# FOUNDRY ENGINEERING

## *(Iron Foundry Practice)*

*Overseas Technical Cooperation Agency*

# Preface

This booklet is intended for the guidance of cast iron foundry practice at public institute and private foundry shops, the accommodation of which shall be given to the foundry engineers from overseas invited by the Government of Japan under the International technical cooperation schemes such as the colombo plan and etc.

It is quite obvious that sound casting shall be oftained by full utilization of the pertinent knowledge and technique, therefore this text book contains subjects of melting control by cupola furnace, casting design, moulding, sand cantrol and its testings, foundry equipments, production control and etc., with applicatiou of abundant illustrations, photographs and data as well as with dynamic examples of 3 different types of foundry shops in private sector for the reference and contribution to the enhancement of the cast iron foundry practice through the combination of the scientific approaches and practical experience.

It is hoped that the text book shall greatly contribute to the further development of the participating countries and in closing it can never be forgot that the compilation of the book became possible by the cooperation of the foundry section, Industrial Research Institute of Aichi Prefecture, Kokko foundry, Ltd., Ochi foundry Ltd., Nagoya plant, and Okada kogyo Co., Ltd.

OTCA

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# Part I

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## § 1 Structure of Cupola

The cupola has been widely used for cast iron melting. The cupola has some characters as follows:

1. Simply structure
2. Continuous melting
3. Low cost of melting

The cupola is a virtical shaft type frunace, consisting of a cylindrical steel shell lined with refractory brick and equipped with a wind box and tuyeres.

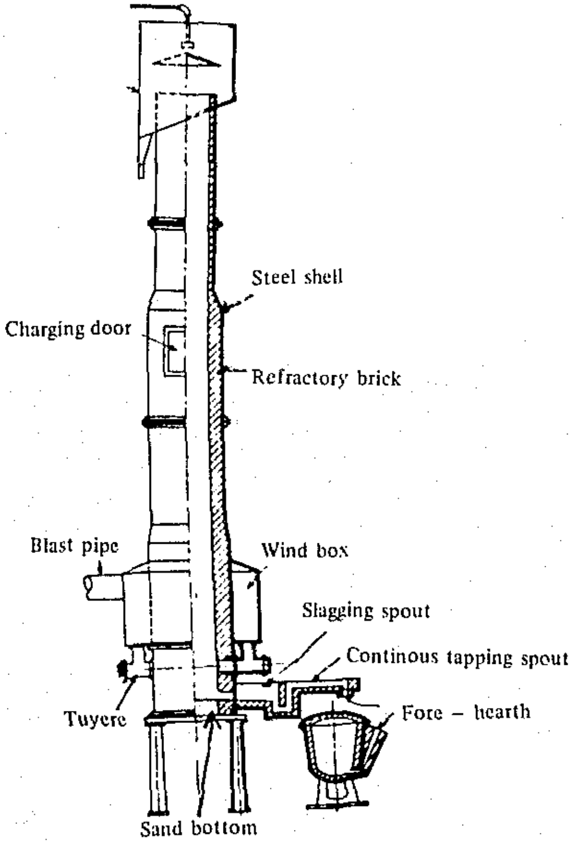


Fig. 1. Structure of the common cupola

(1) Melting capacity of cupola

The inside cross-sectional area at the tuyere level determins the range of the melting rates of a cupola.

The relations of the inside diameter and the standard melting rate are given in Table I and Fig. 2.

Table 1. Relations of inside diameter and standard melting rate

| Inside dia. mm | Area mm$^2$ | | Melting rate W(t/h) | | |
|---|---|---|---|---|---|
| | | | Metal – Coke ratio (%) | | |
| | | 12 | 14 | 16 | 18 |
| 300 | 0.071 | 0.57 | 0.52 | 0.47 | 0.42 |
| 400 | 0.126 | 1.0 | 0.9 | 0.83 | 0.76 |
| 500 | 0.196 | 1.6 | 1.4 | 1.3 | 1.2 |
| 550 | 0.238 | 1.9 | 1.7 | 1.6 | 1.4 |
| 600 | 0.283 | 2.3 | 2.1 | 1.9 | 1.7 |
| 650 | 0.332 | 2.7 | 2.4 | 2.2 | 2.0 |
| 700 | 0.385 | 3.1 | 2.8 | 2.6 | 2.3 |
| 750 | 0.442 | 3.6 | 3.3 | 2.9 | 2.7 |
| 800 | 0.503 | 4.1 | 3.7 | 3.3 | 3.0 |
| 900 | 0.636 | 5.2 | 4.7 | 4.2 | 3.8 |
| 1000 | 0.785 | 6.4 | 5.8 | 5.2 | 4.7 |

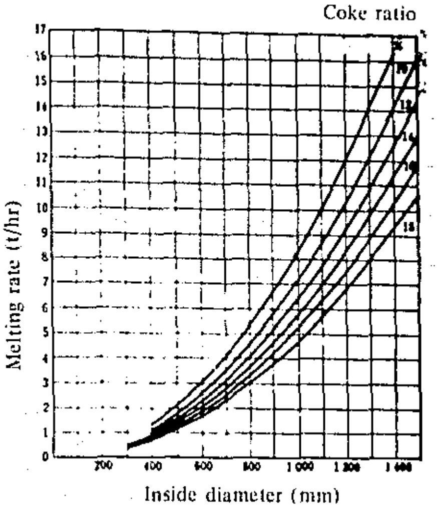


Fig. 2.  Relations of inside diameter and standard melting rate.

(2) Body section of melting zone

The various types of body section are illustrated in Fig. 3.

(a) Conventional type

(b) Enlarged preheating zone type

.......... For sufficient preheating of charges

(c) Enlarged preheating and melting zone type

(d) Enlarged melting zone type

.......... For delivering blast into the center of the cupola.

This type may be suitable for operating of higher coke ratio using poor quality cokes.

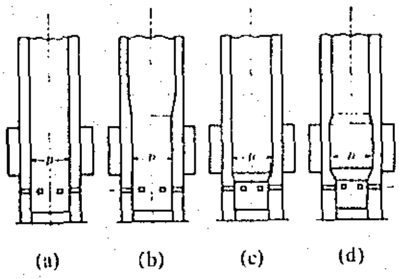


Fig. 3.  Body section of melting zone

(3) Effective height

Effective height is defined as the height of charges above the tuyeres.

* Effective height ratio = H/D

Where

H = Effective height

D = Inside diameter of the cupola at the tuyere level

* Recommended ratios are as follows;

H/D = 5 ~ 6 (for high coke strength)

H/D = 3.5 ~ 4 (for low coke strength)

(4) Well capacity

Well cappacity may be required to hold at least two or three chages of iron.

* Holding capacity = (2 ~ 3) x G x S x V

Where

G = Specific gravity of molten metal (7g/cm)

S = Space in well is used for molten iron (about 40%)

V = Well volume

* Well height (h) is determined by a following equation.

$$h = \frac{\text{Holding capacity}}{\text{Sectional area of well}} + (150 \sim 200\text{mm})$$

* Recommended well heights (h) are as follows;

h = 450 ~ 500 mm (for no forehearth)

h = 350 ~ 400 mm (for with forehearth)

(5) Tuyere

Tuyere ratio is usually on the order of 4 to 15, although larger ratios may be sometimes used for operating high coke ratio using poor quality cokes.

* Tuyere ratio = A/a

Where

A = Cross -- sectional area of cupola at the tuyere

a = Sum of the area of tuyere

* Number of tuyere

| | | $D < 650$mm | $D > 700$mm | |
|---|---|---|---|---|
| One row | | 4 ~ 6 | 6 ~ 8 | |
| Two row | each row | (3 ~ 4) | (4 ~ 6) | |
| | total | 6 ~ 8 | 8 ~ 12 | (for poor cokes) |

(6) Tap and spout

Intermittent tapping requires that the taphole be opened at intervals to deliver iron to pouring ladles. The intervals of tapping are usually predictable since the melting rate of a particular cupola and capacity of the ladles are known.

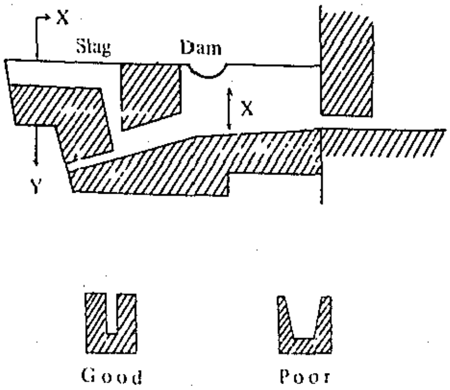
* Tap hole dia. = 30 ~ 50 mm

Slag hole dia. = 50 ~ 80 mm

Position of hole = 200 ~ 260 mm under the tuyere level

Continuous tapping of iron from the cupola is most commonly done by use of some type of dam on the spout. Critical dimensions in the system are the heights of the metal and slag dams above the tap of the taphole.

Continuous tapping front slagging spout is shown in Fig.4.



Trough lining at section x - Y

| P mmaq | X mm |
|---|---|
| 176 | 38 |
| 352 | 63.5 |
| 528 | 89 |
| 704 | 114 |
| 880 | 140 |
| 1056 | 165 |
| 232 | 190 |

P – Wind box pressure

Fig. 4. Construction of front–slagging spout

## Table 2 Standard Dimension of Conventional Cupola

| Dia Inside Lining | Area Inside Lining | Tuyere Ratio | Height Ratio | Effective Height | Well Depth | Wind Box Vertical | Wind Box Horizontal | Thickness Lining Melting zone | Thickness Bottom Sand |
|---|---|---|---|---|---|---|---|---|---|
| D mm | A m | A/a | H/D | H mm | h mm | b mm | l mm | T mm | Tb mm |
| 400 | 0.126 | 4~7 | 6 | 2400 | 400 | 140 | 560 | 160 | 200 |
| 500 | 0.196 | 5~8 | 6 | 3000 | 450 | 165 | 660 | 190 | 200 |
| 600 | 0.283 | 5~8 | 5.6 | 3360 | 450 | 200 | 800 | 190 | 200 |
| 650 | 0.332 | 6~9 | 5.4 | 3520 | 500 | 215 | 860 | 190 | 200 |
| 700 | 0.385 | 6~9 | 5.2 | 3640 | 500 | 230 | 920 | 240 | 250 |
| 750 | 0.442 | 6~9 | 5.0 | 3750 | 500 | 250 | 1000 | 240 | 250 |
| 800 | 0.503 | 6~9 | 4.9 | 3920 | 500 | 270 | 1080 | 240 | 250 |
| 850 | 0.567 | 7~10 | 4.8 | 4080 | 550 | 285 | 1140 | 240 | 250 |
| 900 | 0.636 | 7~9 | 4.7 | 4230 | 550 | 300 | 1200 | 240 | 250 |

## § 2 Principles of Cupola Operation

Successful cupola operation hinges largely on combustion control. With proper combustion, control of metal composition, temperature, and slagging can be accomplished.

(1) Combustion in the Cupola

The major chemical reactions within the cupola are as follows;

$$C + O_2 = CO_2 \quad + 97.8 \quad \text{Kcal/mol}$$

This is the heat producing reaction.

$$CO_2 + C = 2CO - 37.4 \quad \text{Kcal/mol}$$

This is the heat absorbing reaction and extracts heat from the cupola.

Concurrently, $CO_2$content of the stack gases increases while CO content decreases. Experience has shown that, under proper operating conditions, cupola stack gases should contain about 12 to 14% $CO_2$ and 11 to 15% CO.

Assuming that a coke bed of proper height has been established, the balance of coke and air is probably best judged from the composition of the stac gases.

(2) Physical Factors Influence the Gaseous Atomshere within the Cupola.

1 Coke size

The moderate size of coke is still a somewhat debatable question. In general, however, an average lump size between 1/8 and 1/10 the inside diame r of the cupola seems most satisfactory.

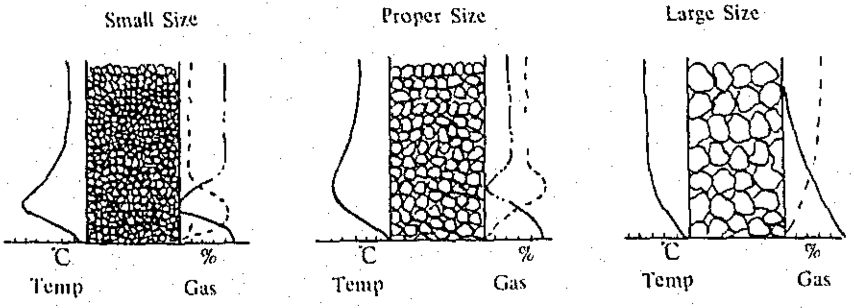


Fig. 5. The relationship between coke size and gaseous atomsphere.

2 Tuyere ratio

In larger tuyere ratio, blast velocity increases, and results in rich CO content of stock gases.

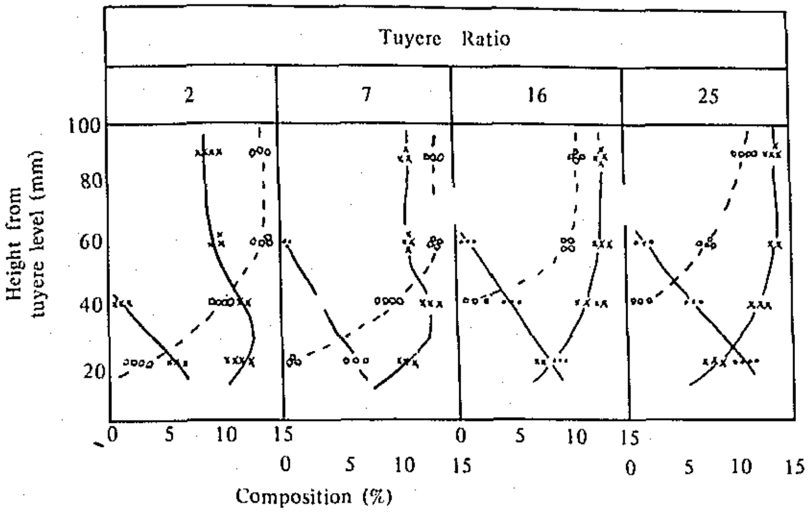


Fig.6. The effects of tuyere ratio on the gaseous atomsphere.

3 Blast preheat

Hot blast increases the temperature of the combustion zone.
The combustion zone (oxidation zone) is decreased slightly in depth.
The reduction zone is increased in depth by amount equal to the decrease in the depth of oxidation zone
Consequently, CO content of the stack gases increases. However, the change has little influence upon the height of the melting zone.

## § 3 Melting Condition

In order to have favorable melting conditions, it is necessary to have a balanced combination of coke and air supplied at the proper rate.

(1) Coke bed height

The height of coke above the tuyeres effects of proper combustion during melting.

For conventional operation, the correct bed height will fall in the range of 1.2 to 1.5 times of inside diameter of cupola.

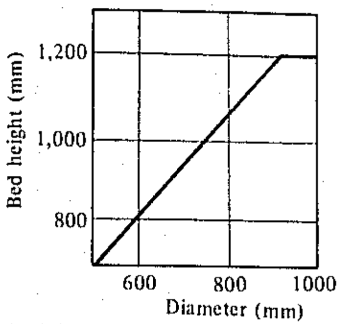
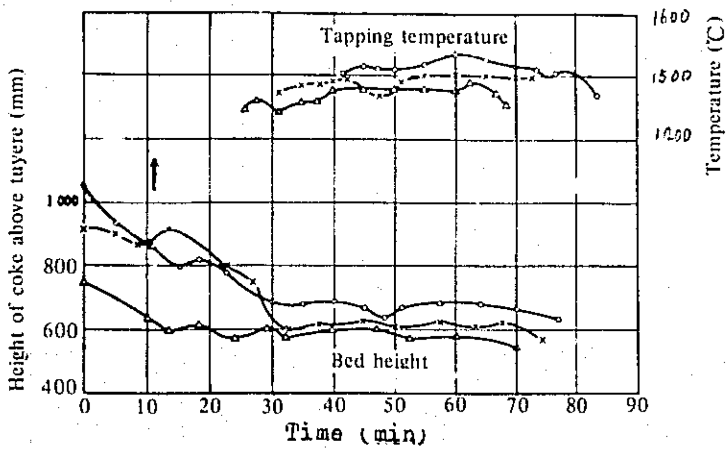


Fig. 7.  The inital bed height based on cupola diameter.



△ Initial bed height 750 mm

× Initial bed height 910 mm

○ Initial bed height 1050 mm

Operating condition;

| | |
|---|---|
| Coke ratio | 14 % |
| Blast volume | 16.5 m/min |
| Blast temp | 300 ~ 350 C |

Fig. 8.  The changes in coke bed height and molten iron temperature.

### (2) Coke ratio

Generally, the higher coke ratio results the higher molten iron temperature.

Table 3 shows the ideal coke ratio that is necessary in order to get desired temperature. This ratio is employed in the case of using coke that includes 10% or less ash.

When the higher ash cokes are employed, the higher coke ratios may be used, such as 20 to 30%.

Table 3 Recomended coke ratio

| JIS Class | Molten Iron Temp. C | Steel % | Ash % | Coke Ratio % |
|---|---|---|---|---|
| FC 15 | 1440 ~ 1470 | 0 | ÷ 10 | 9 11 |
| FC 20 | 1460 ~ 1490 | 15 ~ 30 | < 10 | 11 13 |
| FC 25 | 1480 ~ 1510 | 30 ~ 50 | 10 | 13 15 |
| FC 30 | 1510 ~ 1540 | 40 ~ 60 | < 8 | 14 16 |
| FC 35 | 1520 ~ 1550 | 50 ~ 70 | 8 | 15 18 |

### (3) Blast volume

The proper blast volume can be determined from Fig 9 as a following equation;

$$W/A = 100 \sim 110 \ \mathrm{Nm^3/\ min.m^2}$$

Where

$W$ = blast volume $\mathrm{Nm^3/\ min}$

$A$ = cross–sectinal area of the cupola $\mathrm{m^2}$

This blast volume will make the highest temperature and the least oxidation loss of molten iron.

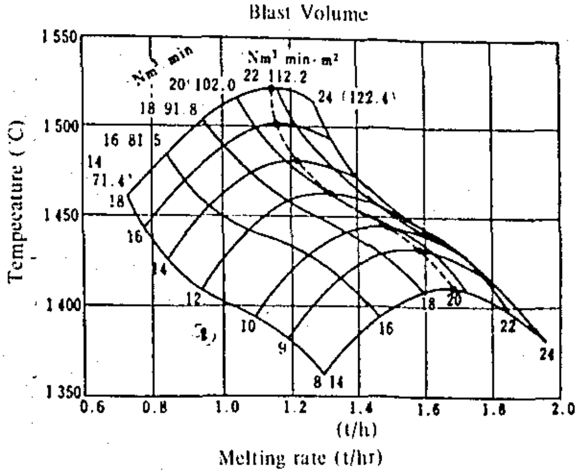


Fig. 9. Relation between molten temperature and coke ratio, blast volume and melting rate.

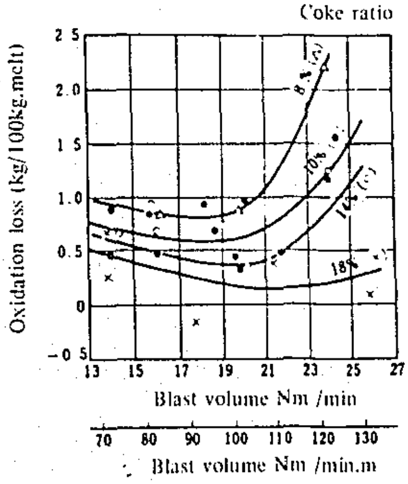


Fig. 10. Relation of the operating conditions and the oxidation loss.

Table 4 Relation between cupola size and operating condition

| Cupola Dia. mm | Standard Melting Rate t/hr | Convetional Melting | | High Temperature Melting | |
|---|---|---|---|---|---|
| | | Coke Ratio | Blast volume | Coke Ratio | Blast Volume |
| 500 | 1 1.2 | 10 13% | 19 20 Nm /min | 15 18% | 21 22 Nm /min |
| 600 | 1.7 2.0 | 10 12 | 27 28 | 15 18 | 33 34 |
| 700 | 2.5 3.0 | 10 12 | 37 38 | 15 18 | 42 46 |
| 800 | 3.5 4.0 | 9 11 | 48 50 | 14 16 | 55 60 |
| 900 | 4.5 5.0 | 9 11 | 60 64 | 14 16 | 70 76 |
| | | FC 20 | | FC 30 | |

Table 5 Relation between iron temperature and coke ratio, blast volume and melting rate

| Coke Ratio | Blast Volume | Bed Height | Iron Temp | Melting Rate |
|---|---|---|---|---|
| Low | Moderate | Decrease | Decrease | Increase |
| High | Moderate | Increase | Increase | Decrease |
| Moderate | Low | Increase | Decrease | Decrease |
| Moderate | High | Decrease | Increase →Decrease | Increase |
| Moderate | Moderate | Moderate | High | Moderate |

### (4) Charging materials

The melting materials should be sized according to the diameter of the cupola in order to prevent hanging and bridging.

The recommended sizes of metals and cokes fall 1/5 to 1/10 the inside diameter of the cupola and they must be as uniform as possible.

The weight of metal materials in each batch uses generally 1/10 the cupola capacity. However, the smaller batch tends to make a more uniform operation.

Table 6 The variations in composition of molten iron depend upon the weight of a batch and charging order of metal materials

| Metal Charge kg | Situation of Steel | Melting Rate kg/hr | C % | | Si % | |
|---|---|---|---|---|---|---|
| | | | Average | Standard Deviation | Averate | Standard Deviation |
| 50 | upper | 845 | 3.44 | 0.076 | 1.82 | 0.10 |
| | lower | 820 | 3.50 | 0.065 | 2.00 | 0.10 |
| | mix | 815 | 3.45 | 0.049 | 1.81 | 0.12 |
| 80 | upper | 825 | 3.20 | 0.094 | 1.80 | 0.12 |
| | lower | 840 | 3.40 | 0.154 | 1.82 | 0.17 |
| | mix | 820 | 3.16 | 0.070 | 1.63 | 0.19 |

The flux charge, usually limstone, approximates 20% of the Weight of the coke charge, although as high as 50% may be employed.

## § 4 Calculating the Cupola Charges

(1) Metal composittion and properties

Carbon and silicon are the most important composition factors influencing mechanical properties.

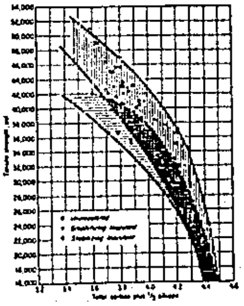


Fig. 11. Tensile strength of 30 mm diameter gray-iron bars as affected by corbon equivalent.

Table 7 JIS class and estimated analysis

| JIS class | Composition % | | | | |
|---|---|---|---|---|---|
| | C | Si | Mn | P | S |
| FC 15 | 3.5 ~ 3.8 | 2.8 ~ 2.3 | 0.5 ~ 0.8 | <0.25 | > 0.1 |
| FC 20 | 3.3 ~ 3.6 | 2.3 ~ 1.8 | 0.6 ~ 0.9 | <0.20 | > 0.1 |
| FC 25 | 3.2 ~ 3.5 | 2.2 ~ 1.7 | 0.6 ~ 0.9 | <0.15 | > 0.1 |
| FC30 | 3.1 ~ 3.3 | 2.1 ~ 1.6 | 0.6 ~ 0.9 | <0.10 | > 0.1 |
| FC35 | 2.9 ~ 3.2 | 2.0 ~ 1.6 | 0.7 ~ 1.0 | <0.10 | > 0.1 |

(2) Composition changes during cupola melting

Table 8 Approximate loss or gain of elements in melting

| Element | Percent loss | Percent gain |
|---|---|---|
| Silicon, in pig and scrap | 10 ~ 12 | |
| Lump ferrosilicon | 15 ~ 20 | |
| Manganese, in pig and scrap | 10 ~ 20 | |
| Lump ferromanganese | 15 ~ 25 | |
| Phosphorus | No loss or gain | |
| Sulfur | | 40 ~ 60 |

(3) Example of calculation

Assume an iron having the following analysis;

| JIS class | C | Si | Mn | P | S |
|---|---|---|---|---|---|
| FC 30 | 3.10 | 2.0 | 0.6 | < 0.2 | < 0.1 |

The method of calculation is explained by the following example.

### Table 9 Example of calculation of metal charges
### Approximate analysis of metal materials

| Material | C | Si | Mn | P | S |
|---|---|---|---|---|---|
| Pig iron | 3.65 | 2.50 | 0.65 | 0.30 | 0.06 |
| Returns | 3.10 | 2.00 | 0.60 | 0.15 | 0.08 |
| Steel scrap | 0.20 | 0.20 | 0.45 | 0.03 | 0.03 |
| Fe–Si |  | 75 |  |  |  |
| Fe–Mn |  |  | 75 |  |  |

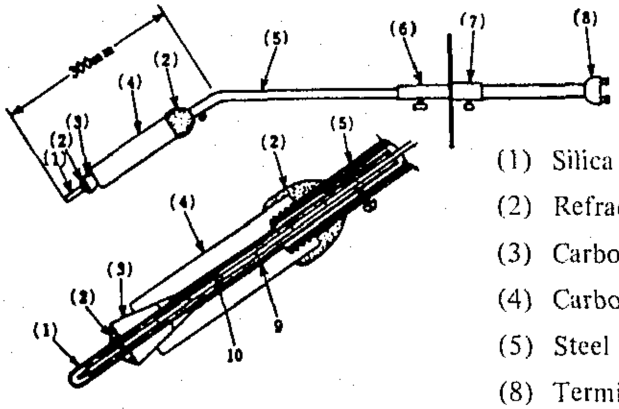
### Mixture calculation

| Material | Per Cent | kg Per Charge | C |  | Si |  | Mn |  | P |  | S |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | % | kg | % | kg | % | kg | % | kg | % | kg |
| Pig iron | 30 | 30 | 3.65 | 1.10 | 2.50 | 0.75 | 0.65 | 0.195 | 0.30 | 0.09 | 0.060 | 0.018 |
| Returns | 30 | 30 | 3.10 | 0.93 | 2.00 | 0.60 | 0.60 | 0.180 | 0.15 | 0.045 | 0.08 | 0.024 |
| Steel | 40 | 40 | 0.20<br>(2.65) | 1.04 | 0.20 | 0.08 | 0.45 | 0.180 | 0.03 | 0.012 | 0.03 | 0.012 |
| Fe–Si |  |  |  |  | 75 | 0.90 |  |  |  |  |  |  |
| Fe–Mn |  |  |  |  |  |  | 75 | 0.185 |  |  |  |  |
| Total | 100 | 100 |  | 3.07 |  | 2.33 |  | 0.74 |  | 0.147 |  | 0.044 |
| *Loss* |  |  |  |  | *-15%* | *0.35* | *-20%* | *0.15* |  |  |  |  |
| Gain |  |  |  |  |  |  |  |  |  |  |  | +0.04 |
| Analysis Charged |  |  |  | 3.07 |  | 1.98 |  | 0.59 |  | 0.147 |  |  |
| Estimated Analysis |  |  |  | 3.10 |  | 2.00 |  | 0.60 |  | < 0.2 |  | < 0.1 |

## § 5 Measuring Apparatus

### (1) Temperature

1 Immersion pyrometer (Fig.12.)

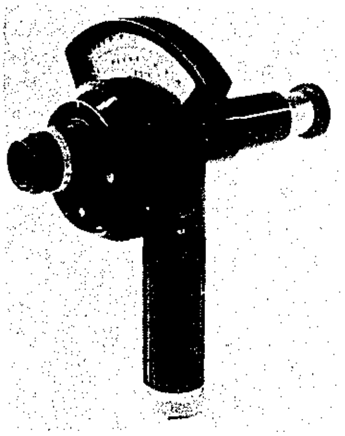


(1) Silica tube
(2) Refractory cemment
(3) Carbon plug
(4) Carbon sleeve
(5) Steel pipe
(8) Terminal
(10) Thermocouple

Table 10 Thermocouple

| Kinds | Materials | | Wire dia. mm | Max. Temp. C | |
|---|---|---|---|---|---|
| | + | − | | Continuous | Overheating |
| Platinum–Platinum Rhodium | Pt 87%<br>Rh 13% | Pure Pt | 0.5 | 1400 | 1600 |
| | Pt 90%<br>Rh 10% | Pure Pt | 0.5 | 1400 | 1600 |
| Chromel–Alumel (C A) | Ni 90%<br>Cr 10% | Ni 94% | 0.65 | 650 | 850 |
| | | Al 3% | 1.00 | 750 | 950 |
| | | Si 1% | 1.60 | 850 | 1050 |
| | | Mn 2% | 2.30 | 900 | 1100 |

## 2 Optical Pyrometer (Fig.13.)



If the filament appears as a light line, its temperature is higher, and if it is seen as a dark line, the temperature is lower than that of molten iron surface under observation.

When the image of the filament disappears, the true temperature can be determined from the meter reading plus corrective value.

This corrective value is obtained from the corrective curve by the emissivity of molten metal. $(\lambda = 0.65)$

Emissivity of moten iron $\Sigma = 0.48 \sim 0.51$

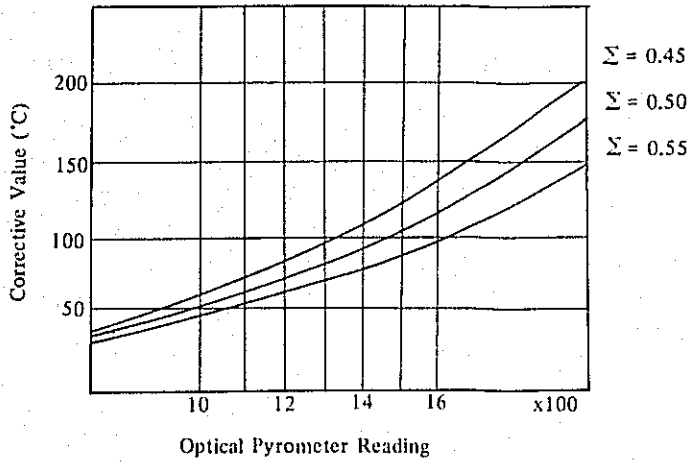
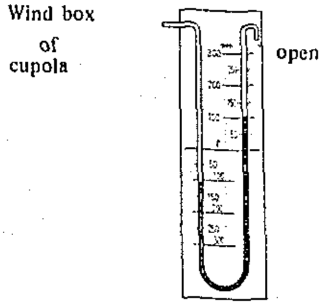


Fig.14. Corrective Curve by Emissivity

(2) Blast pressure and volume

1 Pressure gage (Fig. 15.)



2 Volume gage

Pitot tube calculation

$$Q = 47.1 \times D \times \quad 2gh$$

Where

Q = blast volume m /min

D = inside diameter of blast pipe m

g = acceleration of gravity 9.81 m/sec

$\gamma$ = air density at 20 C 1.23 kg/m

h = velocity pressure mmAq

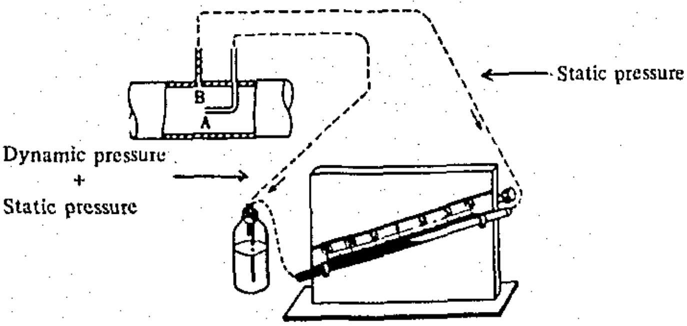


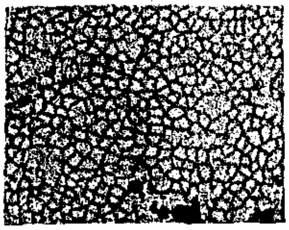
Fig. 16. Differential pressure gage

## § 6 Foundry Test

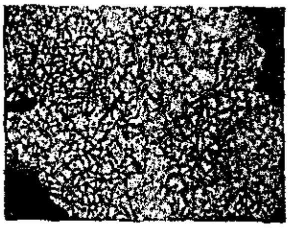
(1) Surface figures of molten iron.

Surface figure appears on the molten iron surface at under 1400 C. However, this is not seen in oxidated molten iron.

Turtle–back form is frequently seen in high C, Si % of molten iron, and bamboo–leaf form is frequently seen in low C, Si % of molten iron.

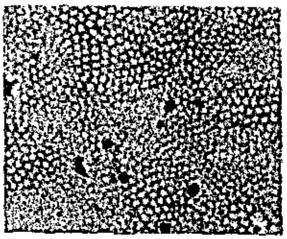


**A : Turtle-back form (Big)**

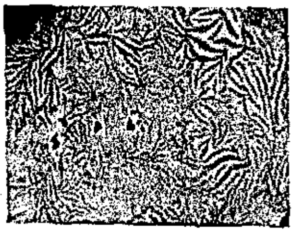


**B : Heap-leaf form**

**C : Bamboo-leaf form (Big)**



**D : Turtle-back form (Small)**



E : Bamboo-leaf form (Small)

Fig. 17. Kinds of the surface figure.

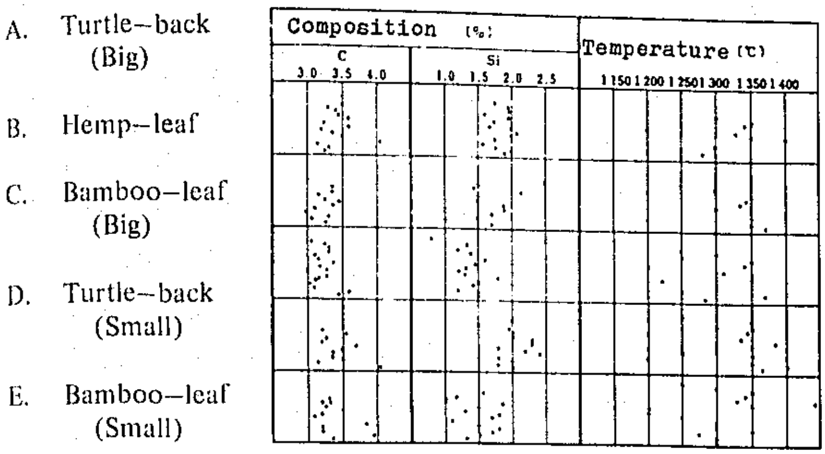


Fig. 18. Composition, temperature and surface figure

(2) Slag colour

Controlled melting with normal conditions is accompanied by the effluence of green or dark green slag from cupola.

Oxidizing melting conditions produce black slag and are accompanied by higher loss than normal melting.

Greenish .......... Favorable
Black .......... Higher FeO and MnO
Light (White) ..... Higher lime and lower FeO

slags granulated in water troughs has a tendency to be lighter in color.

(3) Chill test

Chill test offers a rapid method of integrating the combined effects of carbon and silicon, and co-relating this with the expected properties of the castings, provided the affecting the appearance of the chill fracture are understood understood and interpreted.

The chill portion of the fracture reflects the carbide–forming tendency and carbide stability of iron.

Chill depth is increased by melting under more oxidizing condition, by superheating the iron, decreased silicon and decreased carbon, and addition of various carbide–forming alloys.

Since the composition is only one of the factors which influence the carbide stability of the iron, the relationship between the amount of chill and the composition may vary, however, any deviation in appearance from a standard chill depth indicates a change in the iron.

This change may be affected by a change in chemistry or the effect on chemistry by such influence as oxidation during melting, high moisture content in the blast, or a marked melting temperature change.

The grey portion of the fracture also gives indication of the properties of the metal.

High–carbon–iron develop a dark, coarse grained structure with a dull fracture.

Low–carbon–irons develop a lighter, closer grained structure.

In order to determine the test block which co–elate best with the castings, it may be necssary to experiment with the chill molds and thire design.

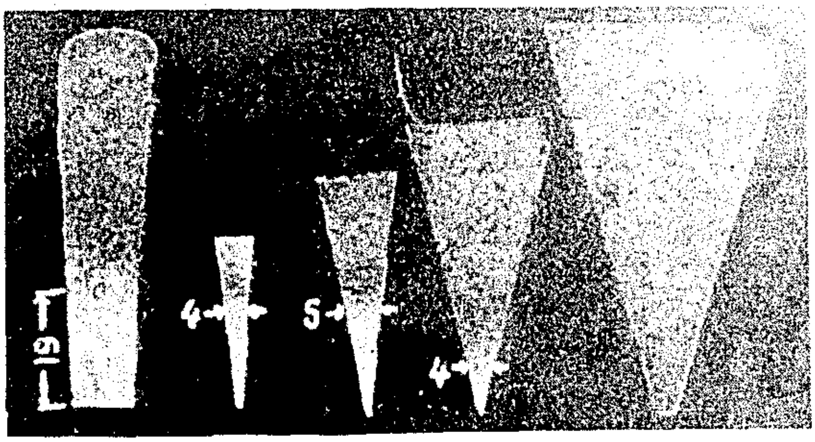
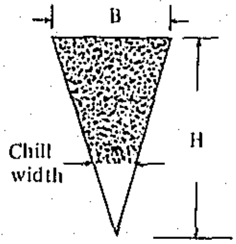


Fig. 19. Chill test casting showing appearance of fractured surface

* Types of chill test specimen (Fig. 20.)

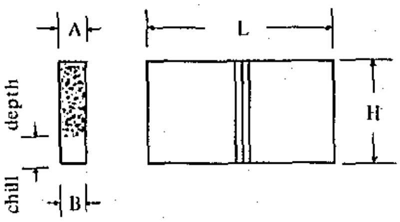
i) Wedge type



Recommended dimension – mm

| No. | B | H | L |
|---|---|---|---|
| W1 | 6 | 25 | 100 |
| W2 | 12 | 32 | 100 |
| W3 | 20 | 38 | 100 |
| W4 | 32 | 50 | 100 |

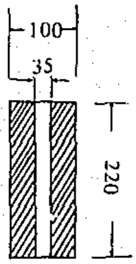
ii) Plate type



Recommended dimension – mm

| No. | A | B | H | L |
|---|---|---|---|---|
| C1 | 6.5 | 3.5 | 32 | 65 |
| C2 | 8.0 | 5.0 | 38 | 75 |
| C3 | 11.0 | 8.0 | 45 | 90 |
| C4 | 13.0 | 10.0 | 50 | 100 |

iii) Cylinder type



Shape of top of chill test specimens

| No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Shape of top |  |  |  |  |  |  |  |

(4) Carbon equivalent by cooling curves

During the cooling of hypoeutectic cast iron from the molten state a temporary arrest or change in the rate of cooling occures due to evolution of heat as the first solid crystals (austenite) are formed at what is called the liquidus temperature.

Further cooling from this temperature proceeds at a comewhat slower rate until iron of a eutectic composition remains.

This then freezes, and more prolonged arrest occurs due to larger evolution of heat.

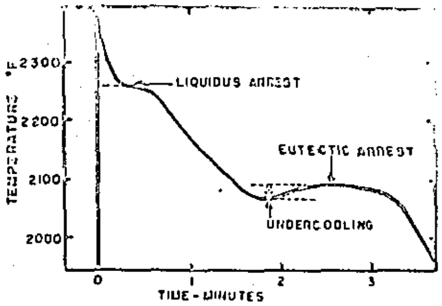


Fig. 21. Typical cooling curve for gray cast iron

The thermal arrests or freezing points of cast iron depend on, and vary with, the composition of the iron. Carbon, Silicon and Phosphrous mainly influence the freezing temperatures.

If the phosphrous content is low and known, the combination of the effects of carbon and silicon can therefore be determined by the measuring the solidification temperatures.

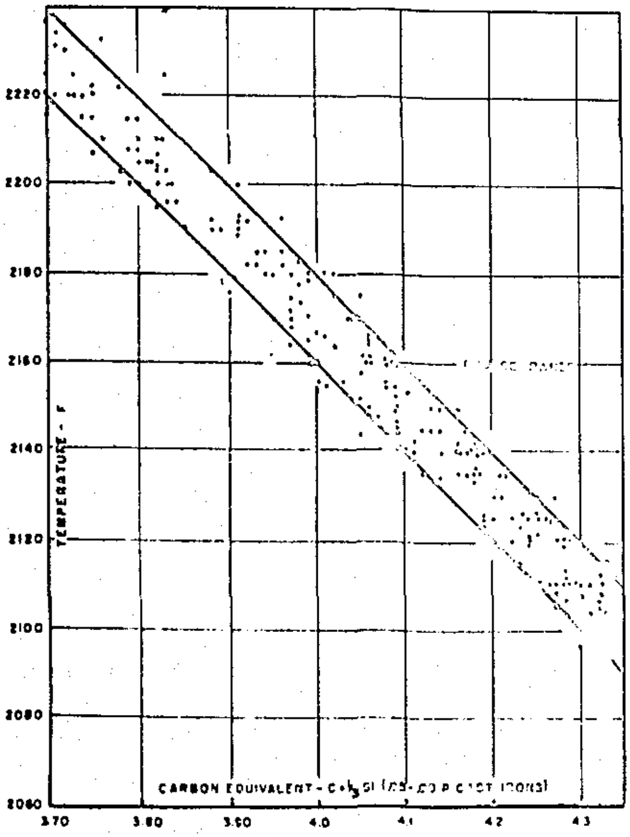


Fig. 22. Liquidus arrest temperature vs. chemical carbon equivalents

## § 7 Molding Sand Test

(1) Preparing foundry sand mixture for test

It is essential that sands are properly sampled if test results are to be representative of the entre lot of sand.

1) New naturally–bonded sands

1 Dry at least 2000 grams for one hour at a temperature 105 ± 5°C

2 After the sand has cooled to room temperature, place it in the laboratory mixer and add sufficient water to produce the desired moisture content plus an additional amount to allow for evaporation during the mixing. The water should be added gradually within 30 sec. time, while the mixer is operating.
Total mixing time should be 5 min.

2) Synthetically–bonded sands

1 Dry at least 2000 grams for one hour at a temperature 105 ± 5°C

2 After drying and cooling to room temperature, weigh out the correct amounts of sands and bonds.

3 Place the dried sand and then the dried bonding materials in the mixer and mix for 2 min.

4 Add the amount water gradually within 30 sec. to give the required moisture percentage.

Note: The percent of moisture is the percent of the weight of the tempered mix, and not the percent of the weight on dry sand and clay.
Since the object of examining new naturally–bonded sand is to test their different properties under conditions simulating those in the founry, experiments should be made with several moisture contents to ascrtain the amout of moisture which develops the maximum degree of that property to be tested.
In synthetic sand mixtures, also, base sands should be tested by varying not only the moisture content but also the bond percentages

to see which combinations give the best properties.

(2) Moisture content

1 The moisture content of a sand mixture shall be determind by drying the sample at 105 ± 5 ℃ to constant weight in a uniformly heated oven, cooling to room temperature (in a desicator) and reweighing.

2 Weights of the sample before and after drying should be determined accuratly.

3 Moisture content should be expressed to within 0.1 of one percent in percentage of original moist sample.

4 If a 50 gram sample of moist sand weighs 47.5 gram after heating and cooling as directed, the percentage of moisture in the sand sample was

$$\frac{50 - 47.5}{50} \times 100 = 5\% \text{ moisture,}$$

or

$$(50 - 47.5) \times 2 = 5\% \text{ moisture.}$$

Note that the miosture content was calculated as a percentage of the original weight of 50 grams.

(3) Test Specimen

1) Equipment for preparing the test specimen

1 Specimen container

The container for ramming the standard specimen shall be a quenched, cylindrically-shaped steel tube with an inside diameter of 50 ± 0.1 mm and a height of 110 ~ 150 mm.

The inside surface of the container shall be smooth and uniformly circular to within ± 0.1 mm.

2 Rammer

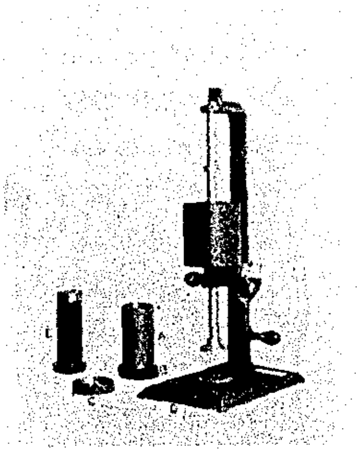
The apparatus for ramming the 50 x 50 mm test specimen shall consist of a steel rod, to the lower end of which is attached a hardened steel ramming head so as to produce a sliding fit with the inside diameter of the specimen container.

A weight of 6.5 ± 0.1 kg shall be mounted on the rod in such a manner that it can slide freely upward and downward on the rod for a distance of 50 mm between the rod surpports.

Total weight of the moving parts of the assembly shall be 8.5 ± 0.12 kg. The weight may raised by a crank attached to a cam and allowed to fall only the specified 50 ± 0.5 mm

3 Tolerance marker

At the top of the frame which supports the ramming mechanism, and at the rear of the rammer rod on the upper support, shall be a scale on which shall be three horizontal tolerance marks. The center mark shall correspond with the top of the rammer rod when a rammed sand specimen of exactly 50 mm height is in the specimen tube after the third ram in the standard procedure and when the ramming head is resting on the top of the specimen. The other two marks shall be respectiyely 1 mm above and below the center mark to indicate allowable tolerance in specimen size for routine testing.



A ..... Specimen container
B ..... Pedestal for specimen container
C ..... Auxiliary cup
E ..... Stripping post

Fig. 23. Standard ramming apparatus

2) Procedure in making test specimen

1 Weigh out a sufficient quantity of temperd sand from the prepared sample to make, when rammed, a column 50 mm high.

2 Place the sand careffuly in the specimen container.

3 Gently lower the ramming head into the specimen container until it is supported by the full 50 mm height and let fall.
Repeat time, making a total of three rams.

4 Note Whether the upper end of the rod corresponds with the center line on the tolerance for research or comparison work, or is within 1 mm tolerance marks for control work.
attained thus indicating the breaking load.

5 If the specimen is not of correct height, discard and remark the specimen.

(4) Permeability

1 Apparatus for determing permeability is shown in Fig. 24.
It is so constructed as to allow 2000 CC of air to flow freely at velocity of more than 300 cc/sec under a pressure adjustable to 10 g/cm

2 With a stop–watch, determine the time required for exactly 2000 CC of air to pass through the specimen.

3 While the air is being passed through the specimen and after the pressure has became steady, read the pressure on the pressure indicator.

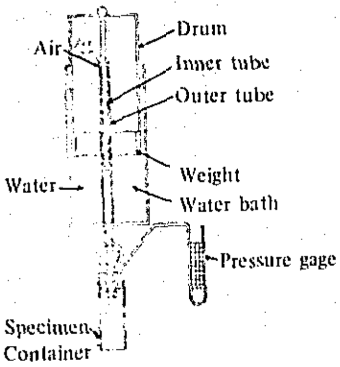


Fig. 24. Permeability apparatus

4 Permeability is expressed as the volume of air (cm ) that will pass per minute under a pressure of 1 g/cm through a specimen 1 cm in cross–sectional area and 1 cm high.

$$P = \frac{v \times h}{p \times a \times t} = \frac{501.2}{p \times t}$$

where

P = Permeability number
V = Volume of air passing through the specimen (2000 CC)
h= Height of specimen (5 cmAq)
p= Pressure of the air
a= Cross–sectional area of specimen ($cm^2$)
t = Time (min)

### (5) Compressive Stength

Compressive strengh test apparatus

The dead–weight type of compressive strength test apparatus, which is suitable for testing both green and dry sand specimens, is shown in Fig. 25. The pendulum weight and the pusher arm are provided with holes, in which may be inserted compression heads which hold the specimen during testing. A motor raises the puser arm through an arc, thus forcin g the specimen to raise the pendulum weight and increasing the load on the specimen until it breaks. on the base frame is mounted a graduated scale the units on which are specific for 50 mm specimen and the shape of which comforms to the arc described by the pendulum weight. A magnetic rider is pushed along the scale a head of the rising pendulum weight until the specimen breaks. The rider then remains at the highest position attained thus indicating the breaking load.

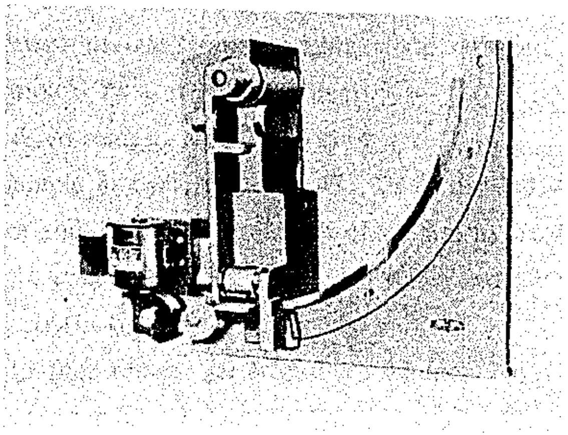


Fig. 25. dead–weight type of compressive strength test apparatus.

(6) Hardness

The hardness to which molding sands are rammed affects two important physical properties of a sand mold;

a) The ability of the sand mold surface to withstand the temperature of molten metals.

b) The degree of permeability of the sand mold.

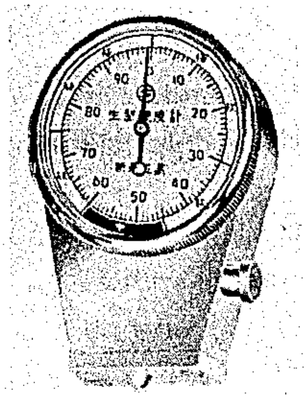


Fig. 26. Hardness tester.

(7) Clay content

1 Choose a repersentative sample weighing about 100 grams.

2 Dry the sample 1 hr at a temperature 105 ~ 110°C

3 Weigh the dried sample, exactly 50 grams.

4 Place the sample in a jar, then add 475 CC of distiled water at room temperature and 25 CC of a solution of sodium hydroxide. (Made by dissolving 30 grams of NaOH in distilled water and dilute to a total volume of 1000 CC )

5 Stir for 1 hr then remove jar from the machine.

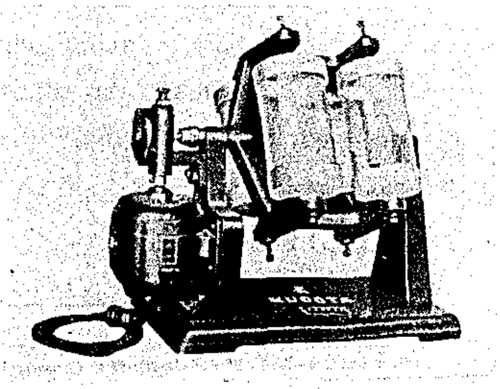


Fig. 27. Rotating sand washer

6 Fill the jar with water to a height of 150 mm and stir contents.

7 allow to settle for 10 min and then siphon off the water to a depth of exactly 125 mm.

8 Add water, again filling the jar to the 150 mm height, stirring the sediment on the bottom. After settling the second time for 10 min, again siphon of 125 mm of the water. Add water again filling to the 150 mm height, stirring the sediment of the bottom. After settling exactly 5 min, siphon off 150 mm of the water.

9 Repeat the process of 5 min standing and siphoning until the water is clear to a depth of 125 mm at the end of the 5 min period.

By this method, that material which fails to settle at a rate of 25 mm per min, is removed from the grain.

This material is defined as JIS clay, which includes grains of 20 microns.

10 Dry and weigh the remaining grain. The difference between the weight of the dried grain and that of the original 50 gram sample represents clay.

(8) Fineness of Grain

1 Place the weighed and dried sand remaining after removal of clay on the uttermost sieve of the assembled series of sieves.

2 The sieves should be agitated for 15 min.

3 Weigh the amount of sand remaining on each sieve and record the weight opposite the sieve meshes.

4 The weitht mutiplied by two represents percentage of each grain size of the sand.

Table 10 Sand Grain Distribution and Fineness Number (JIS)

| Screen | Scale Sieves | (s) | Grain Distribution | | W x S |
|---|---|---|---|---|---|
| Meshes | Microns | Multiplier | (g) | (w) % | |
| 6 | 3360 | 5 | 0 | 0 | |
| 8 | 2380 | 8 | 0 | 0 | |
| 10 | 1680 | 11 | 0 | 0 | |
| 14 | 1190 | 16 | 0.20 | 0.4 | 6.4 |
| 20 | 840 | 22 | 0.60 | 1.2 | 26.4 |
| 28 | 590 | 32 | 1.00 | 2.0 | 64.0 |
| 35 | 420 | 45 | 1.30 | 2.6 | 117.0 |
| 48 | 297 | 63 | 1.70 | 3.4 | 214.2 |
| 65 | 210 | 89 | 4.20 | 8.4 | 747.6 |
| 100 | 149 | 126 | 12.50 | 25.0 | 3150.0 |
| 150 | 105 | 178 | 10.50 | 21.0 | 3738.0 |
| 200 | 74 | 253 | 4.00 | 8.0 | 2024.0 |
| 270 | 53 | 357 | 2.40 | 4.8 | 1713.6 |
| Pan | | 620 | 3.20 | 6.4 | 376.8 |
| Pan | | Total | 41.60 | 83.2 | 12188.0 |
| Clay | Less than 20 Micron | | 8.40 | 16.8 | |

$$\text{Fineness Number} = \frac{\Sigma(w \times S)}{\Sigma w} = \frac{12188.0}{83.2} = 146.4$$

(9) Recommended Property of Mlkding Sand

Table 11 Natural Molding Sand

| Sand use / Property | Small casting (less than 20 kg) | | Small casting (10–50 kg) | |
|---|---|---|---|---|
| | Face sand | Back sand | Face sand | Back sand |
| Moisture % | 6.5 – 7.5 | 6.5 – 8.0 | 7.0 – 8.0 | 7.0 – 8.5 |
| Permearbility | 25 – 30 | 30 – 40 | 30 – 50 | 40 – 60 |
| Comp. strength | 0.5 – 0.8 | 0.4 – 0.7 | 0.6 – 0.9 | 0.5 – 0.8 |
| Hardness | 50 – 80 | 50 – 80 | 50 – 80 | 50 – 80 |
| Fineness No. | 180–260 | 180–260 | 140–180 | 140–180 |

Table 12 Semi–synthetic Green Molding Sand

| Sand use / Property | Small and Medium casting | |
|---|---|---|
| | Face sand | Back sand |
| Moisture % | 5.0 – 6.0 | 5.0 – 6.5 |
| Permearbility | 40 – 80 | 50 – 100 |
| Comp. strength | 0.6 – 1.0 | 0.5 – 0.9 |
| Hardness | 50 – 80 | 50 – 80 |
| Fineness No. | 120–200 | 120–200 |

Table 13 Synthetic Green Molding Sand

| Sand use / Property | Medium and Large casting (20 – 100 kg) | | Large casting (80 – 500 kg) | |
|---|---|---|---|---|
| | Face sand | Back sand | Face sand | Back sand |
| Moisture % | 3.0 – 5.5 | 3.0 – 5.5 | 3.0 – 5.5 | 3.0 – 5.5 |
| Permearbility | 70 – 100 | 150–180 | 120–180 | 130–200 |
| Comp. strength | 0.6 – 1.0 | 0.5 – 0.9 | 0.6 – 1.0 | 0.5 – 0.9 |
| Hardness | 60 – 90 | 60 – 90 | 60 – 90 | 60 – 90 |
| Fineness No. | 100–180 | 100–180 | 70 – 120 | 70 – 120 |

# Part II

*by Takeo Hayakawa*
*Works Manager,*
*Kokko Foundry, Ltd.*

## § 1 Outline of 3 companies.

A is an independent company which is specializing in precision die forging as well as in castings. The productivity in both fields will be the first class in this country.

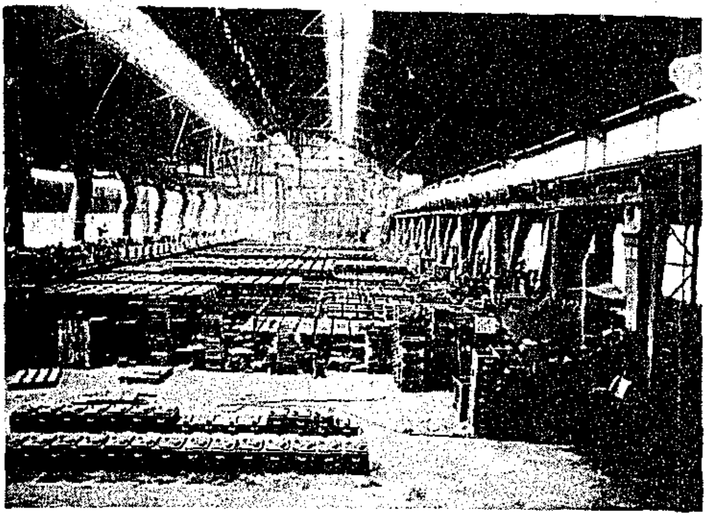


Photo 1. general view in foundry A

The foundry shop is fully mechanized with pallets conveyer system by producing small castings for automobile, home electric appliances and monthly production is about 400 tons by 55 direct workers. The photo 2 shows the inspection of castings.

This company can be specified as one of the foundries of owning high productivity, good surface and high dimensional accuracy as well as of uniformed quality, by semi-synthetic sand maily by natural bonded sand.

Photo 2. Example of castings in A.

B is also mechanized with roller conveyer system and producing castings for reduction gears and brackets for specified motors having 50 ~ 200 pieces of monthly order in constant of which the size will be the medium and monthly production will be about 200 ton by 19 direct workers.

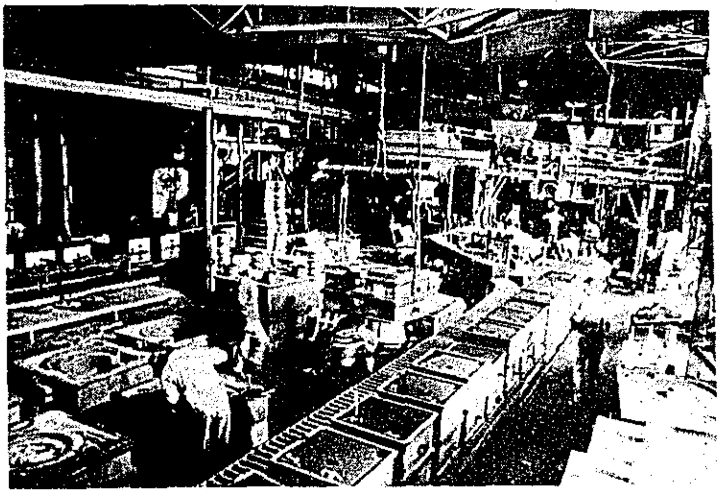


Photo 3 general view of foundry B

The mechanical specification is about 25kg/mm or FC-25 in JIS
In spite of wood patterns are being changed 2 ~ 3 times daily, it has high productivity for which shall largely be admired.

Photo 4 Example of castings
in company B.

C is a jobbin gorder type of foundry with unit weight of castings 100gr ~ 3,000kg used for jig, machine tool, agricultural machine wood working machine, printing machine, valve and others.

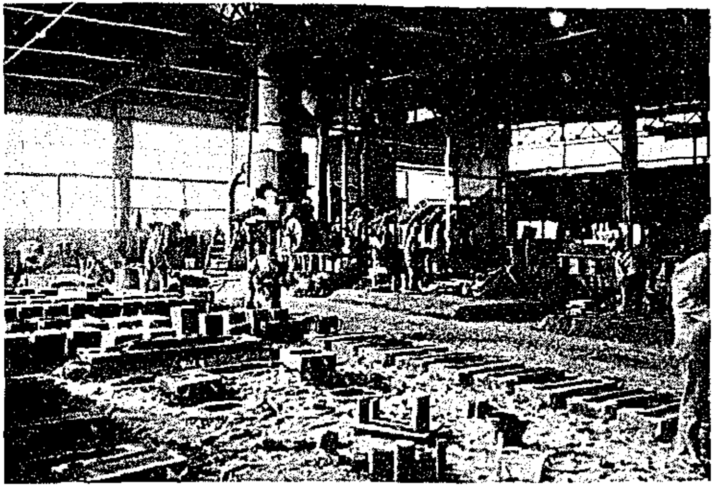


Photo 5 general view of foundry C.

Moulding processes are also in various types such as self–hardening process, natural bonded green and dry sand mould, shell stack moulding and etc.

Melting, sand treatment and material handling were recently rationalized, however, the productivity is still low, as hand moulding is dominant, and high grade cast iron being produced,ie, FC 30 and high tensile strength cast iron, alloyed cast iron.

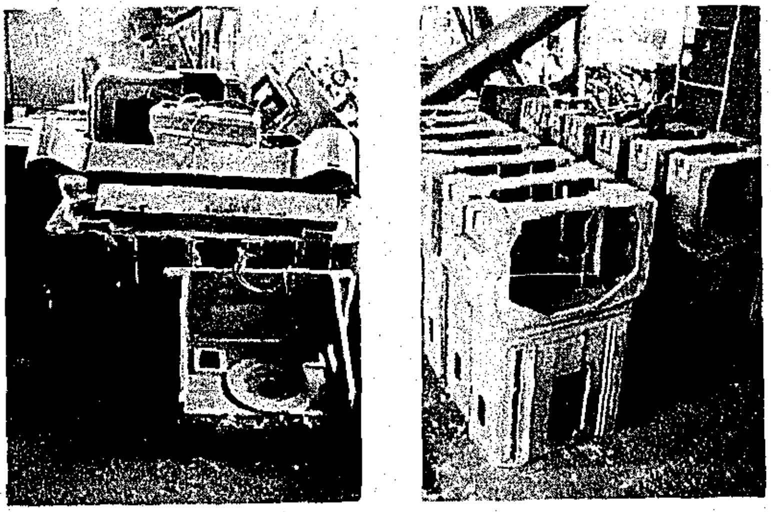
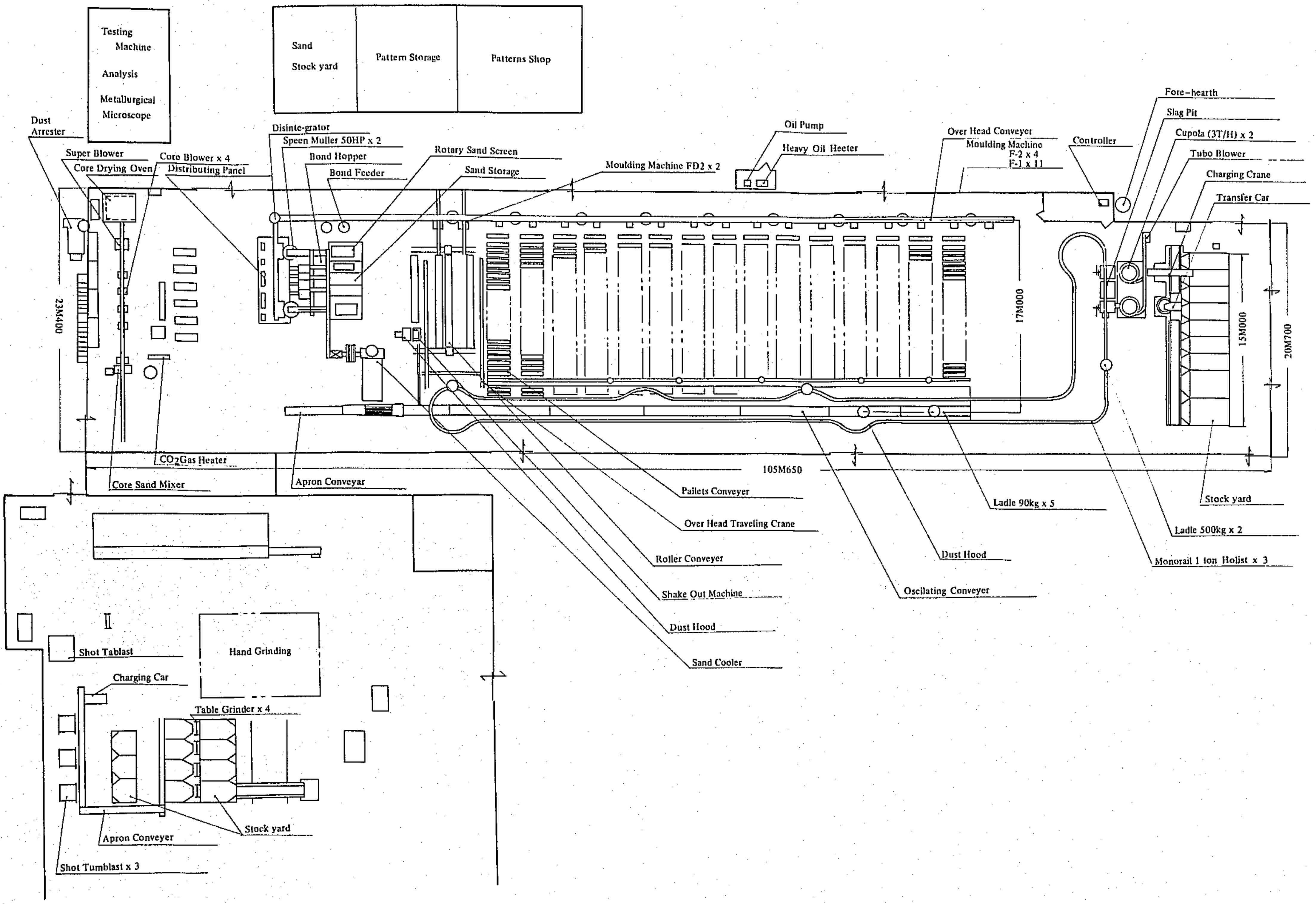


Photo 6 Example of castings in foundry C.

Table 1. Comparison of 3 Companies

| Capital | | ¥ 120,000,000 | ¥ 13,000,000 | ¥ 20,000,000 | |
|---|---|---|---|---|---|
| No. of Employee | | 247 | 55 | 56 | |
| Related to foundry | | 64 | 27 | 56 | In the colomn of superviser, it may consist of staff, engineer, machine maintenance pattern repair, chemical analysis etc. |
| Melting | | 44 | 3 | 3 | |
| Sand | | 1 | 1 | 1 | |
| Moulding | | 21 | 8 | 23 | |
| Core making | | 6 | 3 | 8 | |
| Finishing, inspection | | 13 | 5 | 10 | |
| Superviser | | 8 | 2 | 2 | |
| Office | | 11 | 5 | 9 | |
| Monthly production | | 350 Ton | 200 Ton | 125 Ton | |
| JIS (kg/mm ) | | FC 20 ~ FC 25 | FC 25 | FC 25 ~ FC 30 alloy castiron | |
| type of castings | Unit weight | 0.5 ~ 12kg | 20 ~ 50kg | 0.1 ~ 2,000kg | |
| | Rod No. | 2,000 ~ 20,000 | 50 ~ 200 | 1 ~ 500 | |
| | Use | automobile & diesel Engine parts | | | |
| Moulding process | | Pallet conveyer mainly natural green sand. | roller conveyer synthetic sand | self-hardening process hand moulding | |
| Averge price/Ton | | ¥ 88,000 | ¥ 82,000 | ¥ 110,000 | |

Note 1. Finishing and machine repair etc. works may partly or largely be subcontracted in most cases.


Testing Machine
Analysis
Metallurgical Microscope
Sand Stock yard
Pattern Storage
Patterns Shop
Dust Arrester
Super Blower
Core Drying Oven
Core Blower x 4
Distributing Panel
Disinte-grator
Speen Muller 50HP x 2
Bond Hopper
Bond Feeder
Rotary Sand Screen
Sand Storage
Moulding Machine FD2 x 2
Oil Pump
Heavy Oil Heeter
Over Head Conveyer
Moulding Machine F-2 x 4 F-1 x 11
Controller
Fore-hearth
Slag Pit
Cupola (3T/H) x 2
Tubo Blower
Charging Crane
Transfer Car
23M400
17M000
15M000
20M700
105M650
CO2Gas Heater
Core Sand Mixer
Apron Conveyar
Pallets Conveyer
Over Head Traveling Crane
Roller Conveyer
Shake Out Machine
Dust Hood
Sand Cooler
Oscilating Conveyer
Dust Hood
Ladle 90kg x 5
Ladle 500kg x 2
Monorail 1 ton Holist x 3
Stock yard
II
Shot Tablast
Hand Grinding
Charging Car
Table Grinder x 4
Stock yard
Apron Conveyer
Shot Tumblast x 3

## § 2 Factory layout and operational system

Foundry A is under the fally automatic control in each process, namely, moulding yard installed with 15 palletconveyer lines (one line has 31 carriers with capacity of 5 moulds each), like-wise, melting, sand treatment and finishing as shown in Fig 1.

A-i moulding

Jolt-squeeze type moulding machines are used for the pallet conveyer lines and working procedures shall be shown in the following photoes 7 12.

Photo 7 Jolting drag

Photo 8 Face sand is filled. Storage for face sand is shown in the right side of photo 9.

Toble 2. Standard Snap Flask size

| Flask size m/m | depth | draft |
|---|---|---|
| 250 x 350 | 120 | 4 |
| 250 x 400 | 80 | |
| 350 x 350 | | |

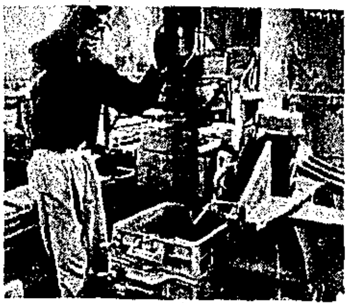


Photo 9 Back sand fill into cope mould

Photo 10 Squeezing cope and drag

Photo 11 Pattern draw

Photo 12 Closing

Table 3

Operational standard time for snap flask type moulding

| Type of works | Time (sec) |
|---|---|
| Pattern setting & rollover | 8 |
| Air cleaning drag pattern | 1 |
| Spray parting & agent | 2 |
| Fill face sand by shavel | 6 |
| Hand ramming | 5 |
| Back sand filling by shooter | 4 |
| Jolting and scraping sand | 10 |
| Set bottom plate | 2 |
| Roll over | 4 |
| Cope cleaning | 2 |
| Spray parting agent | 2 |
| Gates and risers | 5 |
| Fill face sand | 6 |
| Sand settlement | 5 |
| Back sand filling by shooter | 4 |
| Settle corner sand | 3 |
| Sand scraping & fixing plate | 5 |
| Squeezing | 3 |
| Remove fixing plate | 2 |
| Remove sprue Riser pattern | 3 |
| Remove cope with vibration | 4 |
| Pattern draw with vibration | 2 |
| Cleaning sprue etc. by air | 7 |
| Spray surface stabilizer to ingate etc. | 2 |
| Core setting | 6 |
| Closing | 5 |
| Remove flask | 5 |
| Place mould on carrier | 4 |
| Total | 117 |

Apart from pallet conveyer lines, foundry A has roller conveyer line with jolt squeeze stripping type moulding machines for the flask size of (550 x 720 mm, cope depth 150 mm, drag depth 120 mm) to kake castings for engine cover, transmission case etc. (Refer to photo 13,14)

Photo 13. Squeezing by FD type

Photo 14. Closing

A-ii) Core making

One unit of super blowing machine and 4 units of core blowers are used for $CO_2$ core making on which alchol base graphite coating are applied. Cores which shall be used for the section liable to have gas defects, pin–hole, blow etc., are treated by hot air drying oven.

Photo 15. Core making by blowing machine

Photo 16. $CO_2$ core in storage

### A–iv) Sand Treatment

Photo 17 shows general view of sand treatment plant; in order from 2 umts of 50 HP speed muller osillating conveyer, cooler rotary screen and to hopper, the returned sand goes Bonding materials are sent to bond hopper (bin) by compressed air.

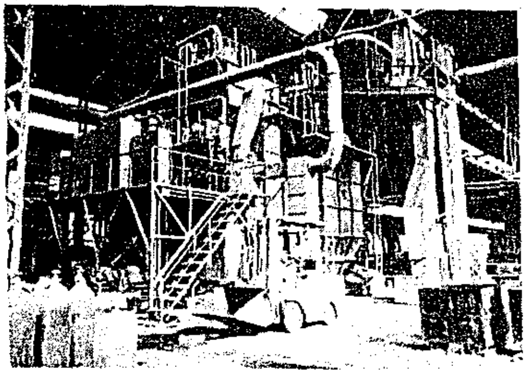


Photo 17. Sand treatment plant in foundry A.

Sand mixtures of 10 ton per hour can be supplied to the sand bins of the moulding lines upon (no–man) automatic control by time setting for weighing, mixing, mulling and etc.

### A–v) Melting

2 units of 3 ton per hour cold blast water cooled cupolas are alternatively operated with automatic charging equipment of 1 ton capacity for the movement of traversing and raising to charge materials as seen in the right top side of photo 18.

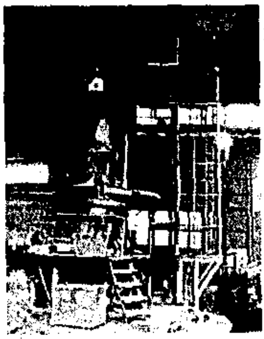


Photo 18. 3 ton cupola (A)

The bucket of the charger is a bottom open type with which has less trouble and can give better combustion condition by making low level in the center and high in the side as shown in Fig.2.
Materials carried by folk lifttruck are placed into inclined storage yard of 20° angle and then into horizontally movable bucket with weighing scale attachment as shown in photo 19.

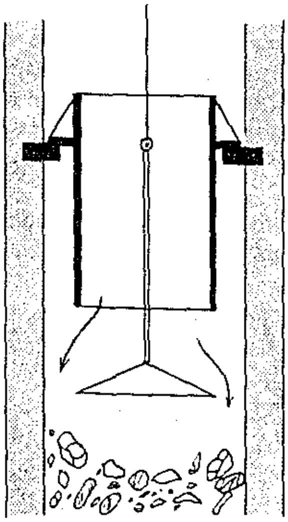


Fig. 2. illastrates charged condition

Continuously tapped molten metal is received by fore–hearth as shown in the left end of photo 18 and then into 500kf ladle with cover attachment, of which carried by mono–rail crane to 90kg pouring ladle above pouring platform. 5 workers out of moulders will do pouring alternatively. Pouring temperature is about 1380~1450 C and the metal is checked by means of chill test and fractured test as well as of top shape formation of test piece (Japanese style) by each 500kg ladle.

Photo 19. Storage yard & scale

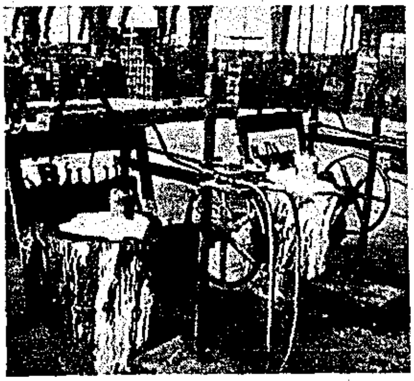


Photo 20. Pre–heating ladle

### A–vi) Cleaning and grinding castings

Photo 21. Cutting ingates etc.

The as cast came from Apron converyer of pallet conveyer lines shall be put into pallet box of 500kg capacity as shown in photo 21. of which lifted by folk lift truck onto inclined working stand for ingates etc. cutting, then to pallet box again upon classification by type of castings.

Photo 22 shows shot tumblast machines and the right side is a castings charger into the tumblast.

The castings upon completion of shotblasting shall be taken down into the pit where there is underground apron conveyer which is connected to the apron conveyer inclination type as shown in photo 23, then the casting go to the grinding and inspection stand as shown in photo 24, and upon the completion of inspection, the product kept in the pallet box is taken into the storage yard by traverser belt conveyer.

Photo 22. Shot tumblast

Photo 24. Grinding and Inspection

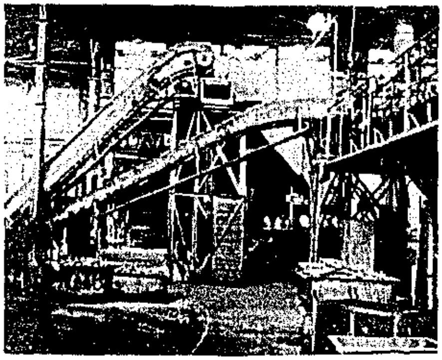


Photo 23. Apron conveyer for castings

High attention should be paid on that special consideration being taken into the mechanization for elimination of man hours, especially in the finishing side.

Foundry B.

The shop is systematically well organized as shown in Fig. 6 with roller conveyer type Automatic moulding line in the center, hand moulding and core–making yards in the side.

B–i) Moulding works

AFD Type automatic moulding procedures are shown in photo 25 ~ 33 and table 4.

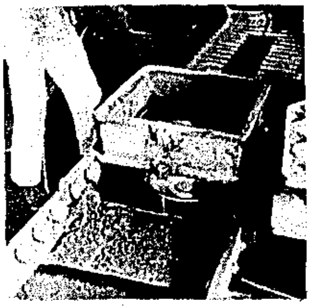
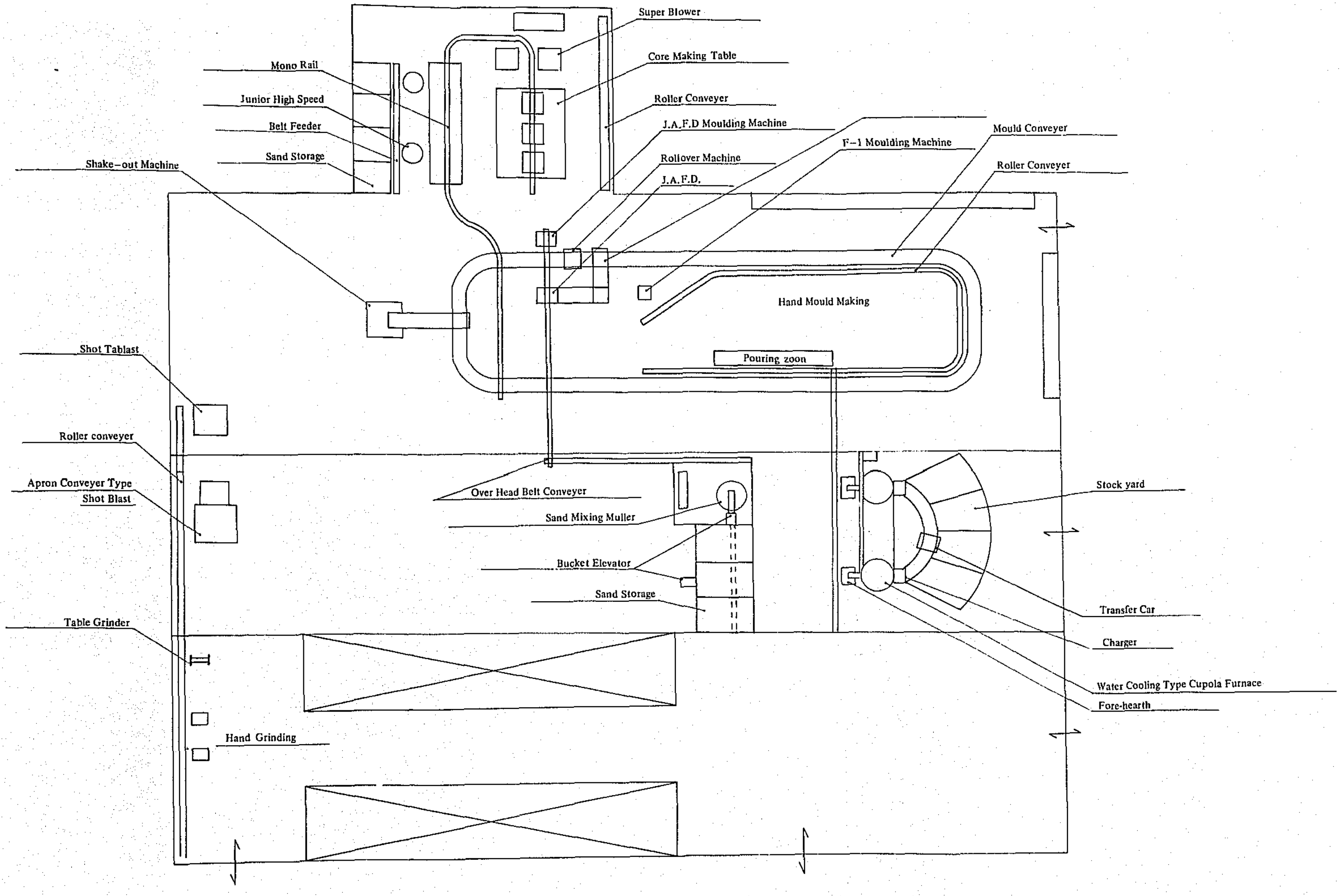


Photo 25. Flask setting

Photo 26. Fase sand filling and setting sprue, patterns etc.

Photo 27. Back sand filling from shooter


Super Blower
Core Making Table
Mono Rail
Junior High Speed
Belt Feeder
Sand Storage
Shake-out Machine
Roller Conveyer
J.A.F.D Moulding Machine
Rollover Machine
J.A.F.D.
F-1 Moulding Machine
Mould Conveyer
Roller Conveyer
Hand Mould Making
Pouring zoon
Shot Tablast
Roller conveyer
Apron Conveyer Type
Shot Blast
Over Head Belt Conveyer
Sand Mixing Muller
Bucket Elevator
Sand Storage
Stock yard
Transfer Car
Charger
Water Cooling Type Cupola Furnace
Fore-hearth
Table Grinder
Hand Grinding

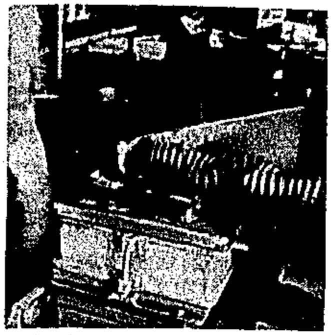


Photo 28. Squeezing after jolting

Photo 29. Pattern draw

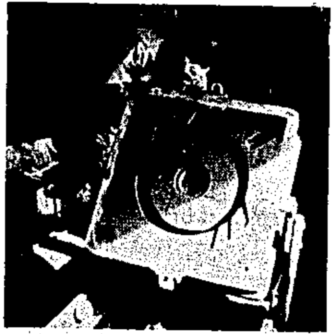


Photo 30. Roll over

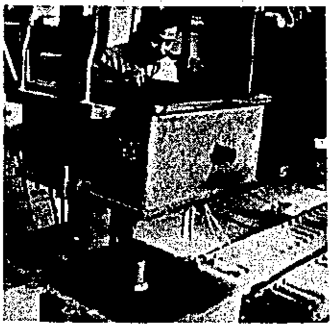


Photo 31. Core setting

Table 4.
Standard moulding time (AFD Type)

| Type of works | Cope moulding time | |
|---|---|---|
| Set flask | 2sec. | 2sec. |
| Cleaning, spraying parting agent | 2 | 2 |
| Set sprue, riser pattern | 2 | – |
| Face sand fill | 3 | 3 |
| Face sand settlement | 4 | 4 |
| back sand fill by shooter | 4 | 4 |
| Jolting | 5 | 5 |
| Sand scraping | 2 | 2 |
| Squeezing | 3 | 3 |
| (air) cleaning | 1 | 1 |
| Pattern draw | 3 | 3 |
| Roll over | – | 4 |
| Remove sprue, Runner pattern | 3 | – |
| Core setting | – | 4 |
| Shift cope for closing | 3 | – |
| Closing | 4 | |
| Mould shift for pouring | 2 | |
| Total | 40 | 40 |

flask size 600m/m x 600m/m cope depth 350m/m
drag depth 250m/m

Photo 32. Closing

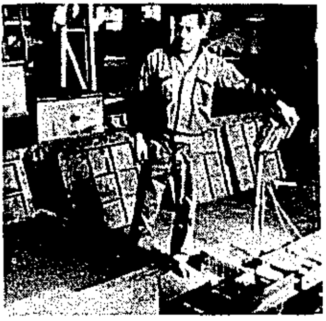


Photo 33 Setro
Set for automatic
mould sending

### B–ii) Core making

In foundry B, new sand is supplid into hoppers as shown in photo 34 from top side and fixed volume of sand comes out of it onto belt conveyer, then treated by whirl mixer treated $CO_2$ core sand and synthetic face sand are kept in backet type storage as shown in photo 35 and carried by 0.5 ton hoist to each working place.

Large core is manually made, however, cores for reduction gears, gear box, motor frame etc. are made by 2 units of superblowing machine with high efficiency and alchol base coating is used in the same way as the foundry A does.

Photo 34. Face and core sand freatment by whicl mixer

Photo 35. $CO_2$ core making

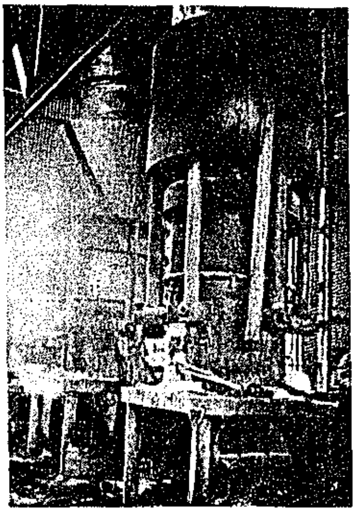
### B–iii) Sand treatment

One unit of simpson type mill with 50 HP is set in the sand plant, the back sand is sent to each moulding yard by over–head conveyer after moisture adjustment.

Photo 36. Sand treatment plant in foundry B.

B–iv) Melting and pouring works.

2 units of 2 ton water–cooled cupola with own designing are alternatively operated. Point of difference here in foundry B is to use fine grain size coke of about 50 mm in order to make higer carbon pick up of the metal, thus possible to charge more steel scrap to lower the cost of metal and naturally cost of coke however, larger capacity of blower as 20 HP is required to blast in higher pre ssure due to the fine grain coke.



Phot 37.

Materials yard is in delta or folding fan shape with charging hopper or backet as the center.

Photo 38.

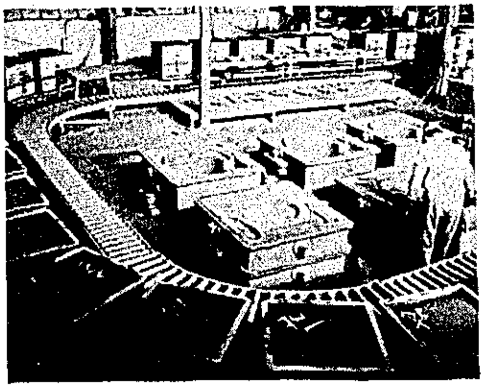


Photo 39.

Pouring works of AFD line shall be done at the pouring platform or stand as shown in the right top of photo 39.

### B–v) Cleaning and grinding

The most nerve racking problem or bottleneck for Japanese foundries shall be in the finishing side as type of works such as cleaning, grinding off fins of castings.
The foundry B is not the exceptional, still hand working can been seen as photo 40, 42.
Photo 41 shows cleaning by shot abraitor, the casting shall be transfered to the table grinder through belt conveyer, there the external surface grinding is made and the internal surface grinding is manually made by hand grinder as shown in photo 42.

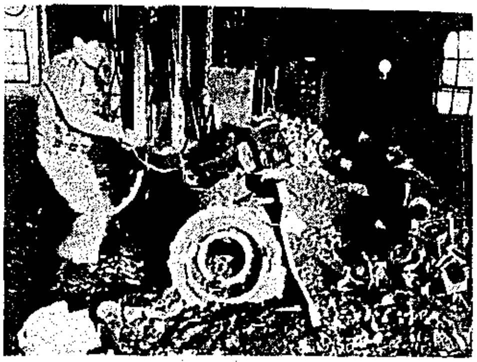


Photo 40. Cleaning

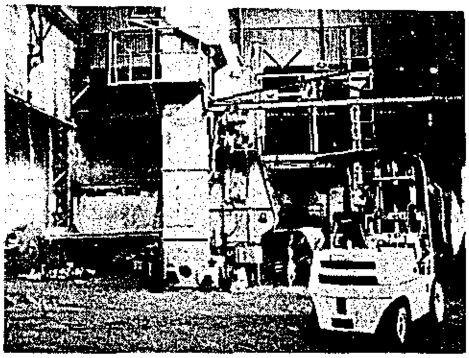


Photo 41. Shot abraitor

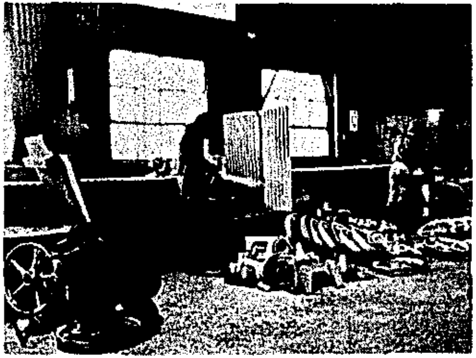
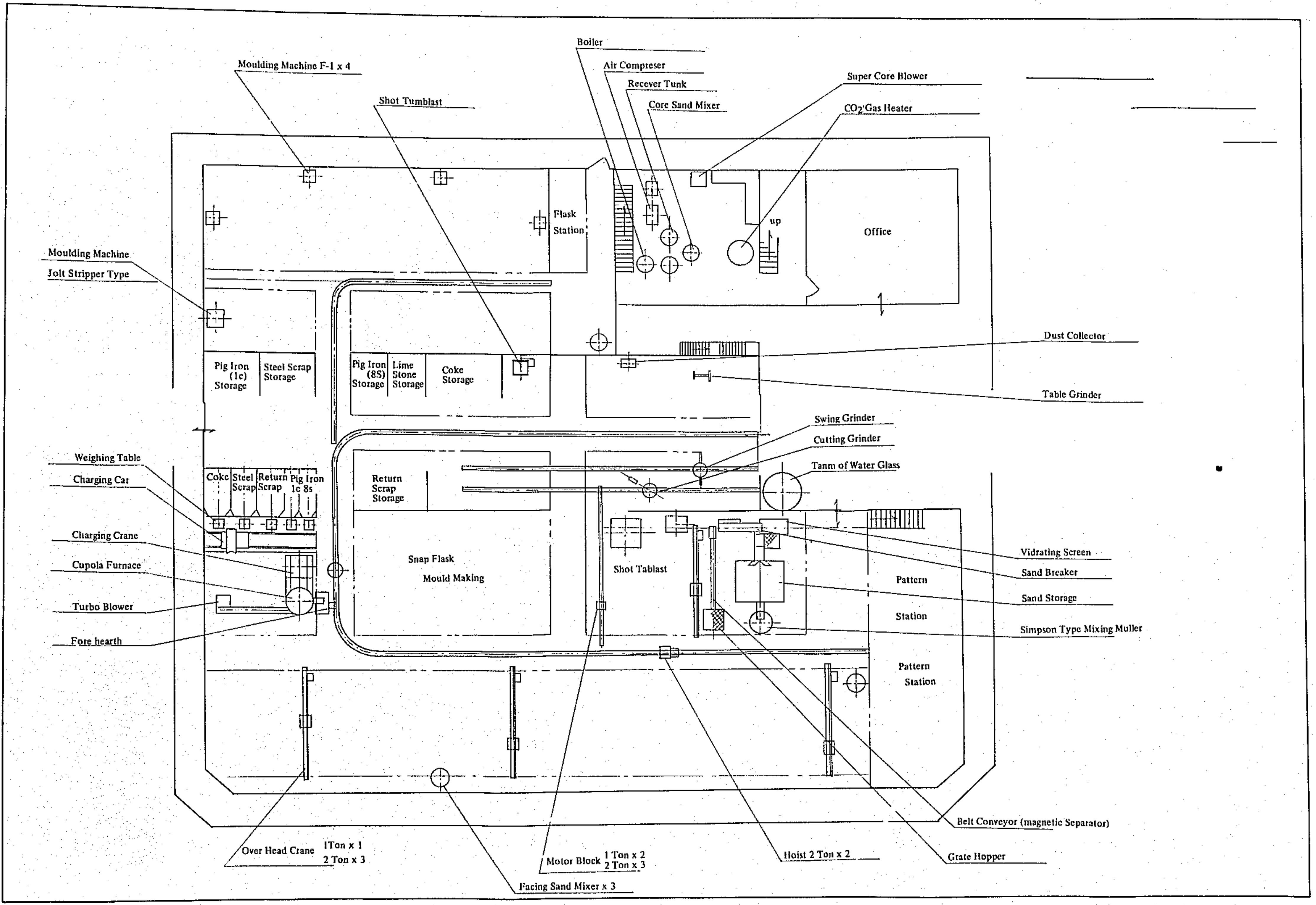


Photo 42. Grinding


Boiler
Air Compreser
Recever Tunk
Core Sand Mixer
Moulding Machine F-1 x 4
Shot Tumblast
Super Core Blower
CO$_2$'Gas Heater
Flask Station
up
Office
Moulding Machine
Jolt Stripper Type
Dust Collector
Pig Iron (1c) Storage
Steel Scrap Storage
Pig Iron (8S) Storage
Lime Stone Storage
Coke Storage
Table Grinder
Swing Grinder
Cutting Grinder
Tanm of Water Glass
Weighing Table
Charging Car
Coke
Steel Scrap
Return Scrap
Pig Iron 1c 8s
Return Scrap Storage
Charging Crane
Snap Flask Mould Making
Shot Tablast
Vidrating Screen
Sand Breaker
Pattern Station
Sand Storage
Cupola Furnace
Turbo Blower
Simpson Type Mixing Muller
Fore hearth
Pattern Station
Belt Conveyor (magnetic Separator)
Over Head Crane 1Ton x 1 2 Ton x 3
Motor Block 1 Ton x 2 2 Ton x 3
Hoist 2 Ton x 2
Grate Hopper
Facing Sand Mixer x 3

Foundry C.

This foundry is applying various types of moulding processes by mainly hand moulding as stated in page 4, and photo 43 ~ 55 show its working conditions.

C–i) Moulding

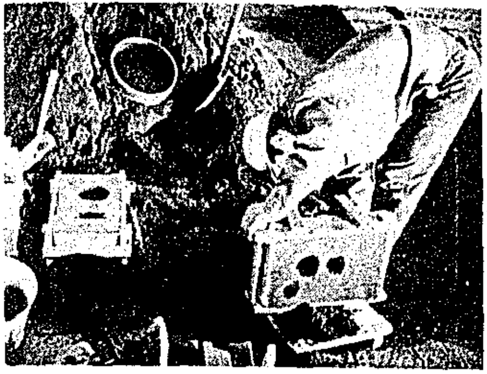


Photo 43 Green sand hand moulding with snap flask

Photo 44. Natural bonded green sand moulding

Photo 45. Graphite coating

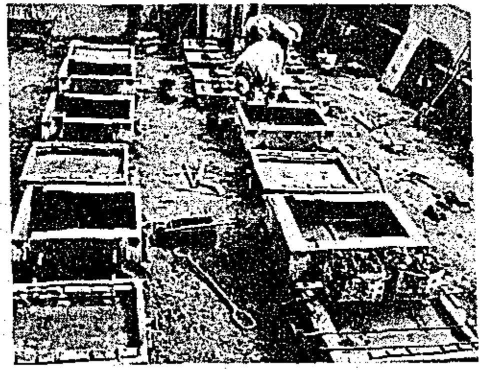


Photo 46. Skin dry hand moulding with self–hardening core

Photo 47. Self–hardening mould

Photo 48. Self–hardening process pit moulding

Foundry C mainly produces castomgs piece by piece used etc., The coated mould for which is as shown in photo 49 and ready for core setting. Small castings such as small valves, agricultural machine parts are made by moulding machine and by floor moulding system as given in photo 50. The pattern shall be changed within 1 to 2 days, as the production scale in each type is small.

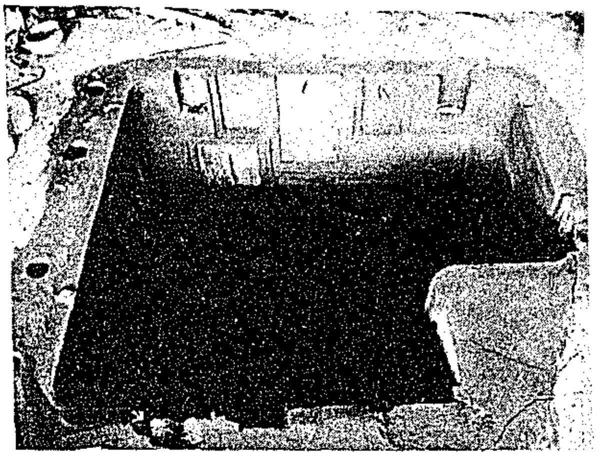


Photo 49. Self–hardening mould (large pit mould)

Photo 50. Green sand machine moulding

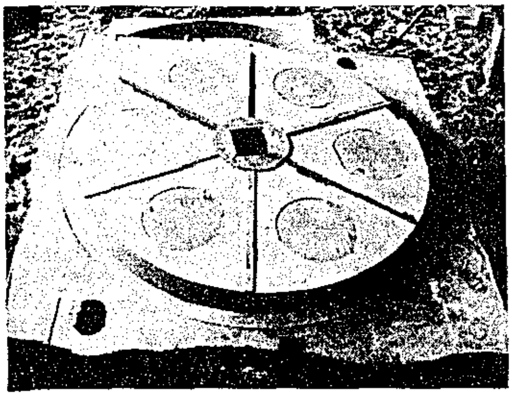


Photo 51. Self–hardening mould (Cope)

Photo 52. Drag pattern reliese

Photo 53. Ready for pattern draw

Photo 54. Pattern draw

Photo 55 Completes pattern draw

Table 5.
Standard moulding time in self-hardening process

| Working factors | Forking time (min) | |
|---|---|---|
| | Worker A | Worker B |
| Pit making | 12 | During this |
| Sand mulling and carrying | – | time 80kg |
| Sand filled in pit & leveled | 1 | x t by whirl |
| Pattern setting | 2 | mixer 3min |
| lift pattern once | 1 | x 6 = 18 min |
| Stamp low density part | 2 | mixing and |
| Pattern resetting | 1 | carry sand |
| Side ramming | 25 | mixture to |
| Back sand ramming | | mould yaod |
| Surface stamping | 4 | |
| Scraping | 3 | |
| Parting line finish | 6 | |
| Reliese pattern | 1 | |
| Sub total | 58 | |

Drag hardening time is 30~60 minutes, there fore takes other job.

| | | |
|---|---|---|
| Sand mixing and carry | | During this |
| Cleaning and parting powdering | 2 | time, sandmix. |
| | 4 | 80kg x 9 |
| Set cope flask, sprue etc. | 18 | = 3min x 9 |
| | 2 | times tot. |
| Sub total | 26 | 29min |

Cope mould hardening time is about 30 minutes, therefore takes other job.

| | | |
|---|---|---|
| Lift cope & roll over | 5 | |
| Cut ingates | 3 | |
| Coating | 8 | |
| Core setting, cleaning | 6 | |
| Closing | 3 | |
| | 5 | |
| Sub total | 30 | |
| Gross total | 114 x 2 | |

The standard working procedures are given in photo 51 ~ 55 and the requred time is given in table 5 to make V–pulley (unit weight 520 kg) by self–hardening pit moulding. 2 workers, A and B spend time as in table 5, B specializes in sand mixture and its handling for supplying to the worker A, consequently doubled time spent by worker A shall be the real moulding man hours.

Regarded with man–hours, core making in this case does not require much time just make simple cylindrical or rod type of core, however, the time consumption in moulding and core making will be about the same in general. Time to be spent for core setting and closing shall be half of the that for moulding.

C–ii) Core making

Small core shall partly be made of self–hardening sand by super–blow machine and $CO_2$ gassing for 5~10 seconds in order to accelerate the hardening time.

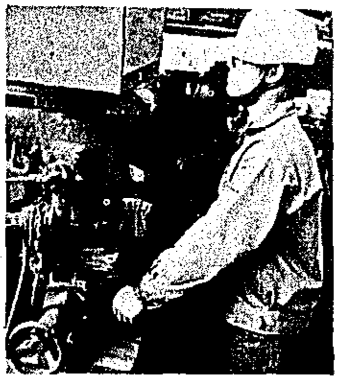


Photo 56 Core making by super blow machine

Large core is all made by self–hardening process in the same way as the mould making, afterwards by slchol (methanol) base coating of ARISTON, GRASTION or (graphite, coke powder + resin + methanol etc.).

## C–iii) Sand Treatment

Self–hardening sand mixture is made by whirl mixer as in photo 57, and natural sand is treated by sand blender (aerator) as in photo 58.

Face sand which requires high strength is mulled by the whirl mixer and the sand handling works in all types are made by mono–wheel hand carriers.

The self–hardening sand can be reused in 70~80% by compact reclaimer machine.

And at present, the foundry C just completed lst project of foundry shop renewal by the own design for the recently set cupola, sand plant under construction and etc.

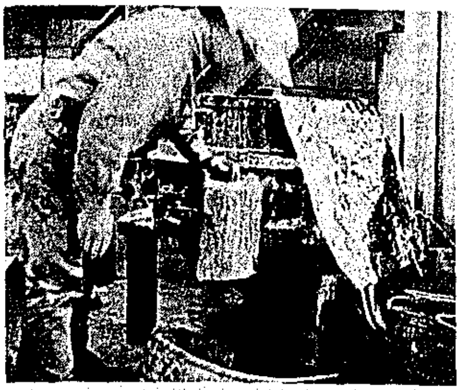


Photo 57. whirl mixer

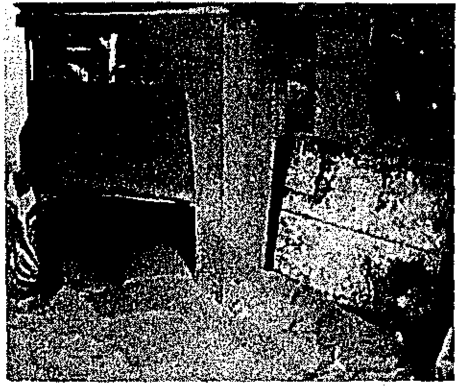


Photo 58. Sand blender

Photo 59. Compact reclaimer

## C–iv) Melting and Pouring

The melting plant of foundry C is the self–designed to minimize the working time loss.
The charging materials can easily be scratched down into the tilting type weighing scale box through the materials yard of 30° in clination as given in photo 60, 61 and 62 for the more sure in weighing scale reading.

Photo 60.

Photo 61

The traversing scale is set on rail in shallow pit almost the ground level as shown in photo 61 and tilting box can eastly replace the materials into the charging hopper or bucket with small pit.
The photo 63 shows for molten metal tapping, photo 64 pouring for large casting and 65 for small casting.

Photo 62 Forehearth in the left and automatic charging machine in the right

Photo 63. 3 ton cold blast cupola in foundry C.

The foundry C is producing many in kinds, therefore various moulding processes and iron castings in properties, i,e., Fc 15 ~ FC 35 in tensile strength of JIS specifications and Ni–Cr Cast iron, Cu–Cr–Mo cast iron etc. as well.
The melting temperature shall be over 1,550 C at a front slagging spout with good enough for innoculation effect.

Photo 64. Pouring (large casting)

The molten metal handling is made by 2 ton hoist with 200kg ~ 600kg ladles to the respective pouring yards. The pouring temperature shall be standardized, namely 1420 C for small castings and 1320 C for over 500kg castings and etc.
Table 6 shows the standard charging materials mixing ratio and table 7 is for targeted chemical composition of cast iron in various types of metals specirication in tensile strenghth.

Photo 65. Pouring (small casting)

Table 6 Standard charging Materials Mixtures

| Charging materials | FC–15 | FC–20 | FC–25 | FC–30 | FC–35 |
|---|---|---|---|---|---|
| Pig Iron (yawata 1-1-C) | 40% | 40% | 20% | 10% | 10% |
| Pig Iron (yahagi 8s | 10 | 10 | 15 | 20 | 20 |
| Return | 50 | 40 | 20 | 10 | – |
| Steel scrap | – | 40 | 45 | 60 | 70 |
| Fe–Mn (75%) | – | 0.1 | 0.25 | 0.4 | 0.6 |
| Innoculant | 50s<br>0.2 | 50s<br>0.3 | Ca-Si<br>0.3 | Ca-Si<br>0.3 | Ca-Si<br>0.3 |
| Split coke | 12.5 | 12.5 | 15 | 15 | 15 |

Remarks: 1charge weight 200kg, lime stone 4%

Table 7 Target chemical compostion of Cast Iron

| Chemical Composition<br>JIS Tensile strength (kg/mm ) | T.C % | Si % | Mn % | P % | S % |
|---|---|---|---|---|---|
| FC – 15 | 3.60 | 2.50 | 0.40 | 0.10 | 0.07 |
| FC – 20 | 3.40 | 2.20 | 0.50 | 0.10 | 0.07 |
| FC – 25 | 3.20 | 2.00 | 0.60 | 0.08 | 0.08 |
| FC – 30 | 3.00 | 1.80 | 0.70 | 0.08 | 0.08 |
| FC – 35 | 2.80 | 1.60 | 0.80 | 0.08 | 0.08 |

### C–v) Cleaning and Grinding

The production system of the foundry C is jobbing order as afore–mentioned and finishing works shall be made manually. The large casting as in photo 66 is being done by chipping hammer and coremetals being taken out.

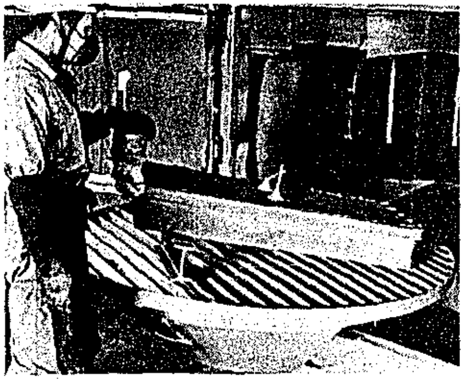


Photo 67. Cleaning by shot Tablast

Photo 68 shows riser, sprue cutting grinder newly developed by foundry C, of which has high efficiency, just 1/5 cutting times of the conventional angle grinder.

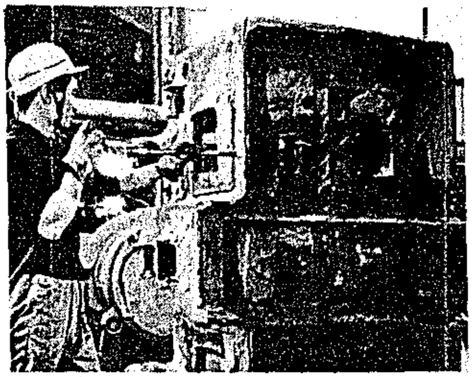


Photo 66 Cleaning of big casting

Photo 67 shows cleaning the casting by shot tablast machine. A core knockout machine was recently developed, by which does not require chipping hammer, of which under consideration for application.

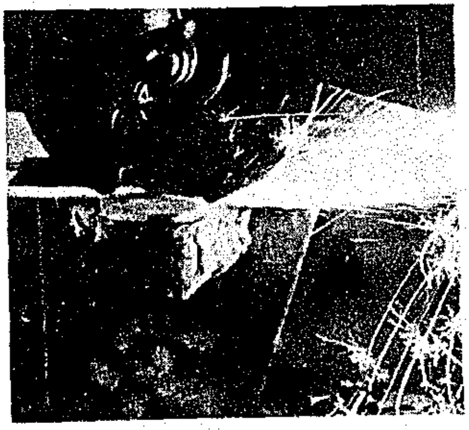


Photo 68. Cutting

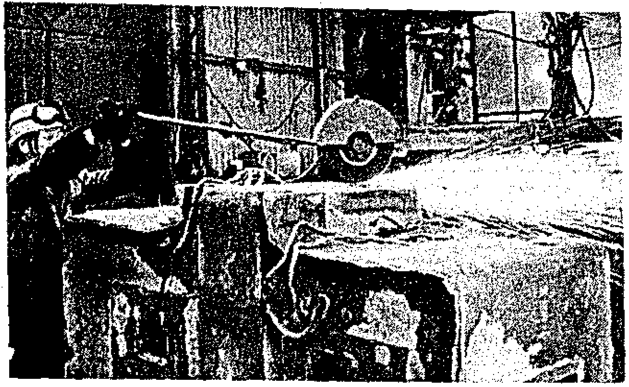


Photo 69. Works by Swing grinder

Photo 69,70 show swing grinder and sander applied in this foundry.
Though manual operation as such be comes in the low productivity, it can not be avoided because every casting is different in shape and size, however, man bours elimination is deeply considered, e.g., by fully utilization of motor–block hoists, folk lift truck etc.

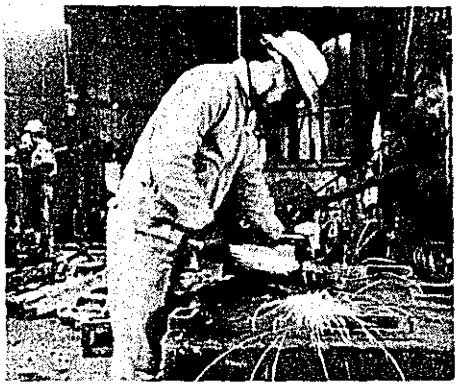


Photo 70. By sander

## § 3 Sand Properties Used in 3 Foundries

Table 8 Sand properties in Foundry A

|  | Mixtures (%) | permeability AFA | Compressive strength kg/cm | moisture % | Use |
|---|---|---|---|---|---|
| Face sand (green) 1 | Ret | 30~50 | 0.65~0.80 | 6.5~7.5 | machine moulding |
| 〃 2 | silica sand 100<br>Am, grap. 10<br>bent 0.5 | 20~35 | 0.75~0.95 | 6.0~7.0 | high strength |
| 〃 3 | Ret 70<br>New 20<br>Am. graph. 10 | 35~70 | 0.70~1.00 | 7.0~8.0 | hand moulding |
|  |  |  |  |  |  |
| $CO_2$core(1) | Silica sand 100<br>Water glass 6.5 | dry 60 | dry 2 | wet 5.0~7.0<br>dry 2.5~3.5 | small castings |
| $CO_2$core (2) | Silica sand 100<br>Water g. 6.0<br>Amor. graphite 5.0 | dry 60 | dry 2 | wet 5.0~7.0<br>dry 2.5~3.5 | Cy linder block casting |

Table 9. Standard grain size distribution of Sand in foundry A

| mesh<br>Type | 6 | 8 | 10 | 14 | 20 | 28 | 35 | 48 | 65 | 100 | 150 | 200 | 270 | Pan | Clay | F.N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Face sand (green) |  |  | tr | tr | 0.2 | 0.3 | 0.5 | 2.0 | 5.0 | 23.0 | 32.0 | 13.0 | 4.0 | 2.0 | 18.0 | 102.2 |
| Face sand (green) |  | tr | 0.2 | 0.3 | 0.5 | 1.0 | 2.0 | 4.0 | 10.0 | 28.0 | 22.0 | 12.0 | 2.0 | 2.0 | 16.0 | 93.9 |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| CO core sand |  |  |  |  | tr | 0.2 | 0.6 | 4.2 | 20.0 | 45.0 | 15.0 | 10.0 | 3.0 | 2.0 | tr |  |

Table 10. Specification in Foundry A for purchase of Sand and Clay

| Type | grain size distribution | | | | | | Clay | Moist % | Chemical composisition | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coarse | | Main | | Fine | | | | Sio$_2$ | Al$_2$O3 | Fe$_2$O$_3$ | Cao tMgo | Ig Loss |
| | Mesh | % | Mesh | % | Mesh | | | | | | | | |
| Sitica Sand (shinooka 6) | 70 | <25 | 70-270 | > 90 | 270 | < 5 | 0.5 | < 0.2 | > 95 | < 3 | < 1.5 | < 0.5 | <1.0 |
| Silica sand (seto 4 ) | 20 | <15 | 20-100 | > 75 | 100 | < 10 | – | < 10 | >96 | < 3 | < 1.0 | < 0.5 | <0.5 |
| Silica sand (seto5) | 30 | < 5 | 30-140 | > 90 | 140 | < 5 | – | < 10 | >96 | < 3 | <1.0 | < 0.5 | <0.5 |
| (nishike 1) | 40 | < 10 | 40-100 | > 78 | 100 | < 12 | – | < 10 | > 85 | < 10 | < 0.5 | < 0.5 | 2.5 |
| | | | | | | | | | | | | | |
| River sand | 40 | < 12 | 40-100 | > 80 | 100 | < 8 | – | < 7 | > 85 | < 10 | < 5 | < 0.5 | <2.0 |
| Natural sand (Okuda 2) | 40 | < 5 | 40-pan | > 85 | – | – | < 18 | < 15 | > 85 | < 10 | < 5 | < 1.0 | <2.0 |
| | | | | | | | | | | | | | |
| Natural S. | 40 | < 5 | 40-pan | > 85 | – | – | < 10 | < 15 | > 85 | < 10 | < 5 | < 1.0 | <2.0 |
| Natural S. | 70 | <10 | 70-pan | > 80 | – | – | < 10 | < 15 | > 85 | < 10 | < 5 | < 1.0 | <3.0 |
| Natural S. | 70 | < 7 | 70-pan | > 75 | – | – | 10<br>18 | < 1 | > 85 | < 10 | < 5 | < 1.0 | <3.0 |
| | | | | | | | | | | | | | |
| Clay | 70 | < 5 | 70-270 | > 80 | 270 | < 15 | > 85 | < 8 | 50-60 | 25-35 | < 5 | – | <20 |
| Bentonite | 70 | < 1 | 70-270 | > 89 | 270 | < 10 | > 85 | < 2 | 50-60 | 25-35 | < 5 | – | <20 |

Toble 11. Synthetic Sand Mixtures and Properties in Foundry B

| | Silica sand | return | bentonite | pellet | cornstarch | moisture | comp.strength | permeability |
|---|---|---|---|---|---|---|---|---|
| % | 20 | 80 | 4 | 1.5 | 0.6 | 4 | 0.7 | 60 |

Toble 12. Example of self–hardening sand mixtures in foundry C.

| | new sand | return | KS powder | water glass | wood flour | bentonite | | use |
|---|---|---|---|---|---|---|---|---|
| Core sand (1) | 50 | 50 | 3 4 | 5 7 | 0.5 | – | 0.2 | large casting |
| Core sand (2) | 60 | 40 | 2 2.5 | 4 6 | 0.5 | 2 2.5 | 0.2 | small casting |
| Mould sand (1) | 20 | 80 | 2 3.5 | 6 7 | – | – | – | for drag |
| Mould sand (2) | 20 | 80 | 2 4 | 6 7 | – | 2 2.5 | – | for cope |
| Mould sand (3) | 50 | 50 | 3 4 | 5 6 | – | 2 2.5 | – | for snap flask |

Molecular ratio of water glass 2.45

Order of mulling and cautions.

1. New sand, returned sand, KS powder (slag plowder), wood flour, bentonite and collapsible agent are placed into the whirl mixer for 5 ~ 10 seconds operation, then KS set (water glass) added with 20 ~ 30 seconds mixer operation, the mulling or mixing time should be the less the better in order not to get the sand mixture heated.

2. The more returned sand used,.the less KS powder added accordingly.

3. KS set addition volume shall be influencial factor to the sand strength, but it is advised to add it in the minimum for the improvement of the sand collapsibility after metal solidification and for elimination of casting defects.

Fig. 7 8 show grain size distribution of sand used in foundry C and table 13 shows its chemical composition.

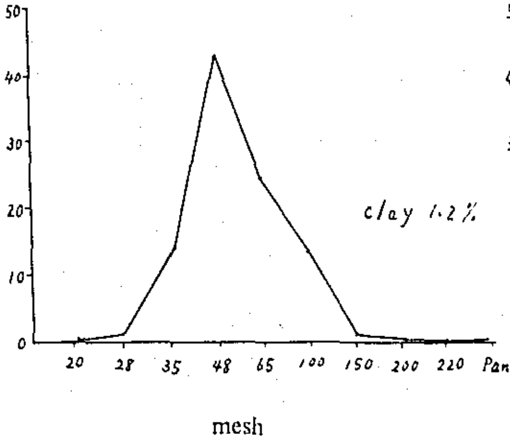


Fig. 7. Grain distribution (New)

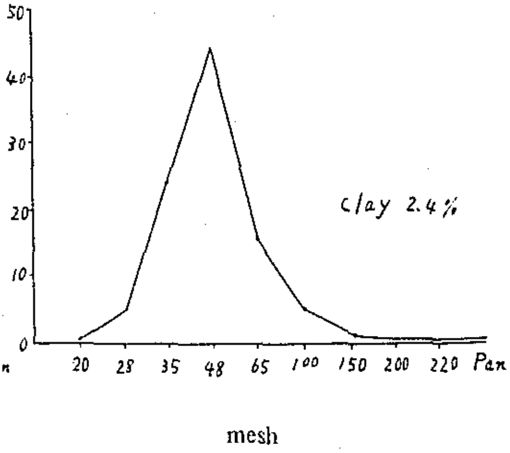


Fig. 8. Grain distribution (Return)

Table 13. Chemical composition of Hamana silica sand grade 6.

| $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | Cao | Mgo | Ig Loss |
|---|---|---|---|---|---|
| 80.56 | 14.08 | 2.56 | 1.96 | 0.34 | 0.49 |

Sand properties testing

Table 14. Self–hardening sand mixture for properties tests

| | New sand | Returns | KS powder | KS set | Wood flour | Bentonite |
|---|---|---|---|---|---|---|
| No. 1 | 50% | 50% | 2% | 6% | 0.5% | 1.5% |
| No. 2 | 50 | 50 | 3 | 6 | – | – |

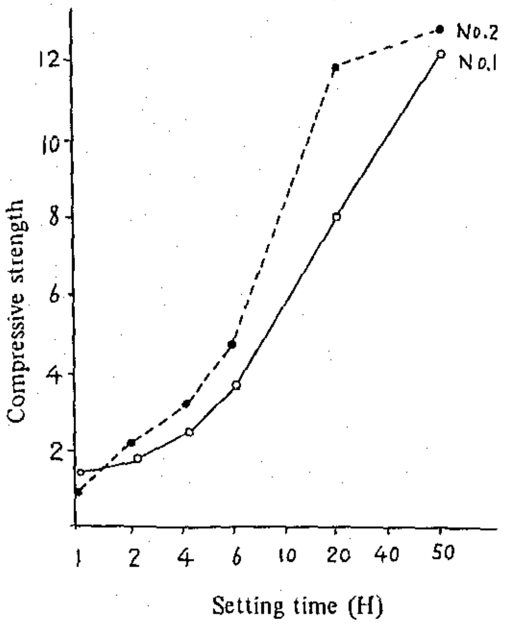


Fig. 9. Setting time & strength

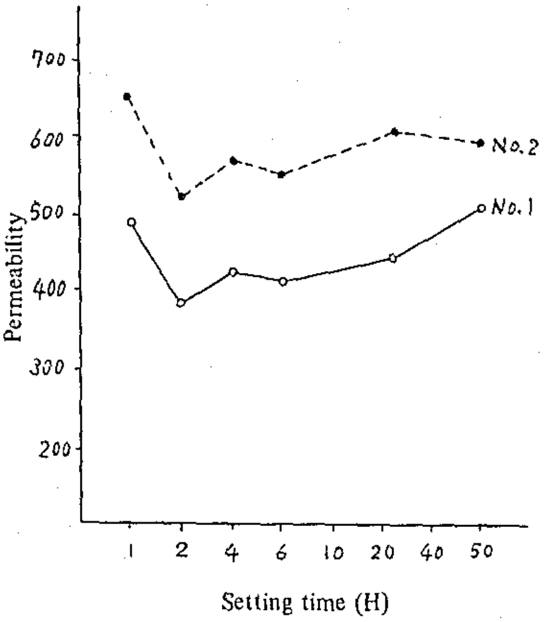


Fig. 10. Setting time & permeability

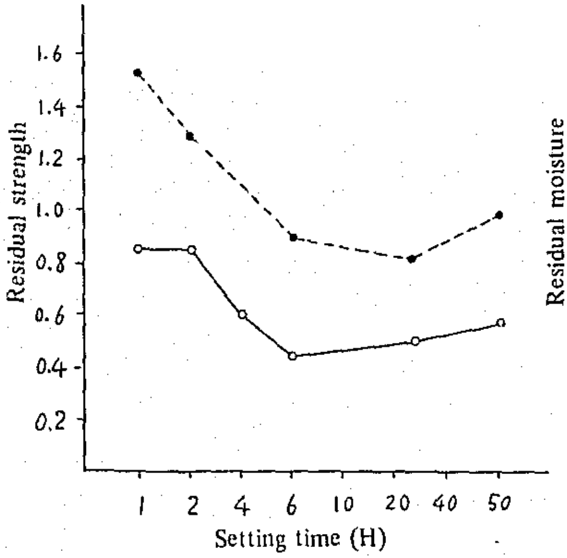


Fig. 11. Setting time & Residual strength (after rapid heating 1,000 C)

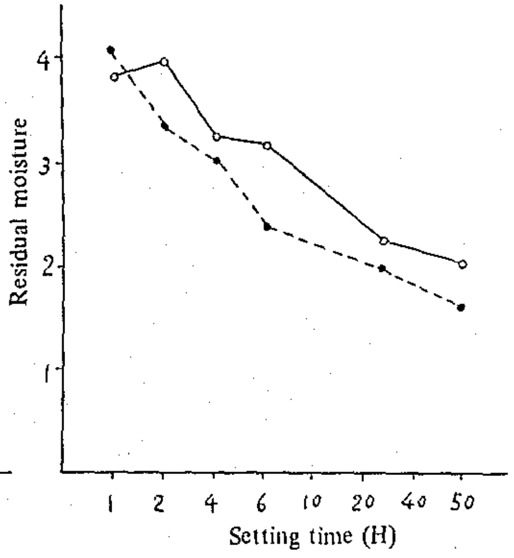


Fig. 12. Setting time & Residual moisture

Advantage and Disadvantage of Self–hardening process

Self–hardening processes in general do not require drying or hardening works as done in $CO_2$ process, therefore, the process can largely cut off man hours as well as material cost etc. Dical process of self–hardening type shall have advantages as follows.

1. No exothermic reaction and poisonas gas.
2. 80 ~ 85 % of sand can be returned as good in collapsibility.
3. Less casting defects due to little residual moisture.
4. Moisture absorption is negligeable.
5. Hardening velocity (benchtime) will not vary from climatic condition.
6. Green strength is largely improvable by a little bentovite addition.
7. Mouldability is good even for beginner.
8. Mould coatability is good for various washes.
9. Low cost, half of $CO_2$ process
10. Casting defects such as scab, blow, pin–hole etc., will be the least therefore it largely lowers reject ratio

As for disadvantageous factors, this process may have sintering (but can be avoided by cautious coating), swelling, and also sand mixing of big volume at one time is not possible because bench time is limited.

## § 4 Productivity

Comparison of 3 companies' productivity shall be as shown in table 15.

Table 15. 3 Companies' productivity

| | | Unit | A | B | C |
|---|---|---|---|---|---|
| No. of employees related to foundries | | | 64 | 27 | 56 |
| Monulding man hours | | | 21 | 8 | 23 |
| Monthly production | | Ton | 350 | 200 | 125 |
| Production (month) | by an employee | Ton | 5.5 | 7.4 | 2.2 |
| | by a moulder | Ton | 16.7 | 25.0 | 5.4 |
| Productivity (month) | by an employee | Manhr/Ton | 45.4 | 33.8 | 113.6 |
| | by a moulder | Manhr/Ton | 15.0 | 10.0 | 46.3 |

Remarks: based on working condition of 10 hours/day and 25 days/month.

Table 16. Working hours analysis in foundry A (1965)

| | melting | sand treatment | core making | moulding | finishing | total |
|---|---|---|---|---|---|---|
| Min/Ton | 355 | 138 | 1,161 | 1,445 | 1,869 | 4,968 |

Table 17. Productivity in foundry C by type of process and size.

| | Self-hardening large | Self-hardening medium | Green skin dry | green by hand | Green by machine | |
|---|---|---|---|---|---|---|
| Man Hr/Ton | 24 | 36 | 49 | 73 | 83 | |
| Mean unit weight | 482 | 72 | 58 | 5 | 0.8 | |

## § 5 Cost Construction

Table 18. Construction of Castings cost

(Foundry A)

| | % |
|---|---|
| Main materials | 23.6 |
| Sub-materials | 19.6 |
| Personnel expense | 14.2 |
| Factory expense | 9.8 |
| Subsidiary cost | 13.6 |
| Selling cost | 4.2 |
| | |
| Non-operating profit & loss | 7.9 |
| | |
| Net profit | 7.1 |
| | |
| Total | 100.0 |

Table 19. (Foundry C)

(by ton)

| | | |
|---|---|---|
| Main materials | 27,798 | 25.1 |
| Sub-materials | 17,802 | 16.1 |
| Personnel expense | 21,195 | 19.2 |
| Factory expense | 12,855 | 11.6 |
| | | |
| Business expense | 15,453 | 13.9 |
| | | |
| Non-operating Expense | 8,869 | 8.0 |
| | | |
| Profit | 6,754 | 6.1 |
| | | |
| Sales price | 110,726 | 100.0 |

It is not possible to exactly compare the two companies by cost construction because of different classification as shown above, however, selling price of casting in A shall be about ¥ 88,000/ton. The materials and labor costs in A are apparently lower then C, as the productivity in A is largely high and steel scrap from forging shop is largely used for charging material.

Table 20. Manafacturing cost by types of works and expense
for ton of casting

| Expense | Total | Melting | Sand reatment | Core making | Moulding | finishing | Common tem |
|---|---|---|---|---|---|---|---|
| Metal | 26,825 | 26,825 | | | | | |
| Direct labor | 14,930 | 1,457 | 370 | 2,215 | 5,573 | 5,315 | |
| Indirect materials | 20,499 | 9,970 | 3,380 | 2,574 | 1,018 | 2,431 | 1,126 |
| Indirect labor cost | 3,782 | | | | | | 3,782 |
| Depreciation | 6,750 | 959 | 2,115 | 558 | 2,316 | | 802 |
| Indirect cost | 11,885 | | | | | | 11,885 |
| Subcontracting expense | 3,481 | | | | | | 3,481 |
| Total | 88,152 | 39.211 | 5,865 | 5,347 | 8,907 | 7,746 | 21,076 |
| Common Expense distributed | | 7.3 | 2.5 | 22.1 | 33.1 | 35.0 | |
| Common Expense distributed | | 1,539 | 527 | 4,658 | 6,976 | 7,376 | |
| Total | 88,152 | 40,750 | 6,392 | 10,005 | 15.883 | 15,122 | |

Table 20 is a cost analysis by types of works in X–company and it indicates that indirect expense occupies rather high.

The cost of castings shall largely be influenced by depreciation expense and productivity and yield ratio as well. Table 21 is presented by foundry A, in which is based on 6 months calculation of charging materials, melting loss, tapping weight sub–melting, materials and wage. The molten metal cost per ton in case of the yield ratio as 100% (melting loss is already calculated) was ¥30,584 by which is used in the following equation and thus the table 21 shows the molten metal cost in the different yield.

$$\begin{array}{l}\text{Cost of molten metal}\\ \text{per ton of product}\end{array} = \frac{30{,}584}{\text{yield ratio}} - (1-\text{yield ratio}) \times \text{Cost of return/ton}$$

Table 21 *Molten metal cost by yield Ratio*

| Yield ratio | Molten metal cost/product Ton | When 65% yield is taken as 100 |
|---|---|---|
| 40 | 65,060 | 161 |
| 45 | 57,514 | 142 |
| 50 | 51,668 | 128 |
| 55 | 47,057 | 116 |
| 60 | 43,373 | 107 |
| 65 | 40,402 | 100 |
| 70 | 37,991 | 94 |
| 75 | 36,029 | 89 |
| 80 | 34,430 | 85 |
| 85 | 33,131 | 82 |
| 90 | 32,082 | 79 |