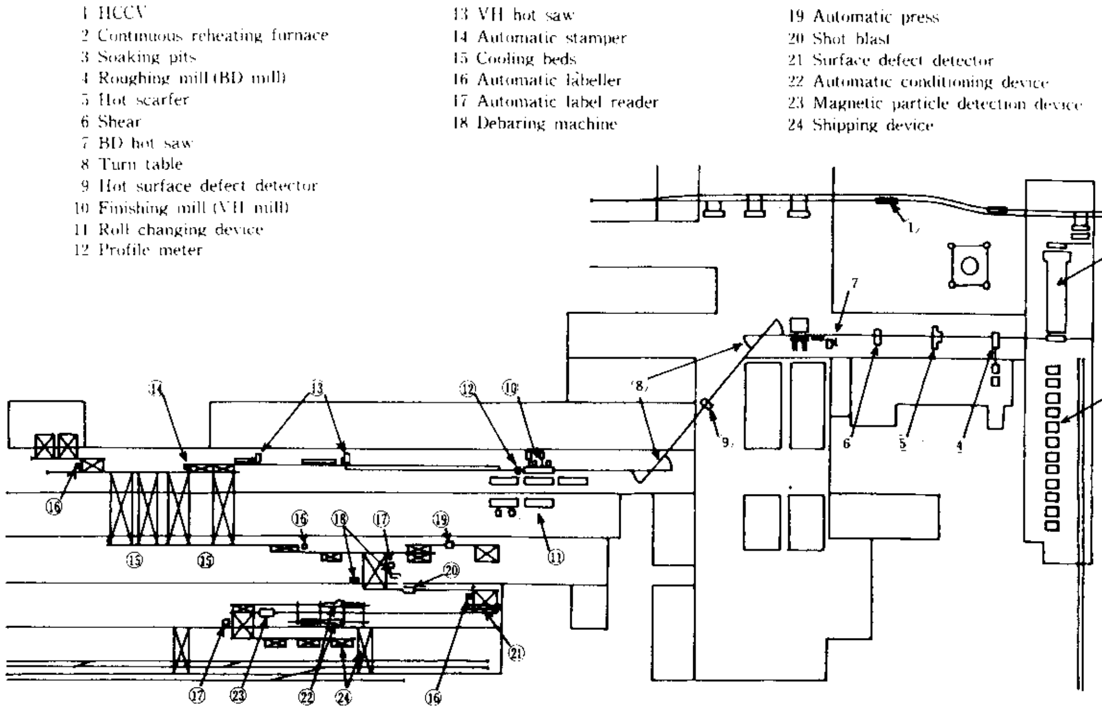

Fig. 1 Layout of the billet mill

(1) Highly computer controlled vehicles travel a distance of about 1 km between the continuous casters and the new billet mill. As these vehicles are heat-insulated, it is possible to prevent drops in bloom temperature. The HCCV system, as a bloom transportation line, serves the same function as a roller table, since it does not disturb the order of torch cutting at the continuous casters.
(2) The reheating furnace was erected by utilizing the foundations of the previously demolished soaking pits for the No. 1 slabbing mill. Considering the goal of continuous operation, the furnace is not provided with a material yard on its entry side.
(3) The No. 1 slabbing mill is used as the roughing mill.
(4) The No. 1 plate mill line facilities were removed and the finishing mill line was installed by utilizing the foundations of these facilities. Turntables that turns through 48° connect the roughing mill with the finishing mill line to form a single continuous billet mill.
(5) The cooling beds of the No. 1 plate mill were remodeled and used in this billet mill.
(6) Square billets, except for special ones, are transported direct to the rod and bar mill while still hot.
(7) Round billets are transported through the cooling beds to an inspection and conditioning line installed exclusively for round billets in an area from which the No. 2 shearing line for the No. 1 plate mill had been removed. Inspection, conditioning, and lot classification can be performed on-line.

Basically, the remaining facilities of the No. 1 slabbing mill were used for the line from the reheating to roughing, and those of the No. 1 plate mill, for the line from the finishing mill to the conditioning line. The layout of the new billet mill enables all materials to be processed on-line. Furthermore, wide-ranging measures were taken in the areas of automated material handling and elimination of material handling manpower, as represented by moves towards craneless operation.

3 Outline of Main Facilities

To achieve continuous operation directly linked to the continuous casters, it is necessary to satisfy basic requirements of stable operation and material quality. Aiming at full automation as a means of achieving this, design and manufacture were carried out with importance attached to the creation of maintenance-free facilities, improvement of control accuracy, and ease of automatic control.

3.1 Highly Computer Controlled Vehicle

The HCCV system was adopted to connect the far-separated continuous casters and the rolling mill and to ensure a high degree of continuity in their operation[6]. Multiple bogies are automatically controlled by IR communication between a loop antenna on the ground and radio receivers on the cars. To improve the reliability of car operation, it is made possible to turn the bogie from the traveling to traverse direction. Multiple bogies can

Table 2 HCCV specifications

Equipment	Maker	Unit	Specifications
HCCV	Toshiba	6	Type : Motor car of bogie type with heat-insulation room Capacity : Max. load 30 t Bloom temp. 900°C Buggy : Inside width 1 800 mm Inside length 13 300 mm Speed : Straight 250 m/min Traverse 60 m/min Drive system : Power ; Dual model system (Trolley & battery) Drive ; Gate turn of chopper (Power generation) Transmission control system : Station -station ; Multiplexing Station -vehicle ; Inductive radio

transport materials highly efficiently without human intervention. **Table 2** gives the specifications of the HCCV.

3.2 Reheating Furnace and Auxiliary Facilities

One continuous reheating furnace is provided, with auxiliary facilities composed of receiving and charging equipment for hot materials and discharging equipment for reheated materials. **Table 3** gives the specifications of the reheating furnace.

(1) Continuous reheating furnace

This reheating furnace is of an energy-saving type for hot charge use only, and is designed for continuous operation synchronized with the CC plant. The furnace has an adjustment function which compensates for variations in charging and discharging capacities. Main features of the furnace are described in the following:

(a) Two-section walking beam design
The walking beams are divided into two sections in the direction of the furnace length. The charging-side beams are operated at a higher speed and the pitch of materials in the furnace is controlled by compensating for variations in the charging and discharging pitches.

(b) Walking beam speed control
To ensure the movement of stock between the divided walking beams, beam speed is controlled at a discretionary stroke using VVVF control.

(c) Installation of high-efficiency recuperators
Exhaust gas losses at the furnace discharge end tend to be large because of charging of high-temperature materials. Recovery efficiency is therefore improved by using air recuperators and gas recuperators in combination.

(d) Heat insulation is reinforced by triple insulation of the skids, lining of the furnace inside wall, and all-ceramic lining of the discharge end side of the preheating zone.

(e) Axial-flow burners are installed in all zones to ensure a uniform temperature across the width of the furnace.

(f) An auxiliary door is installed to reduce heat loss during discharge. Moreover, by the adoption of DDC instrumentation the furnace has such

Table 3 Reheating furnace specifications

Equipment	Maker	Unit	Specifications
Reheating furnace	Chugai Ro	1	Type : Two separate walking beam type with 6 zones Capacity : 350 t/h with hot charge 200 t/h with cold charge Length of furnace : 33 600 mm Width of furnace : 13 400 mm Fuel : Mixed gas Recuperater : 4 pass air rec. & 2 pass gas rec. Drive of walking beam : Lift No.1 WB AC 110 kW Lift No.2 WB AC 200 kW × 2 Traverse No.1 WB 22 kW AC-VV Traverse No.2 WB 45 kW AC-VV

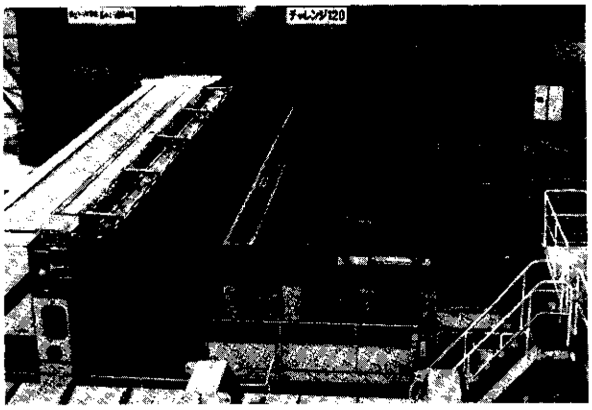

Photo 1 Equipment before reheating furnace

functions as CO–O_2 control, taper heating control in the soaking zone, and control of the number of operating burners in the preheating zone.

(2) Equipment before and after reheating furnace

There is neither a material yard nor crane before the reheating furnace. Instead, a transfer system transports hot materials received from the HCCV direct to the reheating furnace. Reheated blooms are supplied to the breakdown mill-line by an overhead extractor. **Photo 1** shows the equipment prior to the reheating furnace.

3.3 Roughing Mill Line Facilities

The No. 1 slabbing mill was remodeled into a breakdown mill capable of finish rolling of large-section round bars 230 mm or more in diameter. The existing hot scarfer and shear were used without modification and a hot saw for round bars was installed in the line. A new line was installed which connects the roughing mill with the finishing mill by means of two turntables. The specifications of the roughing mill line are shown in **Table 4**. Principal features of the remodeling of the breakdown mill are given in the following:

(1) The automatic positioning accuracy of screwdown was improved from ± 1.0 mm to ± 0.2 mm by applying digital control to the screwdown motor.
(2) A preload motor was installed to permit roll gap calibration at a low speed of 0.5 mm/s. The preloading capacity is 400 t, and the release capacity with a tight screwdown is 560 t.
(3) A descaling device was installed to prevent the formation of scale defects at the breakdown mill in expectation of higher quality requirements in the future. In consideration of its relation to the guide for round bar rolling, this descaling device is situated on the back side of the mill and is operated at pressures of 120 to 170 kg/cm^2. Furthermore, the design of device allows the top header to rise as far as 2100 mm when necessary to avoid interferense with ingot rolling.
(4) A motor-driven roll thrust adjustment device was installed to facilitate thrust adjustment. At the same time, a unique chock clamp system was adopted to reduce clearances.
(5) The mill was modified so that a double roller guide could be installed on the rest bar proper incorporated in the housing over the feed rollers. The rest bar and the roller guide are of a separable type to facilitate the disassembling and assembling of the roller guide. During size changes, the guide can be replaced quickly using an exclusive guide changing device, thus permitting the rolling of large-section round bars of many sizes.
(6) In the breakdown mill remodeling, goals were total automation of the operation of the screwdown device (except for material tilting), the manipulator, the tables, and the descaling device. As a result of such automation, bloom rolling and ingot rolling now require only one operator each.

Table 4 BD mill line facilities

Equipment	Maker	Unit	Specifications
Roughing mill (BD mill)	Hitachi	1	Type : 2-high reversal mill Roll size : 1 500 mmφ x 3 400 mm Lift : 2 100 mm max. Main motor : DC 4 000 kW (30/60 rpm) x 2
Shear	Hitachi	1	Established equipment
Hot scarfer	Union Carbide	1	Established equipment
BD hot saw	Ube	1	Type : Hydraulic slide type Brade dia. : 2 400 mmφ Brade rotation speed : 100 m/s Motor : AC 450 kW V-belt drive
Turn table	KHI	2	Type : Rack-pinion type Table length : 28 m Table width : No.1 1 900 mm No.2 750 mm

Table 5 Finishing mill line facilities

Equipment	Maker	Unit	Specifications
Finishing mill (VH mill)	IHI	4×2	Type : Horizontal mill x 2 x 2 Vertical mill x 2 x 2 Roll size : 950 mmΦ x 500 mm Screw down : Motor drive Screw up : Hydraulic drive Main drive gear ratio : V1 stand 1/32.464 H2 stand 1/28.277 V3 stand 1/27.388 H4 stand 1/22.958
Main motor of finishing mill	Fuji Electric	4	V1&H2 : AC 1 200 kW x 272/680 rpm V3&H4 : AC 1 400 kW x 318/795 rpm Control : AC-VVVF, Digital ASR control
Roll changing device	IHI	1	Stand frame on the 4 stands quick change type Construction : Stand frame 2 Side shifter 2 Drawing car 1 V-stand push puller 2 Roll changing rig 2 Guide changer 6
VH hot saw	KHI	2	Type : Hydraulic slide type Brade dia. : 2 000 mΦ Brade rotation speed : 100 m/s Motor : AC 370 kW Bevel gear drive

3.4 Finishing Mill Line Facilities and Roll Shop

The roll shop was regarded as on-line equipment for the purpose of achieving the roll-chance-free function. Furthermore, although operations have been simplified in order to increase reliability, an unprecedented level of mechanization and automation was attempted. From the viewpoint of stabilized rolling and high dimensional accuracy the hoped-for functions were successfully realized. The specifications of the finishing mill line are shown in **Table 5**. Principal features of the line are described in the following.[7].

(1) The roll-chance-free function is achieved by an automatic rapid (5 minutes) change of buggy carrying four vertical and horizontal stands.
(2) To achieve stable rolling and, at the same time, allow rapid stand changes, rolls with a 950 mm maximum diameter are used in the one-roll, one pass method. The size of the finishing mill is as small as one-half that of the conventional mill and the center-to-center distance of each mill stand is only 2.5 m. There is no intermediate guide.
(3) In the roll shop, vertical rolls are changed without use of crane. For this purpose, the vertical stands are turned 90° to the same position as the horizontal stands, using the turning device shown in Fig. 2. In this manner, substantial mechanization and automation is achieved in the changing of rolls and guides.

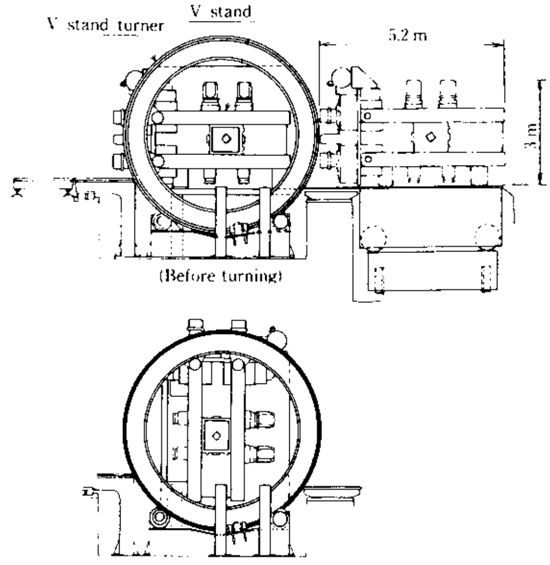

Fig. 2 Vertical mill turning device

(4) Stable rolling was achieved by maintaining the height of the material center at a constant level at the four vertical and horizontal stands during rolling. Because the rolling mill is provided with a reference line, it has become possible to set the guides in a constant position relative to the rolls in the housing regardless of size. Therefore, the facilities before and after the finishing mill perform a passline

adjustment function for each size to be rolled.

(5) As a fundamental concept, setups for changes in rolling size are all performed off-line. Accordingly, each stand where roll changes are necessary is equipped with hydraulically and electrically controlled auto-couplers, thus having the same functions as in on-line operation.

As mentioned above, the roll shop where off-line crane operations had been performed conventionally was mechanized and fully automated. This contributes greatly to synchronized operation and has resulted in a substantial improvement in productivity. In addition to the above-mentioned facilities, this VH mill is provided, on the entry side, with a tongue tilter and pinch rolls for ensuring the ease of bite. Furthermore, two hot saws perform high-efficiency finish sawing of products. These facilities are all fully automated, allowing three operators to perform all on-line operations (mill and hot saws), with three additional operators carrying out the off-line operations, including roll turning. **Photo 2** shows the general view of the finishing mill.

3.5 Cooling Beds and Conditioning Line Facilities

After round billets and square billets are cut by the hot saws at the finishing mill line, their ends are marked with billet numbers. Round billets and square billets take different routes at the cooling beds, then undergo conditioning treatment. **Table 6** gives the specifications of the conditioning line facilities.

(1) Cooling bed for round billets
This cooling bed has transportation and cooling capacities corresponding to the rolling capacity. A walking beam rake-type cooling bed is employed to prevent cambers during cooling. A water cooling device is installed on the delivery side of the cooling bed.

(2) Cooling bed for square billets
This is a walking beam cooling bed onto which square billets are automatically transported. Billets are equally spaced on the bed. Camber during cooling is rare.

(3) Finishing line facilities
As is apparent from the layout in Fig. 1, the finishing line is characterized by the fact that various types of quality assurance equipment are coupled organically with automating equipment. On-line finishing is conducted except in special cases where billets are brought off the line. This line is operated so as to maintain a good capacity balance depending on the product mix. Another feature of this line is its capability to forward billets classified by the lot unit as required by the succeeding process.

3.6 Quality Assurance Equipment

Synchronized and continuous operation can be accomplished only when a complete quality assurance system is established. Operation is supported by various kinds of quality assurance equipment which guarantee proper stock control and surface quality, as well as ensuring size and dimensional accuracy. Good billets are thus delivered for the bar and wire rod mills and seamless pipe mill. Table 6 gives the specifications of the quality assurance equipment, together with those of the finishing line.

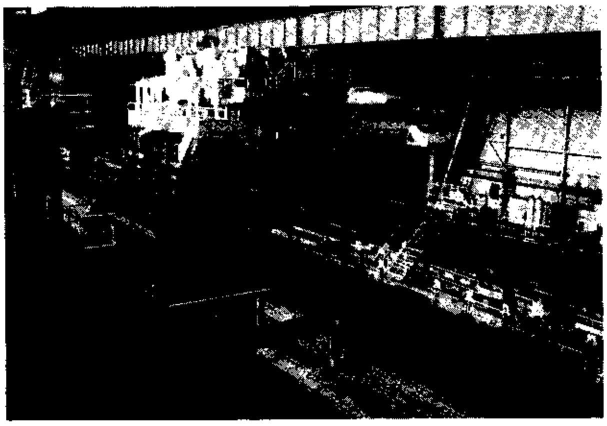

Photo 2 Billet mill line

(1) Hot surface defect detector for billets
A hot surface defect detector of the eddy current multiprobe fixed type was installed to determine the necessity of surface grinding of billets, mainly with those intended for use in wire rods and bars. The level of surface quality required of wire rods and bar products depends greatly on the type and application of products. For products that must be completely free from surface defects, such as cold grade bars, billets are conditioned if any surface defect is detected. However, this device is designed to detect defects 1.0 mm or more in depth in materials following rolling at the breakdown mill.

(2) Profile meter
A profile meter was installed on the delivery side of the VH mill. The main purpose of this device is to assure the dimensional and size accuracy of round billets. This device continuously measures diameter in a full circle along the full length of the piece. One full length, 360° measurement cycle requires about two seconds.

(3) Main defect detector and conditioning grinder for round billets
Surface defects in round billets for seamless pipe 110 to 350 mm in outside diameter are automatically detected and removed by a grinder. Grinding of round billets was already being carried out at the company's Chita Works before the start-up of the new billet mill. By conducting this operation at the Mizushima Works and installing a defect detector of

Table 6 Conditioning line facilities

Equipment	Maker	Unit	Specifications
Cooling bed for round billet	KHI	2	Type : Walking beam (Be able to turn round billet) Size : 12.5 W x 51.5 m Max loading weight : 680 t Traverse stroke : 950 mm
C.B. for square billet	KHI	2	Established equipment from No.1 plate mill
Shot blast	Shintō Kōgyo	1	Type : Billet turning type with 3-rotors
Automatic press	Kojima	1	Type : Hydraulic horizontal press Pressing force : 1 500 t Material : 80 mm~450 mm
Automatic stamper	Narazaki	2	Type : One wheel air hammer type Number of figures : 16
Surface defect detector	Förster	1	Type : Magnetic leakage flux testing type Probe : Holl element 24 channel x 2 head Facility : Depth 0.3 mm Length 5 mm
Magnetic particle detection device	Shimadzu	1	Type : Billet turning type Facility : Depth 0.05 mm
Debaring machine	Noritake	2	Type : Grinder with turning roller
Automatic conditioning device	Noritake	3	Type : Fixed grindstone and revercible car type Grindstone size : 610 mm/203.2 mm x 75 mm Speed : 80 m/s max.
Automatic labeller	Kansai Seiko	3	Type : Swing head type
Label reader	Kansai Seiko	2	Type : Bar code reading type
Online-scaler	Kawatetsu Instruments	4	Type : Load cell type Ingot scaler 30 t BD bloom scaler 10/30 t (Range changing type) VH billet scaler 5 t Conditioning scaler 10 t
Hot surface defect defector	Hara Denshi	1	Type : Eddy current multi-probe fixed type Detection speed : 1.0 m/s Detection zone : 4 surface & 4 edge Number of channels : 84 Facility : Depth 1 mm
Profile meter	Tokyo Koon Denpa	1	Type : 90° swing optical type Source of light : Halogen lamp Measuring range : 60~280 mm (Round billet & square billet) Accuracy : ±70 μm

high detection accuracy the following two points in particular were improved:

(a) The formation of surface defects is detected in an early stage with high accuracy, as is reflected in the improvement in meeting production specifications in the continuous casting and rolling processes.

(b) By completely removing harmful defects before billet shipment, the acceptance rate of tubes is improved and processing time at Chita Works is reduced.

Billets for seamless pipe must be free of surface defects deeper than 0.5 mm because of severe quality requirements. The main defect detector (automatic magnetic leakage flux testing device) is designed to detect defects up to 0.3 mm in depth in consideration of plans for future production of structural large-section round bars. When a defect is detected, the billet in question is transferred to a grinder carriage where the defective portions are ground off by a fixed grinder with a grindstone. Information on the position, depth, and length of defects as detected on primary inspection is stored in a computer in map form. This information is transmitted to the grinder, making possible automatic grinding and on-line reinspection and reconditioning.

(4) Magnetic particle testing device
A magnetic particle testing device was installed on the delivery side of the conditioning line to reinspect for defects that may remain after grinding. Any defects which would be detrimental to products are detected in this reinspection and removed. In consideration of the future production of high-grade steels, this magnetic particle testing device is designed to detect defects 5/100 to 10/100 mm in depth, which cannot be detected by the main defect detector.

(5) Product identification control
Product information is managed by the on-line computer and process computers. Computer control is effected through use of an automatic stamper, an automatic labeller, and an automatic label reader. Individual pieces are thus identified, and product information is read from the label bar code in the succeeding process. In this manner, information processing and automatic control are facilitated.

3.7 Round Billet Shipment Equipment

Billets are classified on the delivery side of the conditioning line as required by the succeeding process, are shipped by a newly-developed shipping method in which a special lifting machine and an automatic rack are combined. This method has solved all the problems of safety, reliability, and personnel requirements connected with the shipping operation as it was formerly performed manually by many slinger workers using lifting tools, such as wire ropes and magnets.[8]. **Photo 3** shows how products are loaded onto transport vehicles using the new shipping device. **Table 7** shows the specifications of the device.

(1) Special lifting machine
This device is provided with rotating arms, a chain, and a link mechanism using a deadweight. Its operation requires only one crane operator.

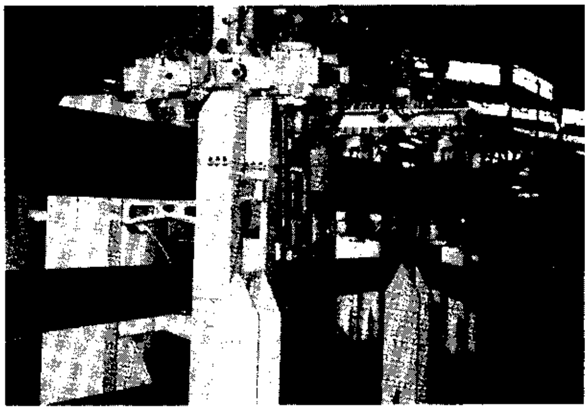

Photo 3 Shipping device

(2) Automatic rack
When billets are placed in the rack, the bar supporting the billet falls automatically with the weight of the materials. It then can receive the pieces which follow. This shipment handling method has made it possible to ship round billets in piles, which had been considered impossible. This method has been applied not only to shipping at the billet mill, but also to loading at the Mizushima shipping quay, unloading at Chita Works after arrival, and handling at the Chita material yard.

3.8 Outline of Utility Facilities

The new billet mill was constructed by remodeling the No. 1 slabbing mill and No. 1 plate mill. With respect to mill utilities, therefore, it was possible to utilize largely not only existing equipment but also piping and wiring for the new billet mill, resulting in a substantial reduction of construction costs. As a labor-saving measures, integrated supply lines were installed for the hydraulic oils and fats for use in newly installed mechanical and electrical equipment. Furthermore, a new centralized monitoring system was installed for the reused existing equipment, and for the newly installed for preventive maintenance.

3.9 Outline of Electrical Equipment

The following principal goals in connection with electrical equipment were set, in order to achieve targets in the areas of continuous and automatic operation and high product quality:

Table 7 Shipping divice specifications

Equipment	Maker	Unit	Specifications
Shipping device	Narazaki	1	Special lifting machine and rack Lifting weight : 20 t max.

(1) Application of DDC by total adoption of plant controllers
(2) Adoption of wide-range speed controlled AC motor drive systems
(3) Adoption of high-performance and high reliability automatic operation systems
(4) Improvement in sensor reliability

3.9.1 Electrical machinery

Energy-savings, high reliability, and high maintainability were the goals for electrical equipment in the new billet mill. All drives, including the main motors of the finishing mill, are of the speed controlled AC motor type, with the exception of some reused existing drives.

(1) Main motors of the finishing mill
The main motors are totally digital-controlled DDC thyristor motors (2 motors, 1200 kW; 2 motors, 1400 kW), the first application, world wide, of such motors in all stands of a 4-stand tandem mill. This system has the following features:
  (a) The motors provide high overload capacity and high rigidity, equivalent to those of DC motors for rolling mills.
  (b) The thyristor transformer equipment has a 12 phase for suppressing high frequency waves to the power source, and the motors, as thyristor-type motors, have a 6 phase drive for the purpose of controlling unavoidable torque ripple. Both systems yield favorable results.
  (c) Control characteristics equivalent to those of DC motors are obtained. Furthermore, speed control accuracy is improved by DDC.
  (d) The problem of commutator sparks is eliminated by adoption of AC equipment. In addition, the problem diagnosis function is improved by the adoption of DDC. Thus, reliability and maintainability are greatly increased.
  (e) The efficiency of this AC motor drive system is more than 2% higher than that of an equivalent DC system. Moreover, the control function for the impact drop compensating observer has been added to this motor. The dimensional accuracy of the leading end of products is improved by reducing the usual speed decrease that occurs when rolled material first comes in contact with the mill rolls.

(2) Auxiliary machines
Speed controlled AC motors with a large overload capacity suitable for DC motor-type applications were developed and adopted in order to realize a complete AC system with the new equipment.
  (a) The new motor was designed to conform to standards for DC motors (JEM1109). Rating, mounting dimensions, and shaft end dimensions were determined to conform to this standard.
  (b) Current-type inverters were adopted as drive controllers. A vector control function was given to those which require speed control. Thus, the same characteristics as DC motors were obtained.

The new auxiliary machines were applied to all drive systems, such as the screwdown device, side guide, and saw gauge, etc. for the first time.
Although the DC motors of the No. 1 slabbing mill were of the MG type, the thyristor leonard system was adopted for the new motors in order to improve control performance. For the roughing mill screwdown motor, the digital leonard system was adopted to make it possible to attain the required automatic positioning accuracy of the screwdown without changing the screwdown drive mechanism. In addition, the following devices were incorporated in the electrical equipment:
  (a) The stand changing system was adopted for the finishing mill stands. Automatic connection was accomplished by installing one auto coupler for each stand.
  (b) Sensors, except in certain cases, have a margin check function for preventive maintenance.
  (c) The optical fiber method was adopted for HMDs and CMDs, and the amplifier was separated. Therefore, cooling is unnecessary and air is not used.

3.9.2 Control system

Thoroughgoing realization of high-speed control was the aim of the adoption of DDC control in the control system for equipment operation control functions, e.g., speed control and APC. Control functions carried out for the purpose of product quality improvement are assigned to the host computer. The features of the control system are shown below.

(1) High-speed transmission
In principle, MODEM transmission was adopted for mass data transmission between the DDC's and host computers, with PIO transmission adopted where high-speed data transmission is required, e.g., tracking signals. For this purpose, an interface controller (IFC) was installed on the DDC side. To allow common access to data by both the IFCs and the plant controller, a multiplex control bus was installed between the two. An optical data highway was adopted for data transmission between the plant controller and the DDC for its high speed and noise resistance. **Figure 3** shows the flow diagram of the transmission system.

(2) Remote I/O
Although process signals necessary for the control system are distributed over an wide area, control

equipment is concentrated in order to improve maintainability. In this mill, control equipment is gathered in four electrical rooms. Signals are collected in each control room, achieving substantial economics in process input/output signal cables. The signals are transmitted to the plant controller by remote I/O to increase efficiency.

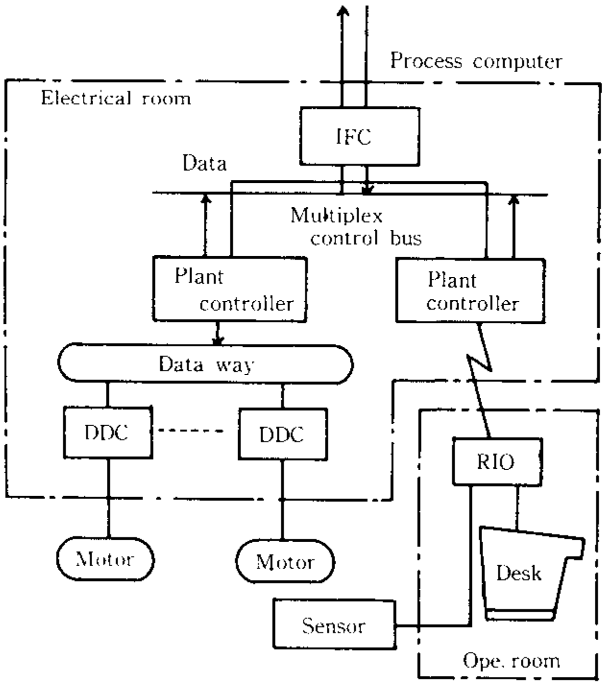

Fig. 3 Flow diagram of transmission

3.10 Outline of Total System Configuration

In the new billet mill, product identification and quality assurance for each billet must be realized at high operation cycles while achieving synchronized and continuous operation in coordination with the continuous casters. To this end, it is necessary to meet the contradictory requirements presented by processing immense quantities of data at high speeds. Therefore, the computer system has be given the hierarchical structure shown in **Fig. 4**.

The central computer, at the top of the hierarchy, has such functions as order entry, material design, preparation of operation instructions, and creation of data bases for operation control and quality control. It interfaces with the Head Office and Chita Works systems. The on-line computer receives operation instructions from the central computer and transmits them to the subordinate units of the system in good time for handling materials. In addition, the on-line computer can feed-forward upstream process operation results to the downstream areas, and perform on-line acceptance/

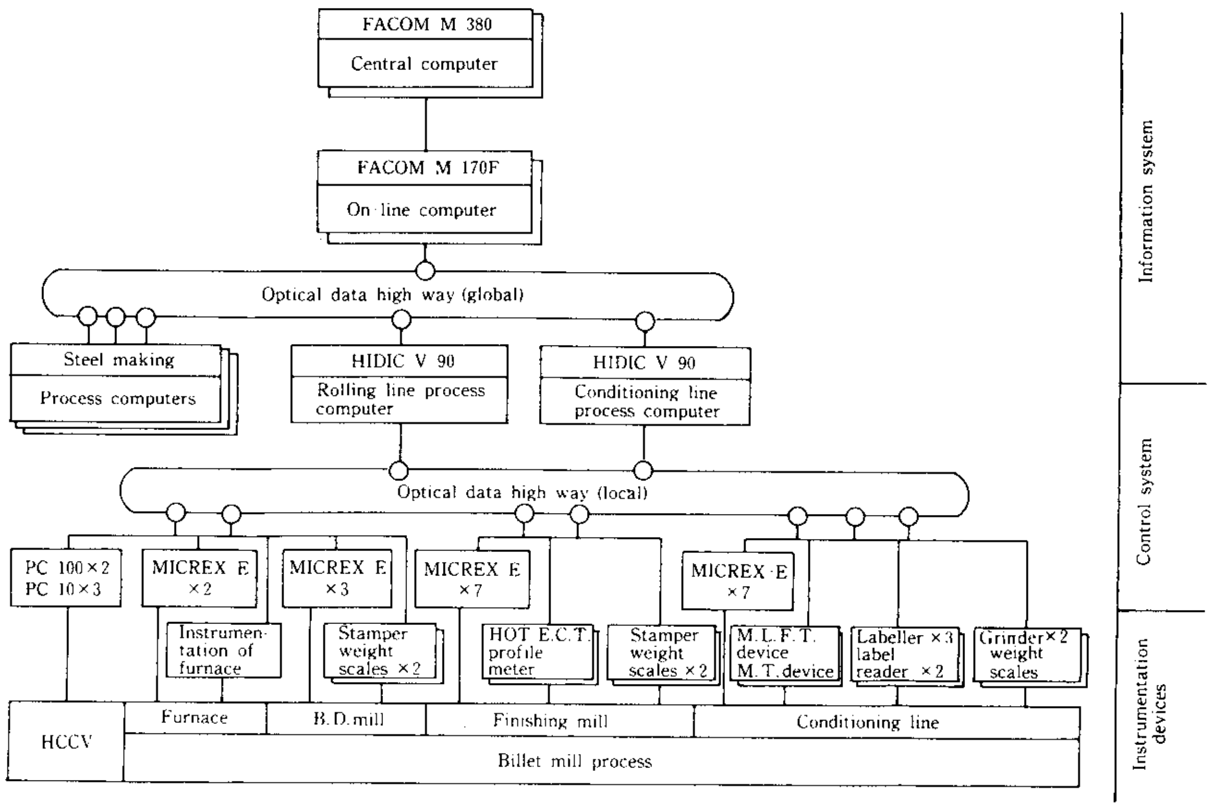

Fig. 4 Configuration of the billet mill information and control system

rejection judgments in real-time. As a result, units at the process computer level or lower can perform process control based exclusively on instructions given by the on-line computer. The process computers establish the set-up data necessary for control of each piece of electrical DDC and instrumentation equipment, and then gather result data. Data processing is performed independently for each billet.

4 Condition of Operation

The start-up of the new billet mill was the beginning of a large-scale rationalization program for the streamlining of the bar steel material manufacturing process, and the first such experience for Mizushima Works. Manpower and materials were shifted from another mill where billets had been produced; this had to be done without affecting the billet supply system. While the No. 1 slabbing mill was kept in 3 shift operation; the finishing mill and conditioning line were gradually started up on single shifts in March, increased to 2 shifts between April and June, and reached 3 shifts in July 1984. In April, the former billet mill, which had been supplying materials to the wire rod mill, was shut down and the production of billets was relocated while the personnel of the shut down mill were transferred and trained. During this period, operators who had participated in the program from the beginning played an important role in the start-up of the new billet mill. Thus, the mill was smoothly put into operation. **Figure 5** shows the amount of production, availability rate, and rolling efficiency from March to August, 1984, illustrating the progress of the start-up of the new billet mill.

4.1 Problems in Start-up Period

In the Shape and Bar Rolling Department of Mizushima Works, conversion to a block mill of the wire rod line is presently being carried out as another revamping program. Until completion of this plan, low productivity 82-mm square billets will be the main product item of the new billet mill. This situation overlapped with start-up troubles of the billet mill, causing various problems. Problems that occurred and measures taken are described below in concrete examples:

(1) Square billets of the 82-mm size were not taken into consideration as a product item in the revamping plan. However, it later unavoidably became necessary to produce this size. With limited time for studying of equipment, operation methods, and systems with respect to this product, it took two months to stabilize operations. A resulting imbalance of capacities among various pieces of equipment in the billet mill disrupted automatic operation, leading to a chain reaction of material congestion, temperature drops, and sensor (HMD) disfunction. The problem was solved by reviewing and improving operation methods, as well as the durability of software for coping with problems.

(2) Many of the software problems became apparent only in conjunction with abnormal cases in the initial stage of start-up. Software was rapidly stabilized as action was taken in response to each problem as it arose. In this connection, when an extremely large system is being brought into opera-

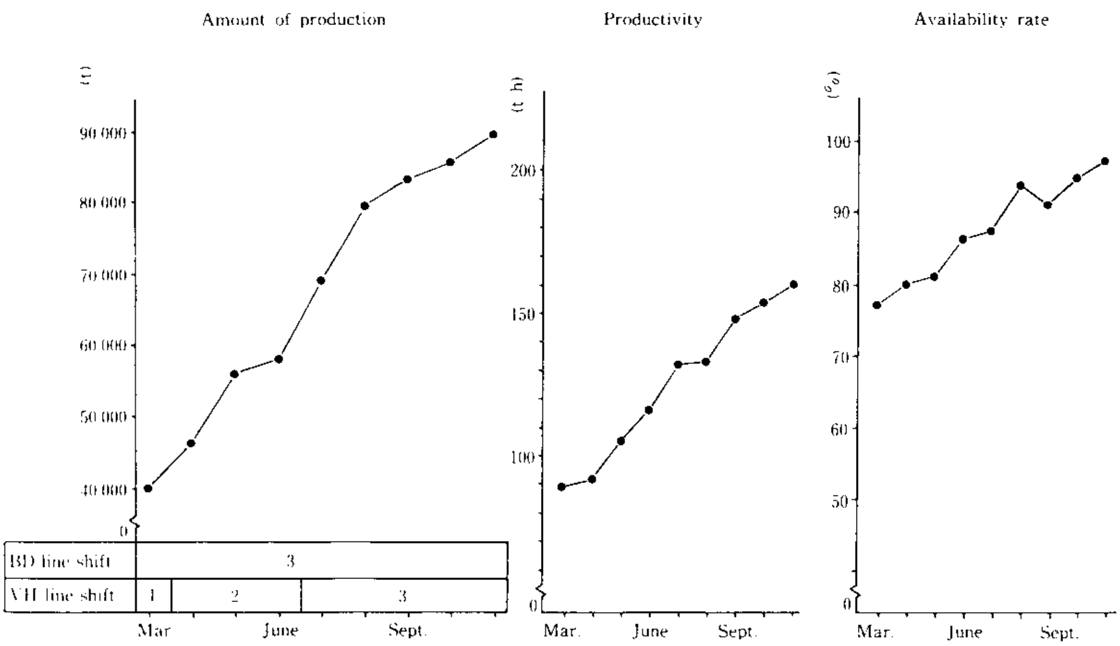

Fig. 5 Production transition

tion, effective system development can be expected by setting enough period of time for debugging in trial operation.

(3) The number of sensors on which automatic operation depends began to increase around May, when production efficiency began to increase. Many of the problems were attributable to vibration, water, or heat. Such problems are now decreasing as measures, including adjustment and review of installation methods and types are taken.

(4) Taking the opportunity of revamping of the new mill, a number of new technologies were developed. At the start-up stage, nonconformance happened to some of the newly developed products, constituting part of the cause of a declined operation rate. By rectifying the nonconformance portions, operations came to function as specified, with rising effect.

(5) With respect to hardware, several occurred which were attributable to causes such as insufficient strength, imperfect measures against heat, and the effect of scale. More elaborate maintenance measures will be taken in the future in consideration of the fact that the roughing mill line, which was constructed by remodeling existing equipment, has undergone a changeover from conventional low-load operation to high-load operation.

Almost all problems that occurred after start-up are of the same type as the early-stage problems. It can be considered that the start-up of the mill was smooth, since operation is now stable after the elapse of half a year.

4.2 Operation Results

During the half-year since start-up, the number of product items has increased gradually. However, the planned product mix has not yet been obtained, so that the full results of streamlining are still to be realized in operation results. The following are operation results, together with future prospects:

(1) Since 82-mm square billets, the productivity of which is low, are the main product at present, results are not always satisfactory in terms of unit consumption of energy. However, the expected unit fuel consumption of 125×10^3 kcal/t was achieved when synchronized operation was conducted. Therefore, the future prospect is good in this respect.

(2) The yield of round billets for seamless pipe was 97.4%. The planned target was achieved.

(3) Dimensional accuracy is within $\pm 1.0\%$ relative to the tolerance, the target being $\pm 1.5\%$. Thus, high-accuracy stable rolling has been maintained from the beginning.

(4) With respect to surface defects, groove scratches occurred in large-section round bars in the initial stages of production. However, improvements have been made following a review of groove shapes and pass schedules. Small-section round bars rolled by the finishing mill are completely free of defects such as sticking and scratches. High quality has been maintained from the beginning.

(5) In the on-line finishing of round billets, the operation of the automatic surface defect detector is stable, thus contributing to the improvement in the yield rate ordered of the seamless pipe produced at Chita.

Thus, operation is satisfactory on the whole. When the new wire rod mill being constructed is brought into operation, the expected effects including shorter lead time and stocked material reduction are expected to be obtained.

5 Conclusions

Six months has elapsed since the start-up of the new billet mill. Operation has been smooth on the whole. The realization of continuous, synchronized operation of the continuous casters and the billet mill was more difficult than expected. However, rapid action was taken by the persons concerned to meet problems. Furthermore, satisfactory operation of the mill was facilitated by the upward trend in steel production, and operation is now approaching the planned condition. Further improvements are planned for equipment, systems, and operation. This new billet mill, it is believed, can be considered a model case for large-scale revamping projects.

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References

1) S. Hachiya, S. Asano, and S. Kamikawa: *Tekkoh-Kay*, (1983) 7, 52
2) S. Hachiya, H. Nakajima, and T. Yamaguchi: *Tetsu-to-Hagané*, **68** (1982) 4, S209
3) Y. Kohno, K. Shima, and F. Fujisawa: *Tetsu-to-Hagané*, **67** (1981) 12, S947
4) S. Harada, M. Inaba, Y. Naka, T. Komiya, Y. Obana, and M. Kodera: *Tetsu-to-Hagané*, **68** (1982) 4, S213
5) T. Nakanishi, K. Ohsugi, Y. Nakagawa, O. Taniri, H. Itakura, and T. Ueda: *Tetsu-to-Hagané*, **70** (1984) 13, S1078
6) T. Nakanishi, Y. Yoshimura, K. Baba, Y. Arimitsu, T. Seto, and S. Watanabe: *Tetsu-to-Hagané*, **70** (1984) 13, S1079
7) T. Nakanishi, T. Seto, H. Kikugawa, T. Fujimoto, and H. Egeyama: *Tetsu-to-Hagané*, **70** (1984) 13, S1080
8) T. Nakanishi, T. Tokumaru, K. Higashioka, K. Ueno, and S. Uesugi: *Tetsu-to-Hagané*, **70** (1984) 13, S1129