3.2.2 Plate Shop

1) Innovative techniques to be adopted for modernization

The basic objectives held in view in drawing up the Modernization Plan are as presented below.

A. Enhancement of productivity, i.e. welding efficiency
   To enhance welding speed: Increase welding current; raise deposition efficiency.
   To improve arc generating rate: To ensure uninterrupted arc; diminish waiting time; let one welder operate multiple welding machines.
   To decrease groove cross section.

B. Enhancement of weldment quality

C. Dispensing with reliance on personal skill

D. Improvement of working environment.

In order to attain the objectives enumerated above, the measures to be adopted are, in the sequence of adoption: Manual—semi-automatic—automatic—robotized welding.

The current status at the Plate Shop is welding largely by manual, with semi-automatic welding applied in part. Before attempting to realize at El Teniente the ideal state of robotized welding, it should be noted that the prerequisite conditions requiring to be satisfied for such a measure are, with present-day technology are:

- Workpieces of identical or similar shape welded in quantity
- Welding conditions applicable to robot matching those required by the products.

Actually, at the Plate Shop, no products of similar form are manufactured in large batches, with the exception of support arches for mine galleries. Even with these arches, moreover, the amount of welding requiring to be done is relatively small compared with the size of workpiece. These circumstances do not justify outlay of large capital investment in expensive equipment.

Overlay repair welding is another category of work involving repetitive work, and thus conducive to automation. But for this also, the current jobs call for multilayer welding, and requiring in part to be welded in all positions, which is not susceptible to automation in the current state of the art.

In consideration of the foregoing circumstances, the practical measure advisable for implementation in the Modernization Plan is to start by abolishing much of the manual welding (with the exception of certain jobs, on account of particular site requirements or workpiece material), and to introduce semi-automatic welding in large part, together with automatic welding where possible. It should be noted, however, that automatic and robotized welding are subject to rapid development, so that an increasing portion of the work at the Plate Shop should become susceptible to automation and robotization in the future.

What requires attention is to foresee in so far as possible the advances to be expected of welding automation in the coming years, to avoid wasteful investment in half-way measures that risk being rapidly outdated with technological progress.

2) Current status of semi-automatic welding in Plate Shop

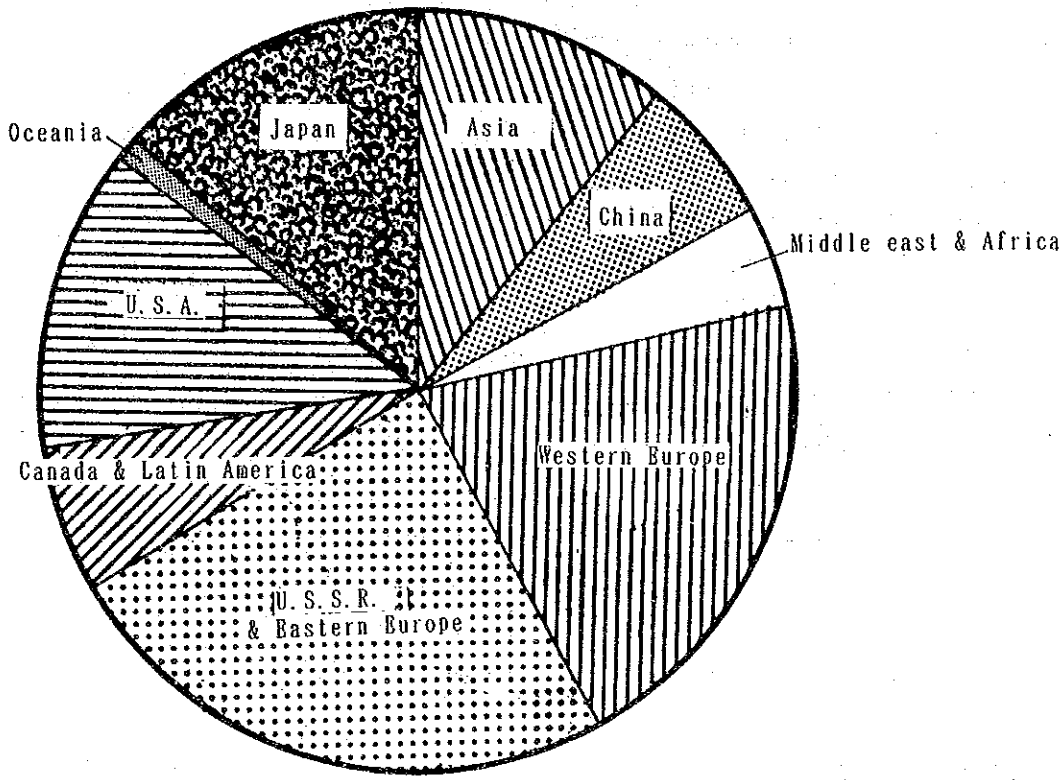
The rate of welding material disposed by welders in the Plate Shop is 0.45 kg/manhour in manual, and 1.75 kg/h in semi-automatic welding. If this rate is taken straightforwardly to represent productivity, it can be said that it is roughly 4 times higher with semi-automatic than with manual welding, and this attests to the necessity of switching from manual to semi-automatic or automatic welding.

Currently, apart from the adoption of MIG welding for thin sheets, (though only to the extent of consuming 300 kg of welding material for this operation), the sole example of welding automation seen at the Plate Shop is open-arc CO_2 automatic and semi-automatic welding in flat position applied to overlay work mainly on ladles and brake drums. This form of welding, while permitting outdoor work under some wind, has the shortcoming of:—

- Difficulty of welding in positions other than flat
- Poor rate of deposition compared with other CO_2 methods of welding
- Rough bead surface, covered with spattering.

(1) Status of semi-automatic welding in other countries

Apart from the socialist countries, the three top region in the world in terms of welding material consumption are Europe, U.S.A. and Japan, as indicated in Fig. 3.2.2-1. In these three regions, consumption was predominant for manual welding 10 years ago, whereas today, semi-automatic welding is consuming more material in Europe, while in U.S. and Japan, it is roughly halved between the two methods of welding.



1983 (1,000tons)

▧	Asia	10.7%	258
▨	China	6.2%	150
□	Middle East & Africa	4.2%	100
▥	Westean Europe	20.1%	484
▦	U.S.S.R. & Eastern Europe	24.9%	600
▨	Canada & Latin America	6.2%	150
▤	U.S.A.	12.6%	303
▩	Oceania	1.2%	30
▩	Japan	13.7%	330
	Sum.	100.0%	2,405

Fig. 3.2.2-1 Demands of weld materials of the world (1983)
(Japan Welding Industries Association)

ANNUAL PRODUCTION OF WELDING CONSUMABLES
RATIO OF SMAW & GMAW IN JAPAN, USA & EUROPE

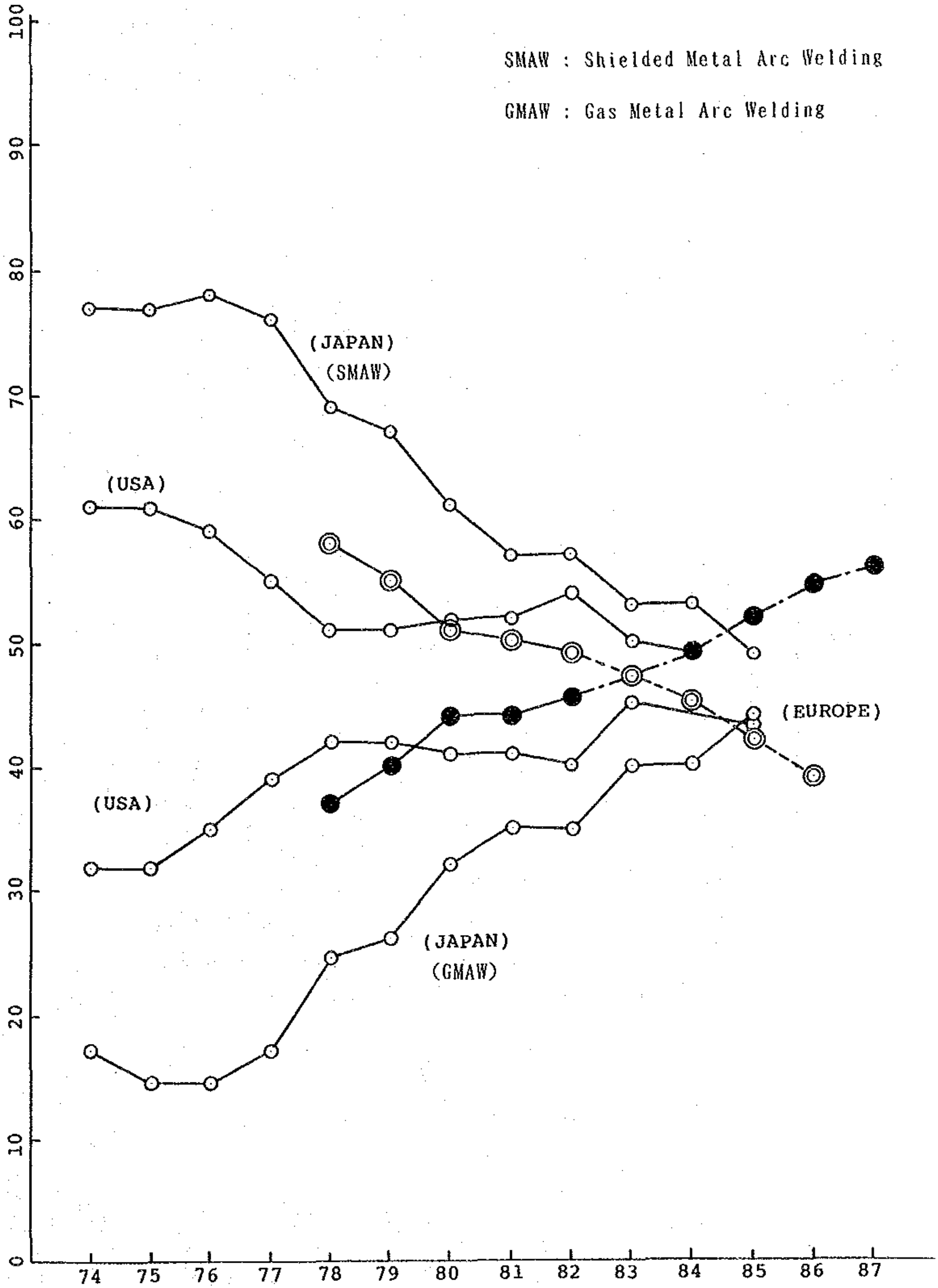


Fig. 3.2.2-2 Production trend of SMAW & GMAW
(Japan Welding Industries Association)

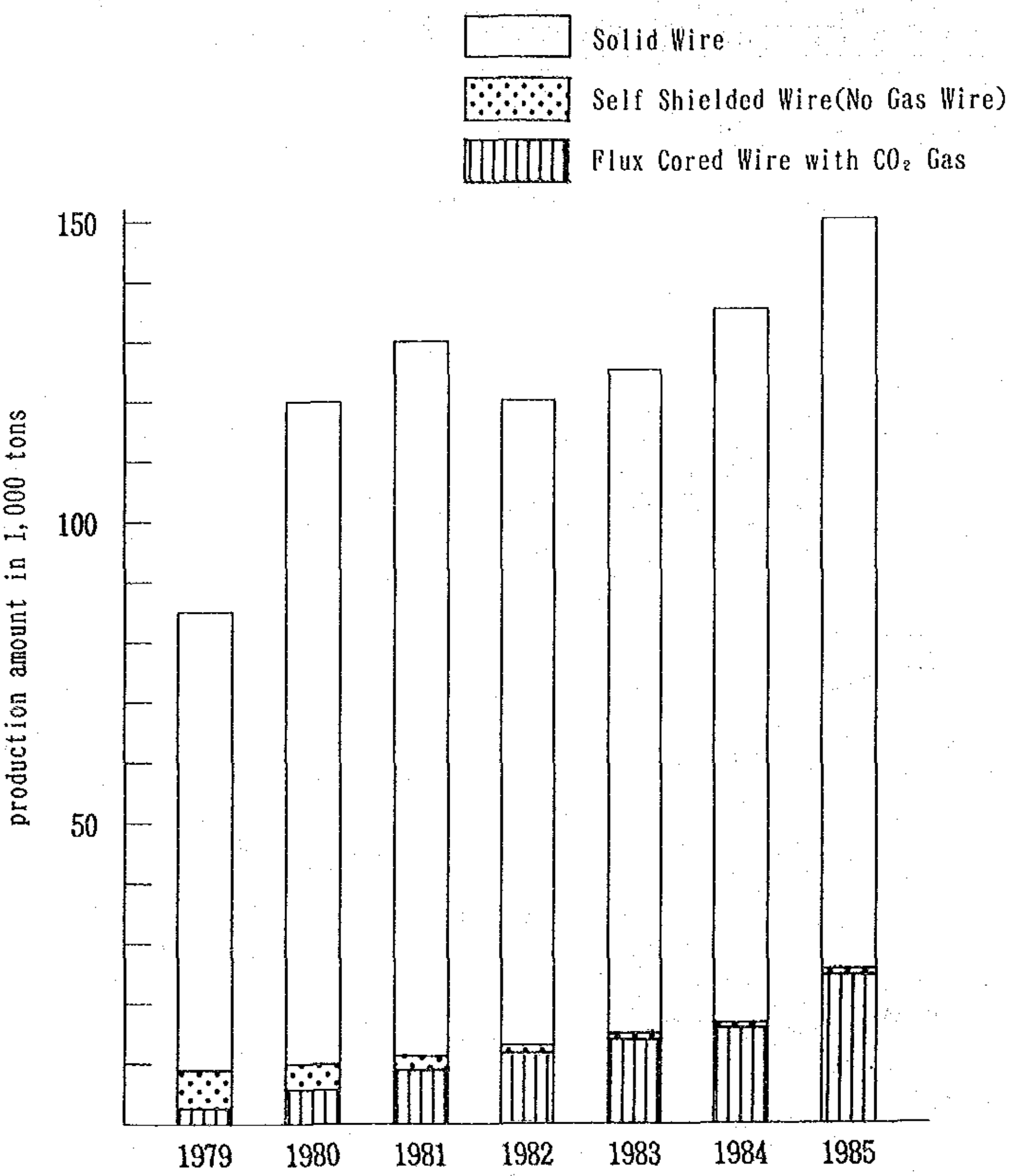


Fig. 3.2.2-3 Semi-automatic welding wire production in Japan
(Japan Welding Industries Association)

Progress in recent years, together with estimates for some years to come, of welding material production intended for manual and semi-automatic welding is presented in Fig. 3.2.2-2, for the three regions cited above. The data for semi-automatic welding in Japan are further itemized Fig. 3.2.2-3 into material for welding with:—

- Solid-wire CO_2 or mixed-gas
- Flux-cored open arc
- Flux-cored CO_2

In Fig. 3.2.2-4, the corresponding data are given covering the Japanese shipbuilding industry, which can be considered as engaged in welding work of nature somewhat similar to the Plate Shop. It is seen that flux-cored CO_2 welding is rapidly taking over the solid wire method, occupying today 3/4 of the total consumption of electrode wire.

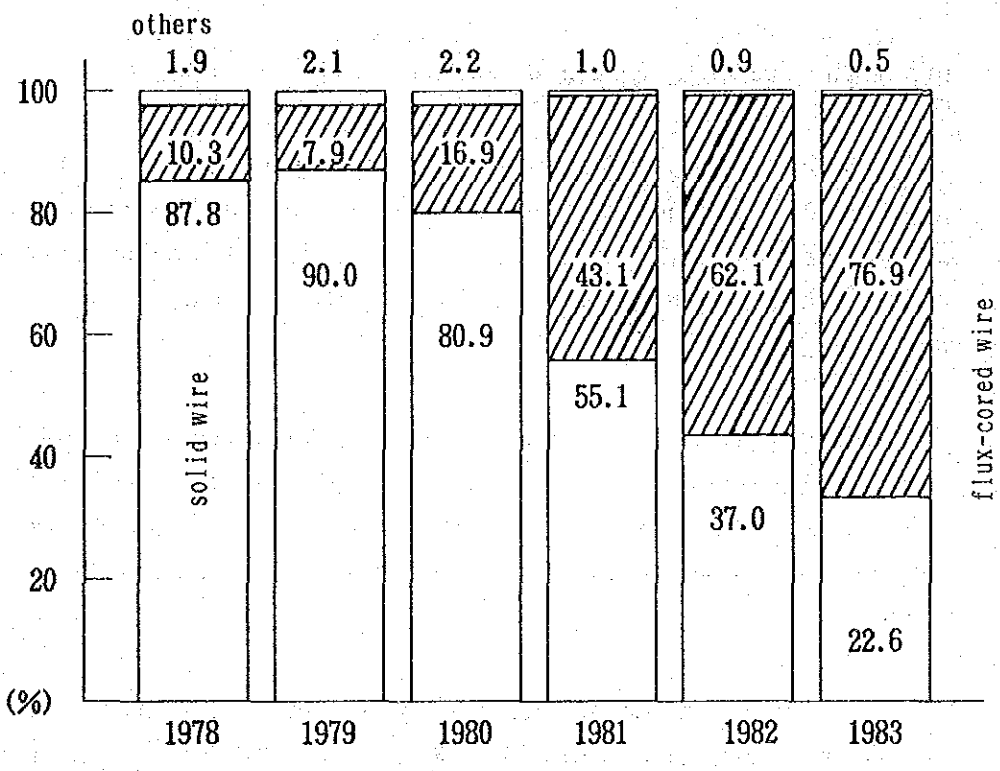


Fig. 3.2.2-4 Trend of flux-cored wire in gas-shielded arc weld in shipbuilding industries

(2) Features of flux-cored CO_2 welding

A description is given in what follows of the features offered by typical flux-cored CO_2 welding wire manufactured in Japan, including records of practical application and experimental results. The electrode wires taken up in this instance are JIS YFW24 (corresponding to AWS E71T-1), compared with JIS D5016 (AWS E7018).

a) Welding at all positions

With solid type CO_2 wire wleding in positions other than flat produced rough welds far from satisfactory. This shortcoming has been eliminated with the development of flux-cored wire, which permits welding in all positions without requiring alteration of welding conditions, and producing an excellent bead of smooth surface.

b) High welding efficiency at all positions

Ease of welding operation is excellent not only for flat but also for other positions. With vertical upward and overhead positions, no drooping of molten metal is caused even with input current as high as 250 A, to produce a fine bead with no difficulty. Welding even in vertical downward position is practicable with this machine.

Welding efficiency is compared in Table 3.2.2-1 between flux and solid CO_2 wire as well as coated electrode arc welding, for plates thicker than 12 mm. It is seen that welding efficiency is particularly high in vertical upward and overhead positions with flux-cored wire, as compared with solid and coated electrode methods.

Moreover, in the case of thick plate, upon selecting a suitable welding condition (e.g. 1.2 mm diameter wire with 230–250 A welding current), passing from butt to fillet welding can be executed without altering the welding conditions, despite changes in welding condition. This faculty, together with the high arc generating ratio, ensures marked improvement of welding efficiency.

c) *High depositing rate*

The rate of deposition is somewhat lower than in the case of solid wire, on account of the electrode containing slag-generating agent—depositing rate 95% with solid, 89% with flux-cored wire, 65% with coated electrode. Yet the speed of deposition is highest, with the high current density realized with this method (see Fig. 3.2.2-5).

Table 3.2.2-1 Efficiency comparison in welding materials

position	type of material	deposited metal in usual conditiun 20 40 60 (g/min) 100	range of amperage(A)
downhand	flux-cored	280	120~300
	solid wire	28	100~350
	manual 6 mm dia.	310	250~330
vertical	flux-cored	220	120~260
	solid wire	150	100~200
	manual 6 mm dia.	190	130~220
vertical -down	flux-cored	280	200~300
	solid wire	—	
	manual 6 mm dia.	320	260~330
horizontal	flux-cored	280	120~300
	solid wire	280	100~300
	manual 6 mm dia.	230	170~250
overhead	flux-cored	250	120~260
	solid wire	150	100~300
	manual 6 mm dia.	180	130~200
horizontal fillet	flux-cored	280	120~300
	solid wire	280	100~300
	manual 6 mm dia.	280	240~290

Remarks:

1) Numerals inside indicate Amperage.

2) dia. 1.2mm, tip wire length 25mm

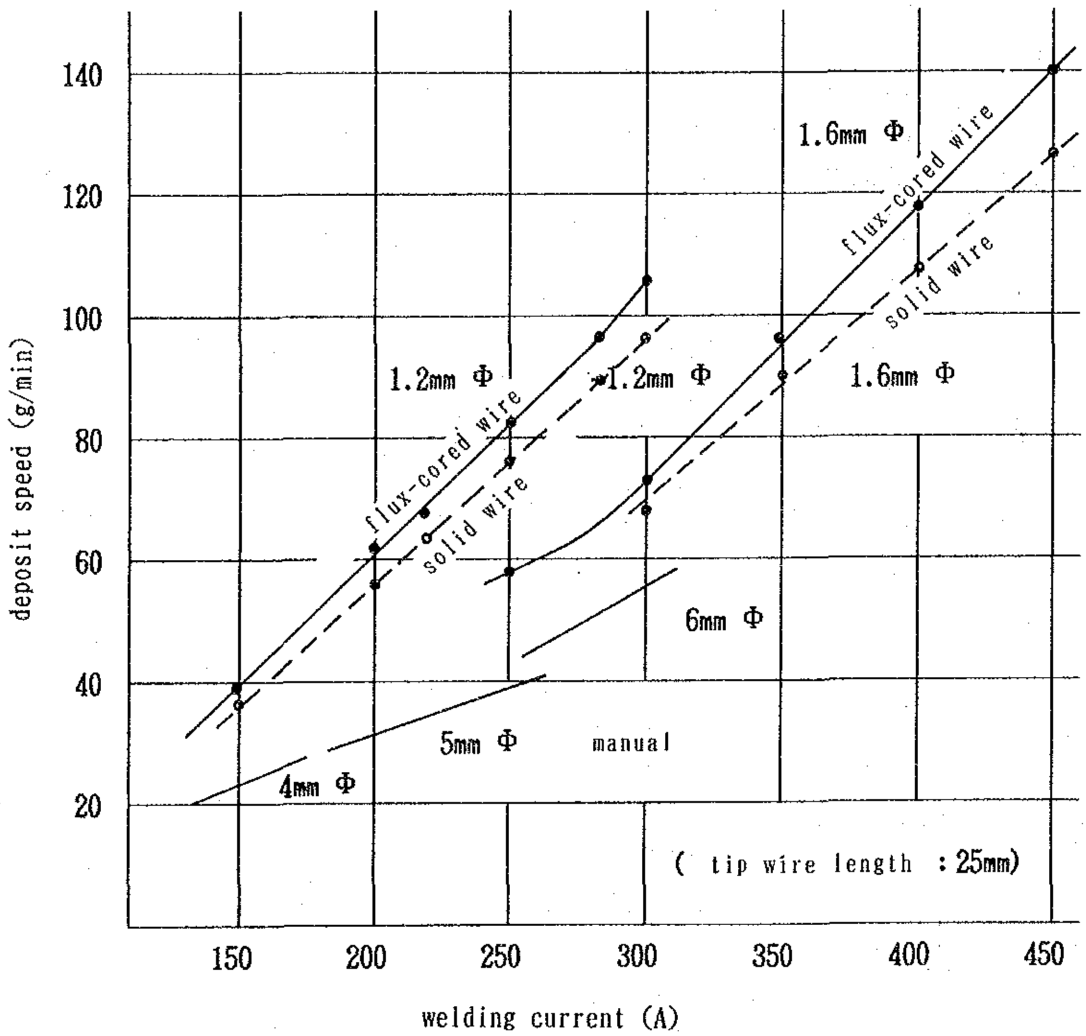


Fig. 3.2.2-5 An example of deposit speed

d) Extremely small spattering compared with solid wire; good slag separation

Upon welding, the bead is smoothly covered by a slag layer of good separating property, which creates a thin oxide film on bead surface. This slag film is easily removed by brushing, in readiness for post-treatment—plating, painting. In contrast, with solid wire, the bead surface is covered by thin patches of slag difficult to remove, while the areas devoid of slag covering carry a thick oxide film calling for grinding to remove. This demands heavy work in surface preparation, when painting, plating or other treatment is required.

The aspect of spatter generation is indicated in Fig. 3.2.2-6.

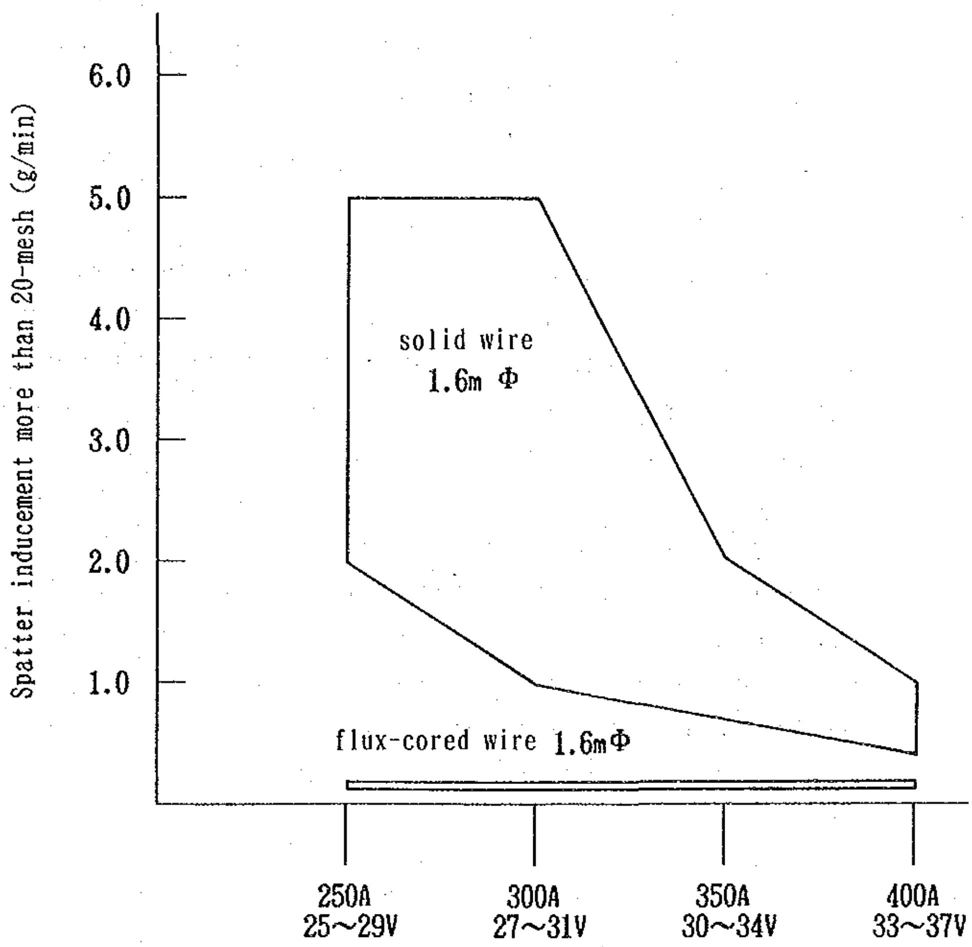


Fig. 3.2.2-6 An example of spatter inducement

e) Performance of wire for flux-cored CO_2 welding

(a) Ease of wire feed

The shortcoming of flux-cored wire in the past was that it slipped easily between the feed rollers, while upon extended use, the conduit liner became clogged, to cause unsteady feed. This was attributed to excessive lubricating agent remaining on wire surface.

A newly developed flux-cored wire has eliminated this inconvenience through improvement of lubricating agent, which serves at the same time as rust-preventive, and this has brought marked improvement of feeding ease. A result of test with this wire is presented in Fig. 3.2.2-7. It is revealed that stable feeding speed is obtainable even with a torch that is sharply curved.

A point to be heeded in using this wire is that it has a soft surface which deforms upon applying excessive pressure between the feed rollers, and care is required in adjusting the rollers.

(b) Rust-prevention

Rust generated on wire surface impairs not only the quality of deposited metal, but also smooth wire feeding. The flux-cored core wire does not have plated wire surface, and this was considered to provide insufficient rust prevention. Improvements in wire surface treatment have eliminated this shortcoming, and little rust is generated.

Rust generation was tested on flux-cored wire, by exposing it for several days in a hot chamber during summer under dusty condition. The result is shown in Table 3.2.2-2, which reveals the marked improvement in rust prevention obtained on the wire. Nevertheless, packages of wire should not be opened until immediately before use, an once opened, the wire should not be left exposed for long periods.

Table 3.2.2-2 Exposure test on CO_2 wire

days of disposal	1	2	3	4	5	6	7	8	9	10	11	12	13		20
improved flux-cored wire 1.2 mm dia.										pitting corrosion	corrosions on upper side				
conventional flux-cored wire 1.2 mm dia.							corrosion start			corrosion all over on upper side	corrosion all over				
solid wire 1.2 mm dia.										pitting corrosion					

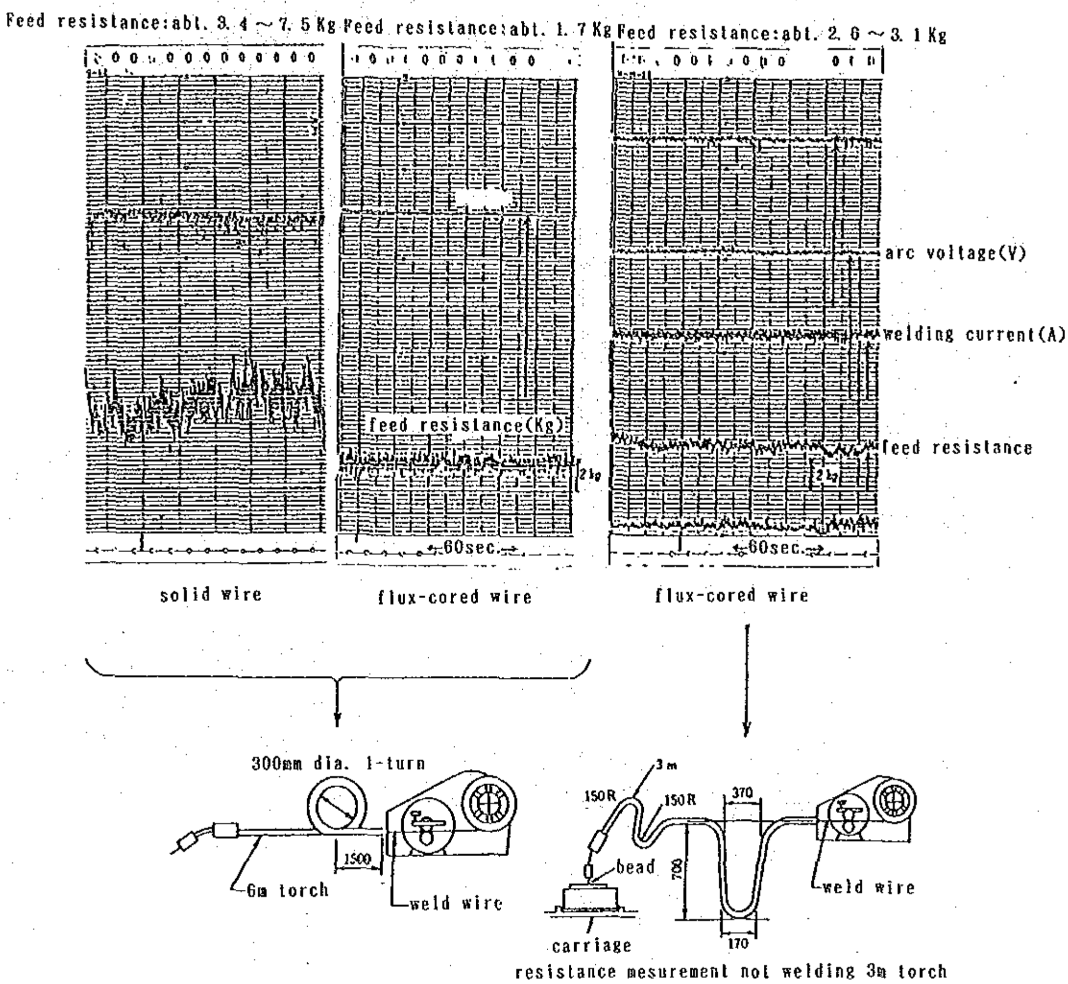


Fig. 3.2.2-7 Test results in severe conditions of feeding resistance

(c) Welding fume generation

Welding fumes were a heavy shortcoming of flux-cored wire in the past, to impair the working environment. Improvements have also been brought in this aspect, and low-fume flux-cored wires have been developed. A comparison of fume generation is presented in Fig. 3.2.2-8 between flux-cored and solid wires. The improved flux-cored wire shows a diminution by 30–40% compared with conventional types, to bring it into line with solid wire.

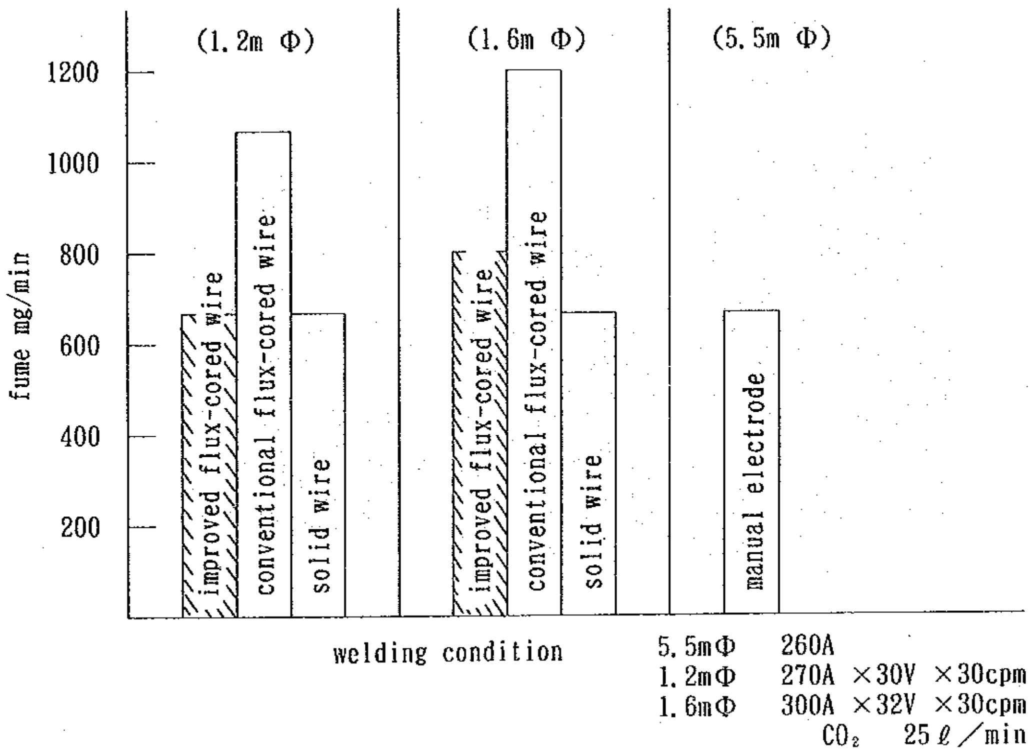


Fig. 3.2.2-8 Fume measurement results

(d) Moisture absorption

Upon exposure of wire to humid hot atmosphere, welding with the wire produced deposited metal containing diffusible hydrogen to the amounts indicated in Fig. 3.2.2-9, revealing very little increase even upon exposure during extended period.

Normally, coated arc electrodes keep absorbing moisture when exposed to atmosphere. the rapid saturation of moisture absorption shown by the improved flux-cored wire is attributable to elimination of moisture-absorbing ingredients such as water glass in the coating.

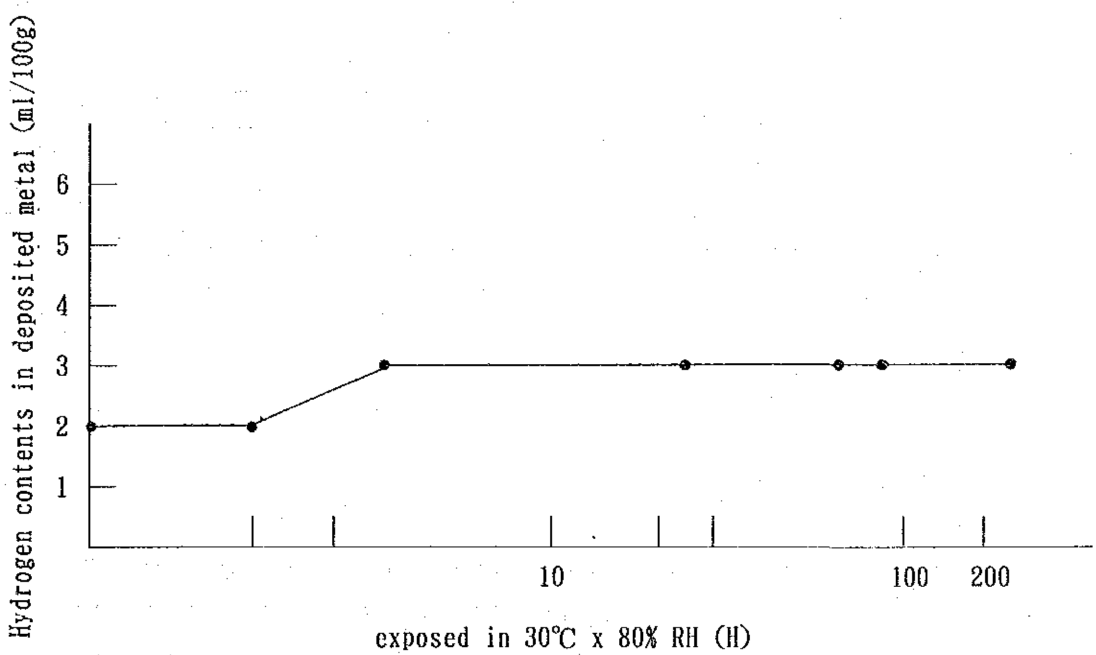


Fig. 3.2.2-9 Relation between exposure hours & hydrogen contents in deposited metal

(e) Radiographic inspection results

Upon inspection of weldment made with improved flux-cored wire, using CO_2 welding, weldment of JIS 1 grade was invariably obtained. The quality of weldment thus ensured can be considered comparable to weldments obtained with low-hydrogen and solid wires.

(f) Chemical composition and mechanical properties of deposited metal

chemical composition

unit:%

	shield gas	wire size	C	Mn	Si	P	S	Ni
AWS E71T-1 JIS D5016	CO_2	1.2mmΦ 1.4 1.6	0.05	1.35	0.45	0.013	0.010	—

mechanical properties

	tensile test			impact test	hydrogen contents
	Y. P	T. S	EL.	Ve 0℃	
AWS E71T-1 JIS D5016	(kg f/mm^2)		(%)	(kg f・m)	(ml/100g)
	52	59	28	11	2～4

3) Overlay welding of hard deposit

Data obtained from the Plate Shop indicate that surfaces of overlaid deposit possess hardnesses of 143–187 H_B (150–200 H_V). For obtaining hardness of this level, electrodes of AWS E71T-1 (AWS E7018 for manual welding) should amply suffice. Even for crusher components demanding higher hardness, flux-cored wire CO_2 welding should be capable of providing ample hardness.

(1) Hardnesses obtainable

The hardnesses obtainlable with flux-cored wire marketed in Japan are 250, 350, 450, 600, 800 H_V (realized as welded).

(2) Features

Depositing speed is as indicated in Fig. 3.2.2-10, which reveals that 3 to 4 times the rate of manual welding is obtainable.

Welding ease is also excellent. For instance, 250–600 H_V wire with titania flux provides high arc stability with extremely little spattering. The resulting slag separates almost naturally, and its removal is easy. Wire for 800 H_V is of metal cored type, but weldability is enhanced by the addition of arc stabilizing agent.

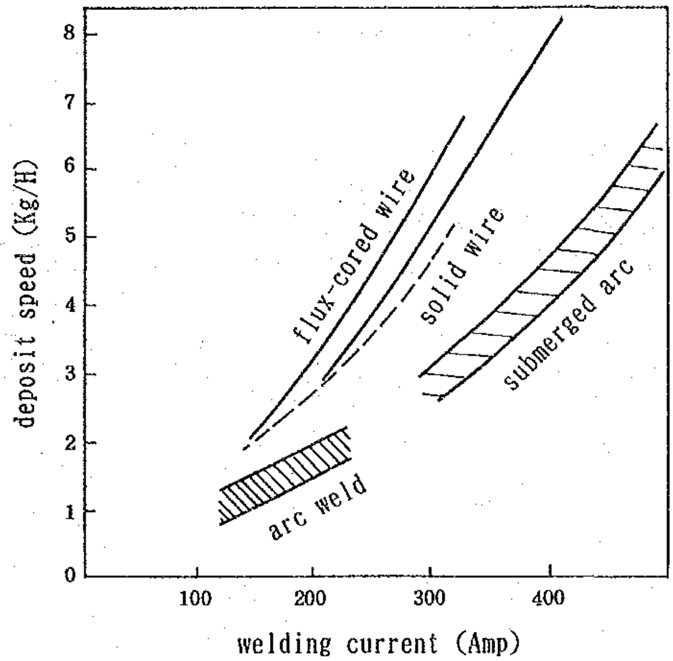


Fig. 3.2.2-10 Comparison of efficiency in hard-facing weld over-lay flux-cored wire

(3) Chemical composition and hardness of deposit

Chemical composition and hardness of deposit is as indicated in Table 3.2.2-3.

Table 3.2.2-3 Example of chemical composition and hardness obtained on deposited metal

Vickers hard.	welding layer	C	Si	Mn	Cr	Mo	V	W	B	hardness mean (Hv 30 Kg)
250	3	0.086	0.68	1.50	0.92	0.40	—	—	—	297
350	3	0.11	0.68	1.87	1.55	0.51	—	—	—	370
450	3	0.10	0.57	1.40	3.40	0.47	0.25	—	—	415
600	3	0.42	0.48	1.20	4.18	0.48	—	—	—	574
800	1	0.84	0.65	1.78	2.95	—	—	1.36	0.41	707
800	2	1.01	0.76	2.00	3.87	—	—	1.88	0.54	817

remarks: Chemical contents, taken from upper most layer.
welding condition:
wire dia. 1.2 mm, welding current 270 A, voltage 30 V, speed 30 cm/min, shield gas CO_2 100%, 25 l/min.
base metal 50 Kg/sq. mm-class HT steel, 19 mm-thick.
inter pass preheat 250~600 → 150~200 °C
800 → 200~250 °C

(4) Welding conditions

The correct input current and voltage range is indicated in Fig. 3.2.2-11. The arc voltage varies with type of power supply and length of connecting wire, and in practice, the voltage should be adjusted to obtain an arc length of 2–3 mm. This wire ensures ample welding condition over a wide range of input current, to permit accommodation to suit the workpiece size, dilution, efficiency and other factors.

(5) Other matters

a) Fume abatement

Hard overlay welding involves carbon and other alloying elements in quantity, which produce fume, and this calls for measures against fume generation, such as effective ventilation and wearing of masks. The amounts of fume generated are compared in Fig. 3.2.2-12 between different electrodes. It is seen that the fumes tend to increase with input current.

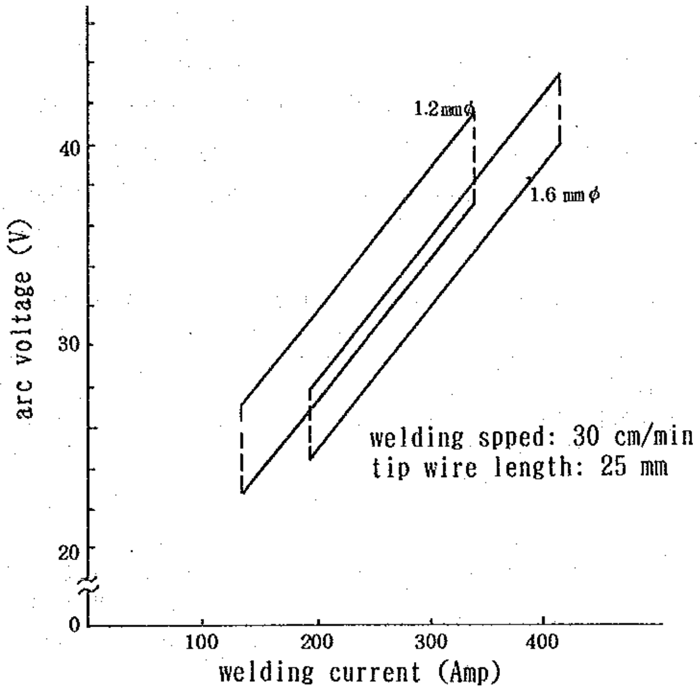


Fig. 3.2.2-11 Welding conditions

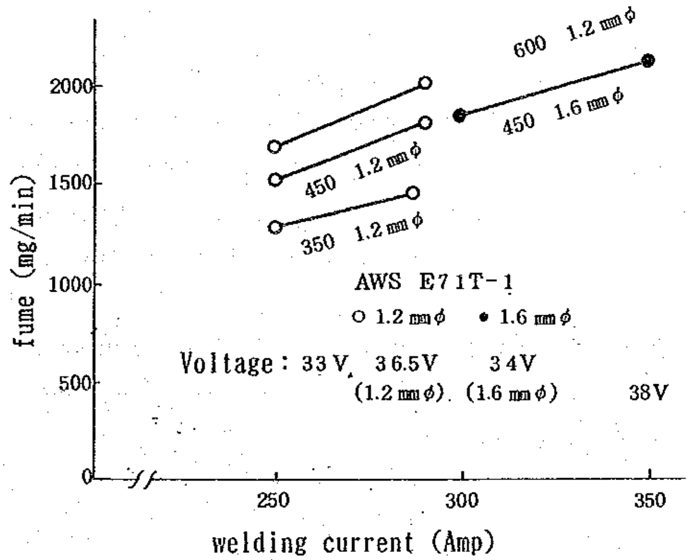


Fig. 3.2.2-12 Fume inducement

b) Cracking of overlay weldment

Hard overlay welding produces a layer that is extremely hard and hence easily cracked. The base metal also is usually of hard material susceptible to cracking. Prevention of cracking calls for proper preheating and postheating. The conditions of heating treatment are indicated in Table 3.2.2-4.

Table 3.2.2-4 Standard conditions for preheating and postheating

Hv Hardness	Inter-pass preheat temp.	postheat	others
250	R.T~150 ℃	350 ℃×30min	600 ℃ stress-relief for reduction of HAZ hardness
350	150~250 ℃		
450	150~350 ℃		
600	150~350 ℃		
800	200℃		

4) Economics of flux-cored wire CO_2 welding

Data on welding efficiency and cost are presented in Table 3.2.2-5 where comparison is made between flux-cored, solid wire and coated electrode arc welding. It is revealed that the time required for welding is shortened by roughly 3.5 times with flux-cored wire as compared with coated electrode, for vertical upward and overhead positions. Comparison of cost also places flux-cored wire above coated electrode by a ratio of 1.3.

Moreover, flux-cored wire welding permits dealing with all positions at the same input current, and the added merit of easily separated slag, bead smoothness and small spattering further enhance the advantages of this method.

Table 3.2.2-5 Cost comparison of various welding methods

weld method		flux-cored CO2 weld	solid wire CO2 weld	manual arc weld
edge preparation		butt joint (12 mm-thick. 50° V-edge)		
position		vertical		
wire dia.		1.2mmΦ	1.2mmΦ	4 mmΦ 4.5mmΦ
passes		3	3	4
current (A)-voltage(V)		220~40	150~20	170~24
welding time (min/m)		19.5	42.3	55.0
shield gas (l/min)		25	25	——
deposit speed(g/min)		70	35	27
deposit efficiency(%)		87	94	60
arc time (%)		50	50	40
material consumption (kg/m)		1.57	1.57	2.17
weld MH (min/m)		39.0	84.6	138.0
unit price (yen/Kg)		500	273	128
weld cost (yen /m)	wire cost	785	429	278
	gas cost	49	106	——
	electr. cost	8	10	18
	labour cost	357	775	1,260
sum.		1,199	1,320	1,561

CO_2 gas price 0.1 yen/l
electircity 4.8 yen/KWH
labour cost 550 yen/H

5) Introduction of flux-cored wire CO_2 welding at the Plate Shop

It is indicated from the foregoing description that flux-cored wire CO_2 welding should be widely introduced at the Plate Shop.

(1) Overlay repair welding

Crusher main frames and ladles should be difficult to automate overlay welding, on account of their configuration, so that semi-automatic welding with flux-cored wire is advisable. This form of welding should thus be introduced to replace the bulk of overlay repair welding undertaken in the Plate Shop, with the exception of certain articles of particular material or shape, such as head, bowl and adjustment ring. Nevertheless, these last-cited three articles could still be subject to a certain degree of welding automation, through the introduction of positioner and manipulator (see Photo. 3.2.2-1).

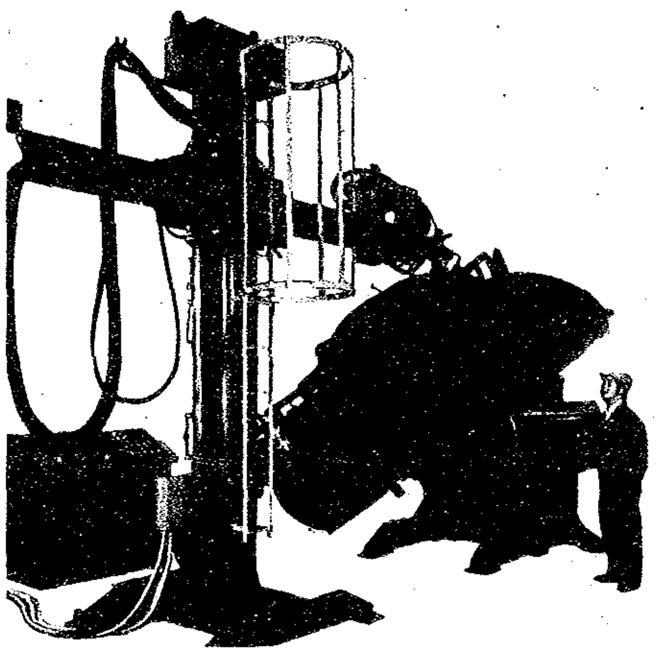


Photo. 3.2.2-1 Example of positioner and manipulator in operation

The modernization plan will be drafted on the basis of the following assumptions:—

- Shop capacity to be based on forecast for 1989
- Consumption of welding material to be based on average unit value of past years
- Annual working days assumed to be 266
- Operation in shift 24 hours a day
- Time required for mounting workpiece on a positioner, dismounting and turning over to take 1 day in total
- Welding operations on positioner to be performed using 1 welding machine
- Rate of deposition to be 2.0 kg/h of wire (2.5–3 kg/h attained in Japan with semi-automatic welding).

The number of positioners considered requisite is, derived from the number of working days required for handling the products, as follows.

A. Head (12 t)

From its shape, the head is the article most susceptible to automatic welding.

425 kg/2.0 kg/h = 213 h
213 h/24 h + 1 day = 9.9 days
9.9 days×13 = 129 days

B. Bowl (6 t)

315 kg/2.0 kg/h = 158 h
158 h/24 h + 1 day = 7.6 days
7.6 days×5 = 38 days

C. Adjustment ring (5 t)

425 kg/2.0 kg/h = 213 h
213 h/24 h + 1 day = 9.9 days
9.9 days×10 = 99 days

Summing us the above values, the total number of days required for welding the envisaged quantity of articles is

$$129 + 38 + 99 = 266 \text{ days.}$$

Assuming 266 days worked a year, the positioner is utilized 100%.

The foregoing calculation would call for the installation of 1 set of automatic welding facility (positioner, manipulator), which would be utilized full time, but in future, another set might be introduced as necessary upon observing actual utilization and productivity.

(2) *Weld structures*

It is advised to apply flux-cored wire CO_2 semi-automatic welding, to all products with the exception of certain structures calling for welding in narrow spaces where aphyxiation with carbon dioxide gas is risked, and of welding jobs presenting difficulty of access to the welding torch, as well as of particular materials like T-1 steel.

Plate splicing with flat position, on the other hand, should be performed with submerged arc welding. This form of welding has already been tried at the Plate Shop, but discontinued upon the equipment becoming old, and for reason of large fluctuations in power supply voltage.

In respect of supporting arches for mine gallery, their production in large quantity would appear to lend themselves to automatic welding, but the amount of welding work involved in comparison to their bulk is not considered to justify fully automatic welding. These products also should be treated by semi-automatic welding.

(3) Flux-cored wire CO_2 welding machines

Fluxed core CO_2 welding machines have in recent years vastly improved their performance, with the incorporation of integrated circuit, transistor or thyristor control. The following description covers a typical model widely used in Japan.

Such machines could be imported from Japan and used without inconvenience, with maintenance provided at site by reference to instruction manual, spare parts being furnished to cover around 3 years.

When used in conjunction with positioner, welding will be performed automatically with large 1.6 mm diameter wire in uninterrupted sequence, so that a welding machine one size larger (600 A) is advisable.

Example of flux-cored wire CO_2 welding machine

		500A type weld machine	600A type weld machine
input electricity		3 Φ 550V	do
cycle	Hz	50/60	do
nominal input	KVA	31.9(28.1KW)	45
output current	A	60~500	60~600
output voltage	V	16~45	15~50
designed working time	%	60	100
dimensions: length x width x height	mm	455 ×617 ×850	500 ×650 ×1,020
weight	kg	152	225
conduit cable length	m	1.5	1.8
max. current	A	500	600
wire dia.	mmΦ	1.2, 1.4, 1.6	1.2, 1.4, 1.6, 2.0
cable length	m	3	3

The principal particulars of the machine are as given below:—

- Combination with a push-pull feeder permits the torch to be positioned up to a distance of 31 m from wire magazine by carrying the pull feeder weighing only 5 kg. This faculty will vastly facilitate welding at elevated positions, such as an ore cars
- Combination with present remote control permits switching to any new welding condition by simple turn of the torch switch
- Arc strike is facilitated by a special control circuit, which also ensures excellent arc following, to constitute an ideal source for automatic welding
- A power economizing circuit installed on primary side stops the primary power supply automatically upon interruption of welding, to eliminate wastage of power
- A self-holding faculty dispenses with keeping the torch switch pressed while welding, to eliminate fatigue in long welding operations
- In case of inordinate temperature rise, an alarm lamp is lighted, and a single-phase trip circuit stops the operation.

(4) Number of welding machines required

There are currently 5 CO_2 welding machines installed, but the introduction in wide scale of flux-cored wire CO_2 welding will call for the acquisition of the following number of such machines.

Welding material consumption corresponding to the production forecast for 1989.

Overlay welding repairs	600 t×45 kg/t×0.001 = 27 t
Welded structures	2,180 t×17 kg/t×0.001 = 37.1 t
	Total = 64.1 t.

Of the welding work consuming 64.1 t of welding material, 100% of overlay welding repairs and 80% of welded structure production is envisaged to be converted to flux-cored wire CO_2 welding (cf. 80–85% automation in the case of Japanese plate shops producing similar articles).

27 t×100 % = 27 t.
37.1 t×80 % = 29.7 t
Total = 56.7 t (by flux-cored wire)
37.1×20 % = 7.4 t (by coated electrode arc welding)

Welding manhours required

27.0 t/2.0 kg/h = 13,500 h (overlay welding repairs)
29.7 t/0.8 kg/h = 37,100 h (other welded structures)
7.4 t/0.5 kg/h = 14,800 h
Total = 65,400 h

The working efficiency of semi-automatic welding machines has been estimated,in consideration of the thick 1.6 mm diameter wire used for overlay welding repair, to be 2.0 kg/h, and other welded structures to be 0.8 kg/h, in reference to corresponding performance in Japan. Manual welding efficiency, of 0.45 kg/h actually recorded in 1985, was envisaged to be improved by roughly 10 %. The number of welding machines required is derived as follows.

65,400 manhours/1,992 manhours/year = 33 men.

There still remains 20% of manual welding to be performed, but since at times all 33 men will be engaged in semi-automatic welding, the number of welding machines to be acquired should suffice to let all the welders engage simultaneously in semi-automatic welding:

$33/2 = 17$ (with 2 shift operation)
$17 + 6 = 23$ (6 units representing 30 % spare).

There currently exist 5 units installed, leaving 18 to be newly acquired. Of these 18, 2 (1 spare) should be a large unit of 600 A.

The foregoing number of units represents coverage only of work by welder's proper. Actually, welding work done by fitters also should be performed by similar machines, so that if financially permissible, another 10 machines should very usefully be acquired for this purpose.

(5) Supply for cabon dioxide

For supply small amounts of carbon dioxide gas, purchase in cylinders would suffice, but with more than 17 welding machines in operation, it should be highly desirable to have a gas distribution network properly installed to permit supply of gas at all requisite positions within the Shop.

(6) Wire roll size

Wire rolls are normally furnished in sizes ranging from 12.5 to 25 kg, large packages of 150 kg also being marketed, and which are extremely efficient for operating automatic welding machines, eliminating frequent wire-changing operation. An example of 150 kg package in use is illustrated in Fig. 3.2.2-13.

(7) Benefit of introducing semi-automatic welding

The benefit estimated to be attained from the introduction of semi-automatic welding, envisaging the full production forecast for 1989, is as follows.

A. Economic benefit

	With semi-automatic welding	Without ditto
Manhours	65,400	113,980 (2,870 t×41 h/t)
Welders (1,992 h/y)	33	58

B. Appreciable enhancement of product quality, on account of smooth bead surface and suppression of spatter

C. Dispensing with welding electrode drying facility, in the absence of low-hydrogen electrodes

D. Less strain on welders on account of the soft arc that is generated

E. Less plyable nature of electrode coated with flux, permitting welding torch manipulation in manner similar to operation with coated electrode

F. No advanced skill required for welding operation, dispensing with highly skilled welders

G. Absence of manual welding electrodes scattered on shop floor, to facilitate cleaning of shop ambience.

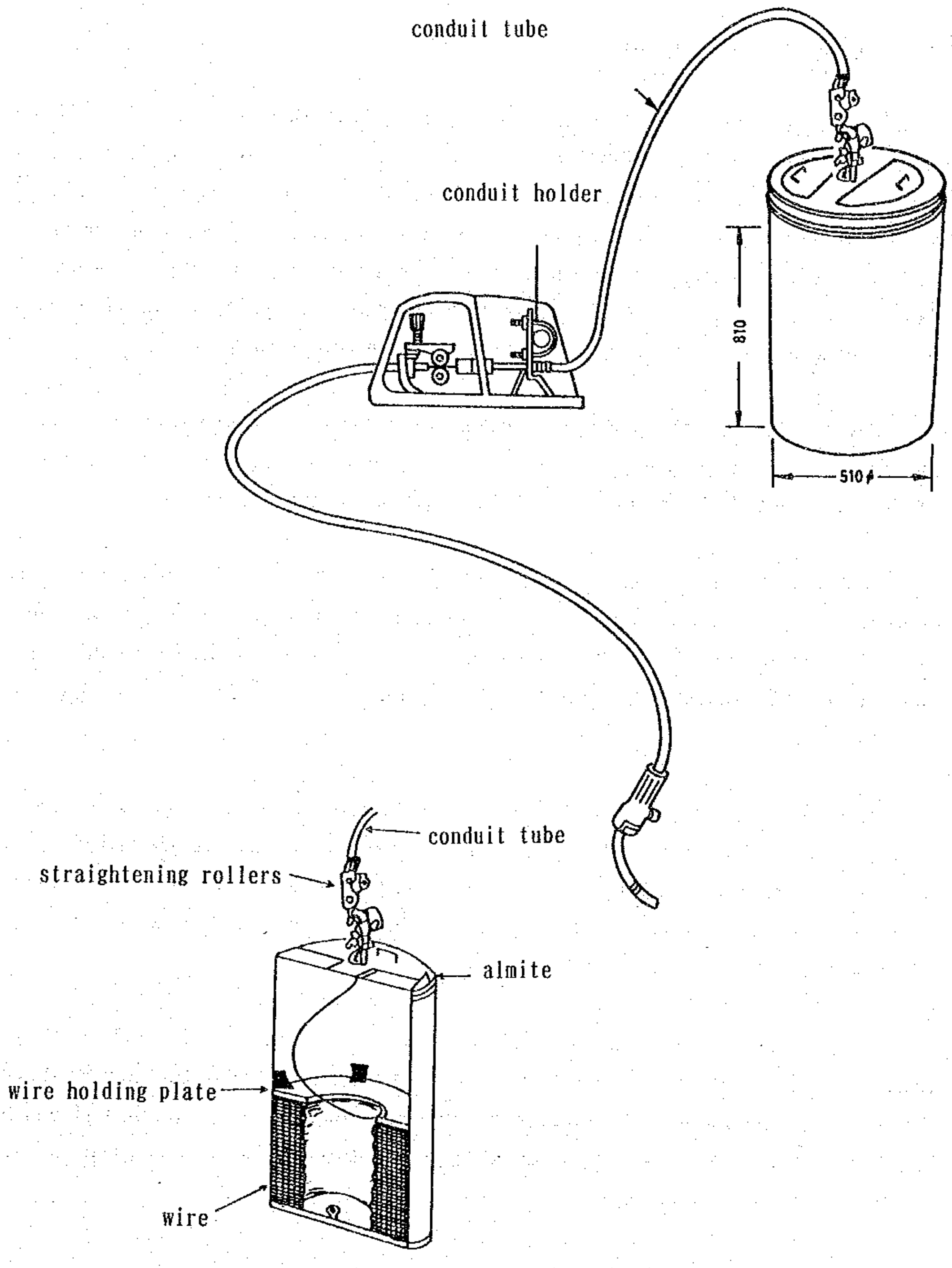


Fig. 3.2.2-13 150 kg wire pack

3.3 Production Facilities

3.3.1 Basic Principles on Facilities Modernizations

Since the processes subject to the modernization plan of this factory are the finishing process in the foundry shop and the welding process in the plate shop, the modernization is limited to part of the processes, in view of the production processes of entire workshops. Even for modernizing part of these processes, however, it must be led to the improvement of productivity and safety as a whole of the factory, considering the interfaces with the related prior and post processes and the interferences with other processes, in the production activities of the entire factory, but not to be executed independently.

Viewing from such standpoints, the current shop layouts can by no way be said smooth in the work flow, because of the poor interfaces, frequent and distanced product transportation. This is especially noticeable in the finishing process in the foundry shop.

Even if part of the processes is modernized under such a situation as the foregoing conditions remain, it can possibly result not only in a less effect, but also rather in a huge amount of cost and time requirements for transferring and modifying the fixed equipment, when the entire factory is to be modernized in the future, thus disturbing the progress of modernization.

This modernization plan needs, therefore, to be established along the future modernization plans (shop scale and arrangement), standing on a macroscopic viewpoint to include the future prospect. While however, looking at the CODELCO's production plans results in finding the production increase plan of about 1.5 fold over a 3-year period up to 1989, but afterward leveled.

Based on the current situation of El Teniente mines, however, it is predicted to increase the mining quantity in order to supplement ore contents reduction and to wear-down increase of equipment due to the mining strata moving to the primary strata, through which the production of these workshops, a service department to the mines, can be expected to be increased continuously even in the future.

Based on the foregoing, the modernization image of future entire shops can hardly be established at this moment, so that it must be left in the hands of future issues, together with the long-term production plan. Since the trend of production increase even in the future can be assumed it is quite obvious that the current issues of shop layout, etc. will become further noticeable. Although the execution of shop relocation is set aside to a future issue, the study still needs to be made on the improvement measures to the problems in the current situation of shop layout.

While, observing the modernization of subject processes rsults in finding that it is desired to introduce the hardware systems of excellent productivity via new technologies, to review the layouts for improving the production process flows, and to improve the environment from the safety and hygiene aspects. Under the actual situation of multi-product-small log production in this factory and under such conditions as production to reach the full power in the coming 3-year period and afterward on the level, the modernization plan cannot help being limited to a certain extent from the profit aspect.

While, however, considering that the trend of continuous production increase even in the future can be predicted as previously mentioned, that it is strongly desired to get rid of the current situation of unfavourable safety performance due to many manual jobs in this factory, and that CODELCO stands on a position to draw up the shop technical level as one of the leading companies in the Republic of Chile, it is hoped to positively promote the introduction of latest, high performance equipment, the layout improvement and the environmental preparation, besides the profitability of partial processes as limited this time.

The foregoing discussed the processes subject to this modernization plan and the related boundaries with respect to the facilities to the foregoing peripheries. At this moment when a long-term production plan can hardly be predicted, the modernization plan would become a certain limited plan, but it shall be established within a profitable range to meet the provisional production increase up to 1989.

Further, anything shall be proposed by attaching to this modernization plan as a future desirous shop plan, which is not incorporated into the foregoing modernization plan with respects to the shop layout issue and improvement, introduction of high performance equipment, environmental improvement, etc. as discussed in this section.

3.3.2 Finishing Process in Foundry Shop

1) Immediate Modernization with Consideration to Profitability

(1) Basic principles on planning

The modernization plan in this section was determined to select and introduce new, high performance facilities equipment, layout improvements, etc. only to meet the profitability, among all others as mentioned in para. 3.2.1 "Finishing Process in Foundry Shop" of Section 3.2 "Modernization Programs" above.

Since the general-purpose automatic grinding machine not accepted in this plan is very expensive, although it is already practicalized in such mass production fields as automobile industry, etc., its introduction will not pay to a various, small lot production shop. The current status in Japan also indicates a behind diffusion of it.

It is also desired to urgently execute the shop layout improvements. However, this expects a comprehensive improvement effect to include all other related processes, so that this cannot be included in this profitability evaluation of finishing process only, while it shall be proposed as a theme for "future desirous shop" as mentioned in sub-para. 2) below.

(2) Introdution of equipment, machines, jigs and tools

The existing equipment and machines in the finishing process in this shop are well maintained and even now used effectively. Comparing these equipment and machines with the latest models results in the most of same types of equipment and machines in the basic machining process, even though the latter are made to a certain extent of higher performance, if they are limited to those meeting a various, small lot production of product dimensions and shapes. Even replacing them with the latest ones will, therefore, not result in an epoch-making productivity improvement, thus leading to a return of profit offset with the expensive equipment cost.

For the introduction of new technologies and equipment like in this case, it is important first to thoroughly study on what functional and performance equipment are necessary to machine the subject products, on how the product design and machining processes are better to be improved in order to make the effective use of these equipment, etc., and then to reflect the results upon the plan and execution. Especially in the finishing process, measures on how to induce the fins at an easyly machinable position and to reduce the quantity have a value equal to the introduction of a high performance equipment. Since the various, small lot production processes require a frequent change of settings, because of small lots, the contrivance of jigs to increase the efficiency of such handling, etc. will contribute greatly to the productivity improvement.

Since the production needs to be increased in a short period, however, the foregoing study is written for parallel execution herein. The plan envisages to introduce the following equipment and machines expectable to demonstrate the effects for the time being.

- Constant peripheral-speed, swing grinder
- 3-ton turntable
- 1-ton turntable
- High frequency grinder

The specifications of these equipments and machines are given in Table 3.3.2-1 "New equipment for finishing process" below, whose contents are described as follows.

a) Constant peripheral-speed, swing grinders

The large-type (15 HP) swing grinder currently applied to the middle and large castings grinding work is of type to greatly reduce the grinding ability, as well as to drop the peripheral speed as the whetstones were, because of the fixed rotary type.

Since the supply power frequency was changed to 60 Hz at present, the peripheral speed is also dropped greatly.

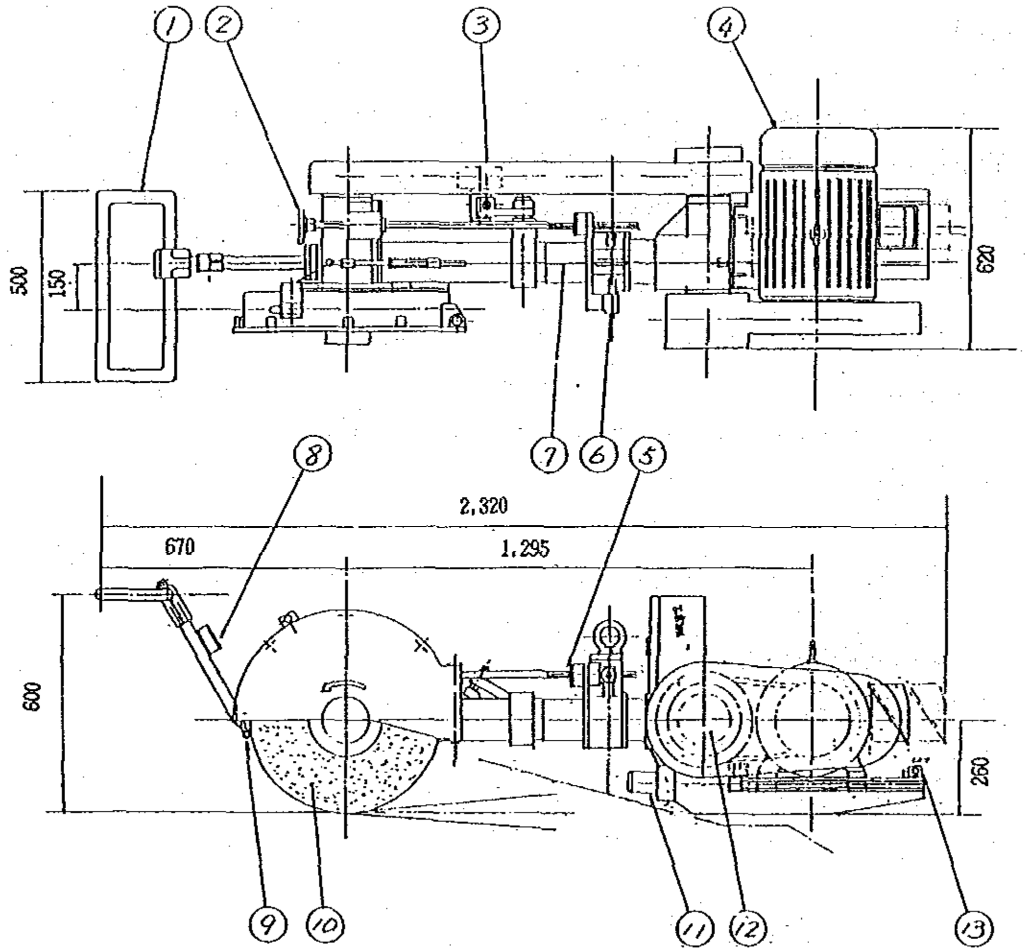


Figure 3.3.2-1 Constant Peripheral-Speed, Swing Grinder

No.	Name	Specification
1	Handle	
2	Front/rear balance handle	
3	Tension pulley	
4	Motor	15 kw, 4P
5	Front/rear balance adjusting	
6	Right/left balance adjusting screw	
7	Peripheral-speed Synchronization wire	
8	Operating switch	Start, stop and revolution adjustment
9	Detection lever	
10	Grindstone	
11	Revolution adjusting motor	
12	No-step variable pulley	
13	Limit switch	Whetstone application limit detection

A constant peripheral-speed, suspended type grinder is to be introduced as a replacement with this grinder. The constant peripheral-speed mechanism is as detailed in para. 3.2.1 above. The adoption of this type, based on the actual performance data in Japan, results in 1.5 to 2.0-fold in the grinding efficiency and a half in the grindstone consumption vs. the fixed rotary type. Figure 3.3.2-1 above gives the appearance view of constant peripheral-speed, suspended type grinder. Table 3.3.2-2 below gives the principal specification of constant peripheral-speed, suspended type grinder.

Table 3.3.2-1 New Equipment for Finishing Process

No.	Name	Q'ty	Specification
1	Constant peripheral-speed, suspended type grinder	4	15 HP; grindstone = 510ϕ x 50t x 50.8ϕ mm; Peripheral speed = 50 m/s
2	3-ton turntable	2	3 tons; Table diameter = 1,000ϕ mm
3	1-ton turntable	2	1 ton; Table diameter = 800ϕ mm
4	High frequency grinder	6	Power supply unit = Inverter Grinder = Pot type, 180ϕ mm, 1.4 KW

Table 3.3.2-2 Specifications of Constant Peripheral-Speed, Suspended Type Grinder

Item	Specification
Horsepower	15 HP
Whetstone size	510ϕ x 50t x 50.8
Peripheral speed	3,000 m/min (constant)
Outside dimensions	620W x 600H x 2,320L
Weight	300 kg

b) Turntables

A fixed steel table of about 600H×800W×1,500L mm is now used for suspended type grinders. This requires a frequent repositioning work by cranes even for ring-form castings. Turntables are to be introduced in place of these fixed work tables, cable of turning at any speed via a motor and stopping at a given rotary angle, so that the horizontal rotary work settings can be omitted, not only limiting to the ring-form castings. Further, setting the jigs meeting the product shape on the turntables allows the angles to be loaded on, and the setting work to be simplified.

Figure 3.3.2-2 below gives the appearance view of turntables. Table 3.3.2-3 below gives the principal specifications of turntables.

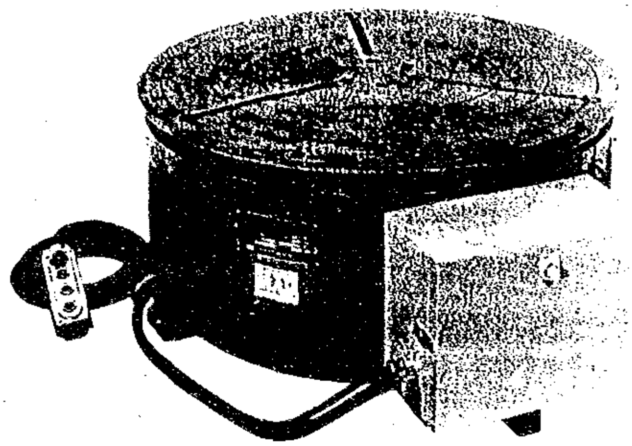


Figure 3.3.2-2 Turntable

Table 3.3.2-3 Principal Specifications of Turntables

	For 3 Tons	For 1 Ton
Loading weight	3,000 kg	1,000 kg
Table diameter	ϕ1,000 mm	ϕ800 mm
Outside dimentions	ϕ1,000 x H466 mm	ϕ800 x H363 mm
Table revolution	0.05 - 0.5 r.p.m.	0.05 - 0.5 r.p.m.
Weight	600 kg	400 kg

c) High frequency grinders

For the portable grinders to be applied to the manual finish in this shop, a pneumatic type is mainly applied. The pneumatic grinders require such large-scale auxiliary equipment as air compressors, piping lines, etc., thus spending a lot of maintenance cost and electric power cost and whose grinding efficiency is also not so good.

High frequency grinders are to be introduced in place of them. The recent high frequency grinder is made of compact, light weight type whose grinding performance is increased to 2 or 3-times that of pneumatic type through the high torque retention, etc. at a duplicate grinding, which is a feature of it. The power consumption is also one-sixth to one-tenth that of pneumatic type. Use of a small, light inverter for high frequency generator facilitates an ease of carrying it arround, thus allowing you to apply it simply at any place. Figure 3.3.2-3 below gives the appearance view of high frequency grinder. Table 3.3.2-4 below gives the principal specification of high frequency grinder. These are angle and hand (bar) types of grinders, besides the pot type, capable of applying in combining with an inverter.

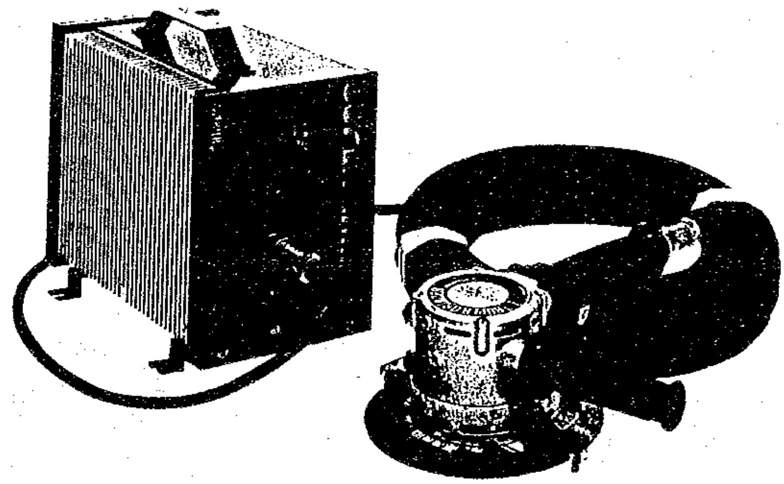


Figure 3.3.2-3 High Frequency Grinder Set
(An Example of Pot Type Grinder with an Inverter)

Table 3.3.2.4 Principal Specifications of High Frequency Grinder Set

Inverter	Power supply capacity Output frequency Control Dimensions Weight	2 KVA 400 Hz Inverter system 200 x 270 x 348 mm 7.5 kg
Grinder (Pot type)	Grindstone size Maximum frequency Maximum output Control Outside dimensions Weight	180ϕ x 6t x 22.23 mm 4,800 m/min. 1.4 KW Soft-start by inverter and electrical brake by inverter 198 W x 110 H x 316 L mm 2.7 kg

(3) Equipment layout

The existing equipment and machines as they are now arranged shall be replaced with new equipment and machines. For new turntables, no foundation is especially placed with concrete, but fixing them to an extent free from runout upon hitting a product will do. Rather, they are better able to be moved easily by a crane, if they are desired so depending upon the product types.

Figure 3.3.2-4 below gives the equipment layout in the finishing shop.

2) Future desirous workshop plan

The foregoing Section planned to introduce some new equipment for finishing process under the conditions to do so of those expectable to have a return of profit to meet the immediate production plan.

Viewing this from the entire finishing shop, this basically remains at a little change, i.e. this is limited to a partial improvement which can hardly be said modernization, viewing from the points of such issues held at the present situation as rationalization of production lines, introduction of new technologies, environmental improvement, etc.

Although no quantitative profitability can be calculated in this Section, this Section shall propose the shop layout, introduction of new technologies, equipment layout and environmental improvement, which are deemed necessary for improvement through the future prospect.

(1) *Entire shop layout plan*

a) Problems on current shop layout

There are following problems as discussed in sub-para. (2) "Transportation and work layout in the finishing process" of para. 3.2.1 "Foundry shop," Section 3 "Modernization Programs" above.

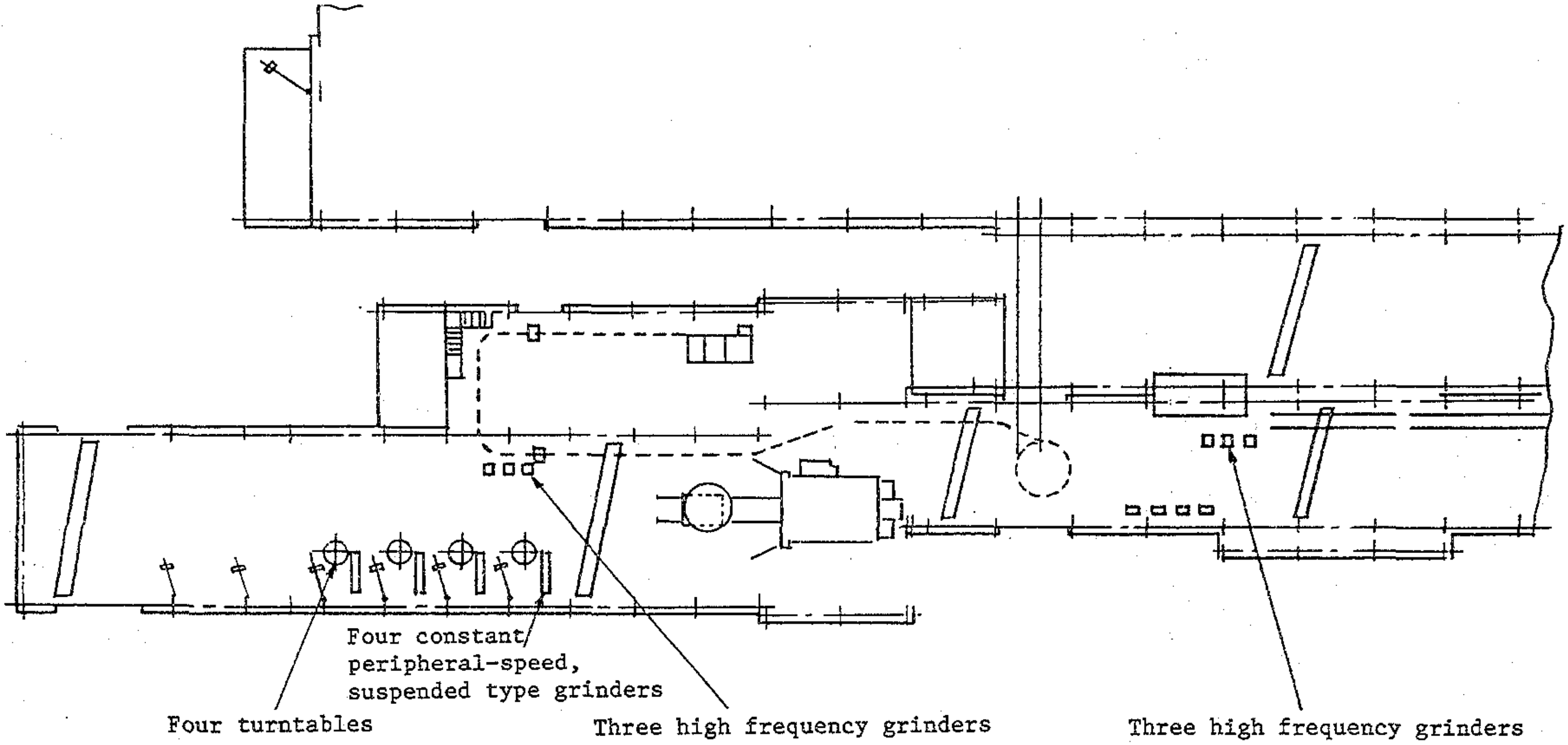


Figure 3.3.2-4 Finishing Shop Equipment Layout Diagram

(a) Layout of heat treatment furnaces

Since the existing heat treatment furnaces are located at a position far away from such the prior and post processes as riser cutting, shot blast and finishing/grinding work fields, the work results not in a continuous flow, thus suspended. This increases the transportation work without an added-value, thus resulting in reducing the operating rate of not only the heat treatment furnaces, but also of the related equipment.

(b) Layout of finishing shop

The finishing shop is broadly divided into such four zones as (1) finishing, grinding and shot blasting of large items, (2) shot blasting and manual finishing of small items, (3) riser cutting and (4) small item finishing and inspection. These shops are neighbored to each other, but the alignment of shop building columns runs out, so that the overhead cranes are installed in each shop independently, thus forming the independent shop from each other. This avoids the continuous work flow, whereby increasing the transportation work without an added-value as well.

(c) Layout of shot blast shop

The shot blast shop is provided with a turntable type for large items and a drum type turntable for small items, both of which are located in the finishing/polishing shop far away from such prior and post processes as shake out, riser cutting and heat treatment furnaces.

This also deviates from the work flow as same as the previous items, thus increasing the transportation work, place occupation pursuant to transportation, and scattering of removed sand on floor to worsen the surroundings.

(d) Layout of middle and small-mold making shop and melting shop

Both shops are centered in the foundry shop group, connecting each other, but both have a narrow working space. Especially, four small-mold conveyor lines are installed in the shop of 7,620 mm in width, thus making the working (safety) passages impossible to be secured. The electric furnace also occupies about a half the shop of 12,600 mm in width at the center of the melting shop. A passage provided between the electric furnace and the casting place aligned at the opposite side is also narrow, together with a bad stepping base in full of sand. This can be no way be said safe. Considering that the production of middle and small products like liners is to be increased in the future, space needs to be expanded.

b) Desirous entire shop layout plan

An entire shop layout plan is given in Figure 3.3.2-5 below to solve various problems on the shop layout as discussed in the previous section. Since this plan places the importance onto solving the current problems, it is necessary for you to conduct a comprehensive study thoroughly for entire workshop, together with the future long-term production plan, before the execution of relocation (transfer, modification or new construction). The contents of this layout plan are discussed as follows.

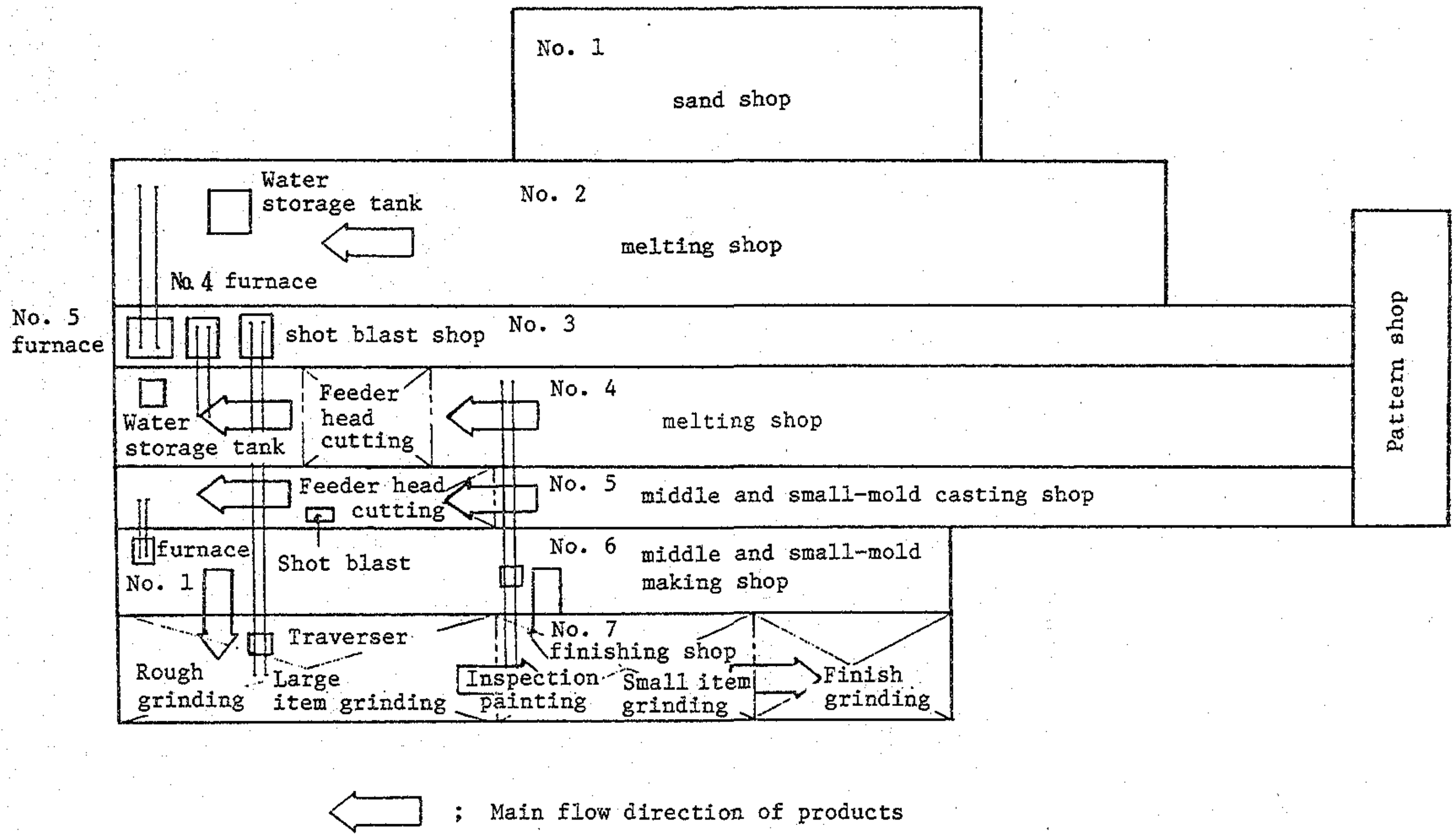


Figure 3.3.2-5 Entire Foundry Shop Layout Plan

(a) Additions and modifications of shop buildings

The existing shop building is planned in such that the existing finishing shop is to be modified to two straight buildings (Nos. 6 and 7) and that the welding shop and middle/small-mold making shop are extended westward to align the west end straightly.

(b) Change of shop zonings

① Finishing shop

No. 7 building as modified is to be used for finishing shop, from which the shot blast and riser cutting work fields are relocated to some other places, which are now located in the same shop, thus forming an integrated line of such work fields as rough grinding, large casting grinding, finish grinding, small casting grinding, inspection and painting.

② Middle and small-mold making shop

No. 6 building as modified is to be used for middle and small-mold making shop to solve the current problem of narrow space.

③ Melting shop

The small item casting lines out of those in the pouring shop are to be transferred to the modified No. 5 middle and small-mold casting shop.

(c) Relocation of heat treatment furnace

Nos. 1 and 3 furnaces currently installed at a position away at the east side of the melting shop are to be relocated to the added west side indoor areas of Nos. 4 and 6.

This greatly reduces distances to and from the prior and post processes of the heat treatment furnaces, and the concentration of three furnaces can improve the efficiency of furnace operation and maintenance.

(d) Relocation of shot blast shop

The shot blast shop is to be relocated to the west side area of Nos. 3 and 6 buildings considering the combinations with such prior and post processes as shake out, riser cutting and heat treatment.

(e) Relocation of riser cutting areas

The riser cutting areas are to be relocated to the west side of the melting and casting shops in Nos. 4 and 5 buildings, respectively, in order to make the work flow better.

(f) How to determine the shop layout

It is necessary for arranging the shops and major equipment to make the work flow continuous without suspension along the manufacturing processes and to reduce the transportation frequency and distances. The transportation routes and quantity its among processes differ and become complicated, depending upon the product items (materials) and quantities. Estimates based on the 1989 product items and quantities are as shown in Figure 3.3.2-6 and Table 3.3.2-5 below.

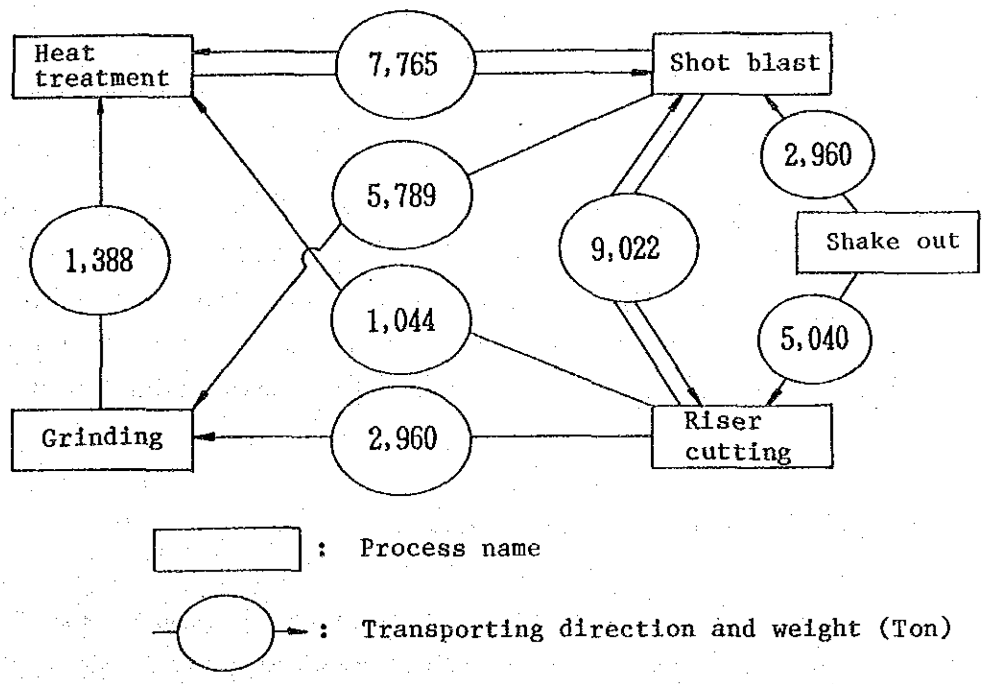


Figure 3.3.2-6 Transporting Weight Among Processes (1989)

Table 3.3.2-5 Transporting Weights Among Processes (1989)

Transportation Route	Weight TON/Year	Percentage
Riser cutting ↔ Shot blast	9,022	25.1
Shot blast ↔ Heat treatment	7,765	21.6
Shot blast ↔ Grinding	5,787	16.1
Shake out → Riser cutting	5,040	14.0
Shake out → Shot blast	2,960	8.2
Riser cutting → Grinding	2,960	8.2
Grinding → Heat treatment	1,388	3.9
Riser cutting → Heat treatment	1,044	2.9

Figure 3.3.2-6 and Table 3.3.2-5 above indicates that about a half the total transportation is occupied by the riser cutting, shot blast and heat treatment processes. It is, therefore, necessary to locate them closer to each other and to make the transportation method and efficiency better. The entire foundry shop layout plan given in Figure 3.3.2-1 above is drawn by the foregoing ground.

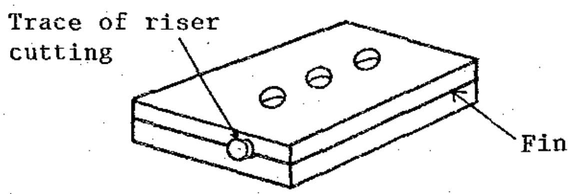
(g) Transport means among processes

Transportation itself has no element to raise the product value, so that it must be minimized. It is especially necessary to reduce the steps and frequency of loading and unloading pursuant to transportation.

This layout plan considers these factors to minimize the intra-road transportation by vehicles up to a possible maximum extent and to use the overhead cranes for transportation in the buildings and the self-travel bogies on the rails for tranportation among buildings. It is, however, important to achieve a higher efficiency of transportation by using the special pallets, etc. to meet the product shapes of small and medium items.

(2) Introduction of new technologies

Among all other products to be input into the shops the liners for ball and bar mills occupy about 65% as weight percentage. These liners vary in shape and dimensions, but basically form a thin square as shown below.



Basic from of liner

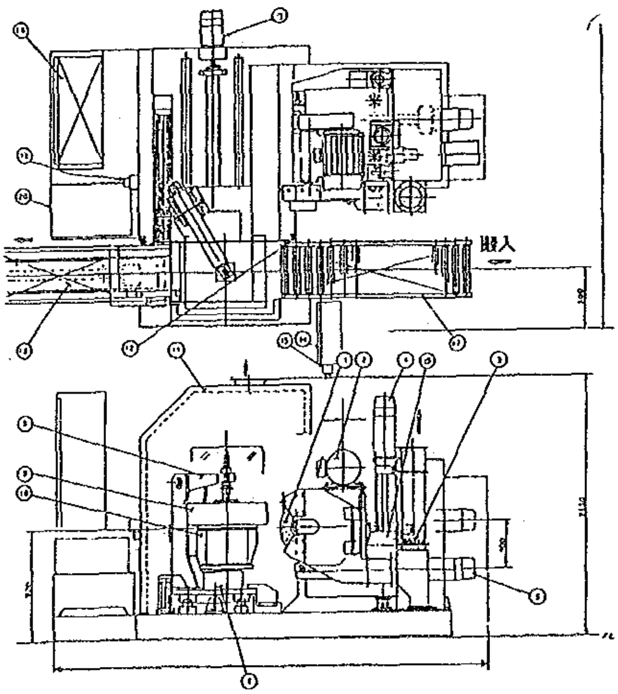
The liner production is planned to about 10,000 liners (1989) per year. The large, swing type grinders are currently used for finishing the fins and traces of feeder head cuts, which is a heavy labor requiring physical power and generates dust greatly.

The improvement is desired in this regard. To replace this swing-grinder, there is an automatic grinding machine to mechanize the manual work and further to automate the fine grinding adjustment. Since this machine is very expensive, it is necessary for you to thoroughly study the investment effect before introduction. We believe it is deserved to study, because it can be expected to relieve workers from heavy labor, to improve the safety, sanitation, quality, etc. The double-end grinders of fixed type are now applied to grind small items of sizes to allow the manual handling. They have a disadvantage to greatly reduce the grinding performance by dropping the peripheral speed, as well as to wear the grindstone, because of fixed type. There are recently the constant peripheral speed fixed type grinders in place of them. The following discuss further in detail about these new machines.

a) Automatic grinding machine

Figure 3.3.2-7 below gives the appearance view of automatic grinding machine. Table 3.3.2-6 below gives the principal specification of automatic grinding machine. This machine is intended to grind the four side surfaces, and featured with the full automatic processing of CNC 4-axial control from chucking a work loaded in via a roller conveyor up to unchucking it at the unloading roller conveyor inlet after the end of grinding, through a combination of cast face following system and contact/release system. For the lots of a same shape, teaching it with the first one unit allows the rest to be ground automatically at a high accuracy and in a short time.

Such functions of this machine as cast face following system and contact/release system are as detailed in para. 2.3 "Current Production Technologies" above. The introduction of such a high performance machine can expect not only an increase of liner grinding capacity, but also the diffusive effects (e.g., motivating the developments and improvements, such as applications of mechanisms and methods held by this machine to other fields, pressing the correcepondence of prior and post processes to meet the operation of high performance, etc.) to many fields mastering the latest techniques by workers.



No.	Name
1	Grindstone
2	Grindstone drive motor
3	Grindstone feeder
4	Y-axis controller
5	Z-axis controller
6	A-axis controller
7	X-axis controller
8	Clamp
9	Work
10	Receiving jig
11	Dust collection hood
12	Shutter
13	Air unit
14	Operating panel
15	Teaching box
16	Controller
17	Infeed conveyor
18	Work unloader
19	Flexible grinding unit
20	Hydraulic unit

Figure 3.3.2-7 Automatic Grinding Machine

Table 3.3.2-6 Principal Specifications of Automatic Grinding Machine

Item	Specification
Grindstone dimensions	510ϕ x 50 x 50.8 mmϕ
Peripheral speed	3,000 m/min.
Horsepower	15 KW
Subject work dimensions	200H x 500W x 1200L mm
CNC control	Simultaneous 3-axial control X-axis = (Round trip of table) Y-axis = (Vertical movement of wheelhead) Z-axis = (Back-and-forth movement of wheel-head) A-axis = (Table revolution)
Outside dimensions	3,000W x 4,000L x 2,150H mm
Weight	10,000 kg
Price in Japan	¥46,000,000

b) Constant peripheral speed fixed type grinder

Figure 3.3.2-8 below gives the appearance view of constant peripheral-speed fixed type grinder. Table 3.3.2-7 below gives the principal specifications of constant peripheral-speed fixed type grinder.

As detailed in para. 2.3 "Current Production Technologies" above, this machine is provided with a constant peripheral-speed mechanism capable of maintaining a gap between the worktable and grindstone at a constant, and a high efficiency attainable a constant, optimum high speed at all times, through moving (forward) the grindstone position by the adjusting handle, corresponding to the wear of grindstone. An auxiliary footing device to press a work is also provided as an improvement of workability, capable of easily feeding a high pressure cohesion force, thus reducing the burden of workers. The adoption of this machine can greatly improve the grinding efficiency and grindstone consumption. The Japanese data indicate about doubling in the grinding efficiency and about a half in the grindstone consumption.

Table 3.3.2-7 Principal Specifications of Constant Peripheral-Speed Fixed Type Grinder

Item	Specification
Drive motor	7.5 KW-4 P 1,500 r.p.m.
Grindstone dimensions	455ϕ x 50t x 50.8 mm
Peripheral speed	50 m/s
Work table	Vertical, back-and-forth, turning and horizontal direction adjustable
Outside dimensions	approx.1240 W x 1240 L x 1180 H mm
Weight	900 kg
Price in Japan	¥2000,000

(3) Equipment layout and environmental improvement

The product flow in the shops is planned to have an integrated flow from west to east, such as large item grinding, finish grinding, small item grinding, inspection and painting, by receiving the large items via the west side traverser and the small items via the central traverser. All equipment is planned to be installed along this flow. Since the automatic grinding machine handles a great deal of liners, a principal product of this shop, the storage area before and after it is also taken into consideration. This layout plan is given in Figure 3.3.2-9 below.

No.	Name	Specification	Remarks
1	Grindstone	P510x50x50.8	
2	Motor	7.5 KW 4P	
3	Varistor	PJ-150	Option
4	Starting switch		
5	Grindstone feed handle	Manual operation	
6	Electromagnetic switch		
7	Amount of dust collection wind	20 m^2/min.	

Weight About 900 kg

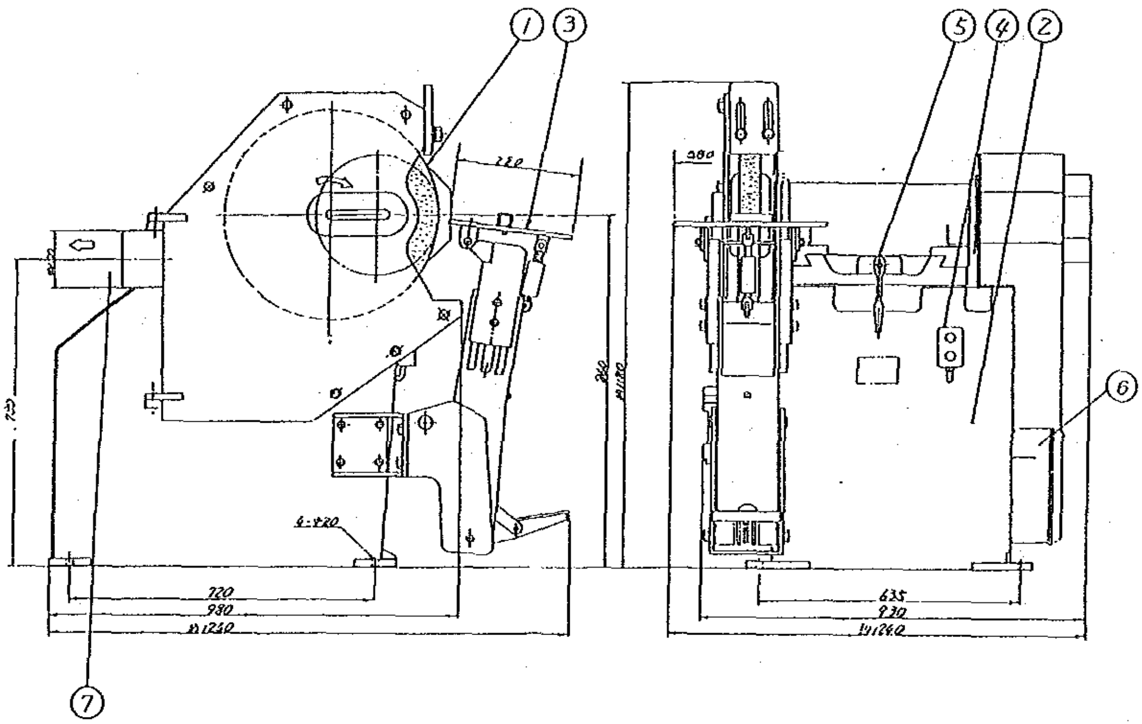


Figure 3.3.2-8 Constant Peripheral-Speed Fixed Type Grinder

For the environmental improvement, the shop floor is planned to cover the floor fully with concrete to make the floor flat and smooth, on which the work passages are to be identified with white lines. The dust collectors for suspended type grinders are to be installed of powerful bag filter type, selecting the proper positions of suction inlets to be installed to the swing grinders, where surely catch the particle dust and fire-flakes. Consideration also needs to be given to the brightness in the shops. The lighting and illumination are planned to secure 100 to 200 lux (at 1 m above floor) for general work fields and 200 to 300 lux (at 1 m above floor) for finish grinding and inspection fields.

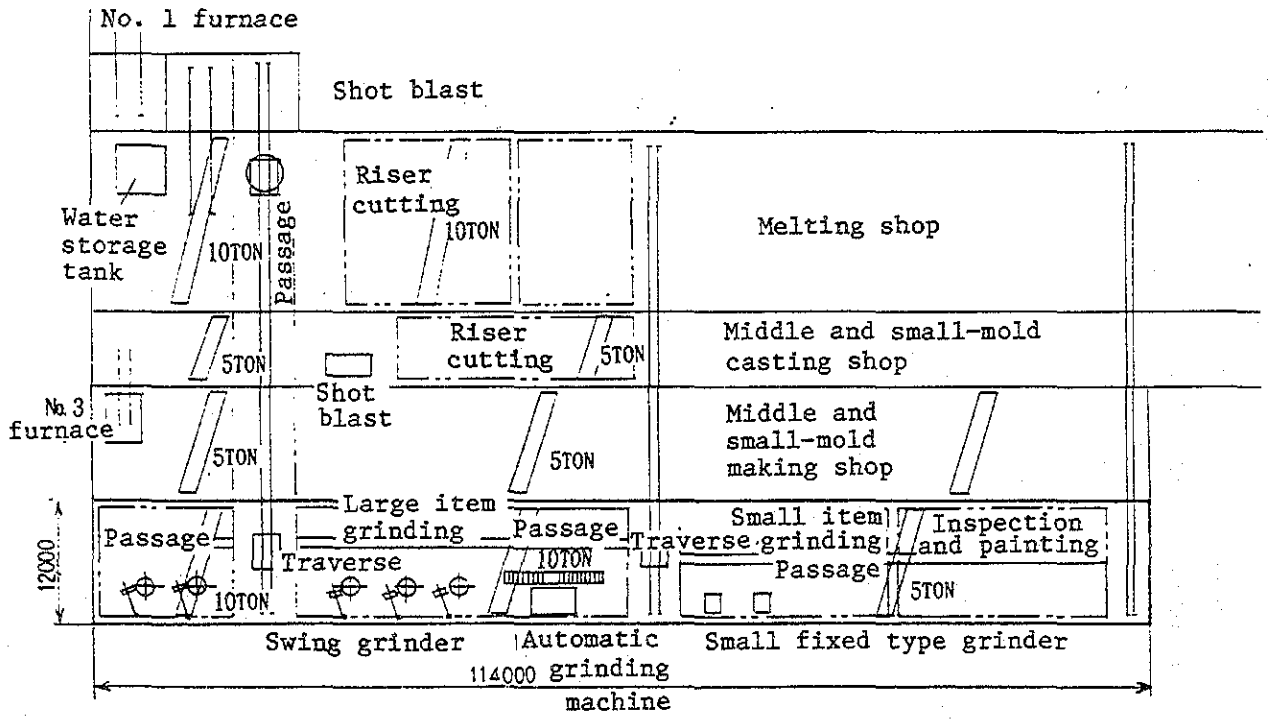


Figure 3.3.2-9 Finishing Shop Machine Layout Plan

3.3.3 Welding Process in Plate Shop

1) Present modernization with payability considered

(1) Basic principles in program planning

The modernization plan described in this section is to introduce new techniques and facilities described in the preceding 3.2.2 Modernization of Production Techniques. These techniques and facilities are considered to be sufficiently payable when viewed from the result of the financial analysis (payability evaluation) which is described later.

However, as to the improvement of the shop layout pointed out in Section 2 Current Production Facilities, a proposal will be made as "Future Desirable Shop" described in 2), below since the improvement of the shop layout is a matter of the entire plate shop, not a matter concerned with only the welding process.

(2) Introduction of facilities, equipment, jigs and tools

As to the course of modernization of welding process and its definite means, as described in detail in the preceding paragraph for the modernization of production techniques in welding process, adoption of semi-automatic welding at large scale and automatic welding for welded overlay on repair parts from the current manual welding with partially semi-automatic welding is considered possible and it is planned to introduce the following facilities and equipment in line with the said adoption of semi-automatic and automatic weldings:

CO_2 welding machine
Positioner
Manipulator
Automatic profiling controller
Table lifter
CO_2 gas piping
Submerged are welding machine
Electrode desiccator
Assembly and welding surface plate

Specifications for these facilities are shown in Table 3.3.3-1 Newly Installed Facilities for Welding Process. Detailed descriptions of these facilities are provided below.

Table 3.3.3-1 Newly Installed Facilities for Welding Process

No.	Name	Units	Specification
1	CO_2 welding machine	16	500A, using wire dia: ϕ1.2 and 1.6 mm Construction: Power supply, welding wire feeder, welding torch, gas regulator, remote controller
2	CO_2 welding machine	2	600A, using wire dia: ϕ1.2, 1.4, 1.6 and 2.0 mm Construction: Power supply, welding wire feeder, welding torch, gas regulator, remote controller, cooling water unit
3	Positioner	1	15 Ton, table size: 2500 mm
4	Manipulator	1	Boom's vertical moving distance: 3000 mm Boom's horizontal moving distance: 1000 mm
5	Automatic profiling controller	1	Welding head position control
6	Table lifter	1	3 m x 1000 kg
7	CO_2 gas pipe	1	1-1/4" x 100 m, 1" x 300 m with the header
8	Submerged arc welding	1	1200A, using wire dia: ϕ4.0, 4.8, and 6.4 mm Construction: Power supply, welding wire feeding head, traveling carriage rail
9	Electrode desiccator	1	400°C, 50 kg Inner dimensions: 200 (H) x 300 (W) x 580 (L) mm
10	Assembly and welding surface plate	1	Shape steel embedded concrete surface plate 0.15 (t) x 6.5 (W) x 20 (L) m

a) CO_2 welding machine

Latest CO_2 welding machine will be introduced for semi-automatic and automatic weldings of general welding structures and various build-up welding repair parts at the plate shop.

When compared with existing CO_2 welding machines, this new welding machine is excellent in arc start and arc follow-up at current levels rainging from small to large current, with flexibility in profiling uneven materials to be welded and resistance against movement of hands, and is best suited to welding in all positions as well as automatic welding. In addition, the self-holding feature eliminates the necessity for keeping the welding torch depressed during welding with a consideration for long hour work, and when compared with the existing manual expected.

Type 500A and 600A welding machines will be introduced. Type 500A is used for general semi-automatic welding, while Type 600A is used mainly for automatic welding of repair parts through build-up welding.

Type 500A is shown in Figure 3.3.3-1 and Type 600A in Figure 3.3.3-2. Further, the principal specification of Type 500A is shown in Table 3.3.3-2 and that of Type 600A in Table 3.3.3-3.

Figure 3.3.3-1 500A CO_2 Welding Machine

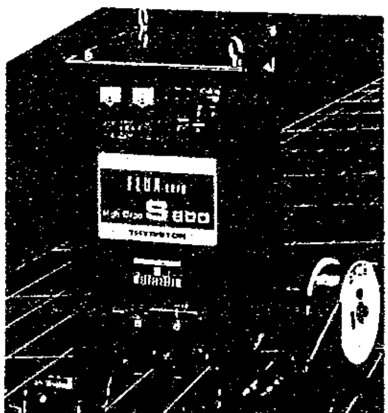


Figure 3.3.3-2 600A CO_2 Welding Machine

Table 3.3.3-2 Main Specification of 500A CO_2 Welding Machine

Component	Item	Specification
DC power supply	Input power Rated input Output current Output voltage Rated duty cycle Outer dimensions Weight	3 ϕ x 550 V x 50 Hz 31.9 KVA 60 to 500A 16 to 45V 60% 455 x 617 x 850 mm 152 kg
Wire feeder	Using wire dia.	ϕ 1.2 and 1.6 mm
Welding torch		Gun type
Gas regulator		With a heater
Remote controller		

Table 3.3.3-3 Main Specification of 600A CO_2 Welding Machine

Component	Item	Specification
DC power supply	Input power Rated input Output current Output voltage Rated duty cycle Outer dimensions Weight	3 ϕ x 550 V x 50 Hz 45 KVA 60 to 600A 15 to 50V 100% 500 x 650 x 1020 mm 225 kg
Wire feeder	Using wire dia.	ϕ 1.2, 1.4, 1.6 and 2.0 mm
Welding torch		Gun type
Gas regulator		With a heater
Remote controller		
Cooling water unit	Flow rate	1 ltr./min.

b) Automatic welding

For the mean time, it is intended to apply automatic welding to Head, Bowl and Adjustment of Ring out of build-up welding repair parts. The welding machine to be used is the above-mentioned 600A CO_2 welding machine, and the positioner, manipulator and automatic profiling controller will be introduced as automatic welding system and the table lifter as the working scaffolding. The structure of this system is shown in Figure 3.3.3-3.

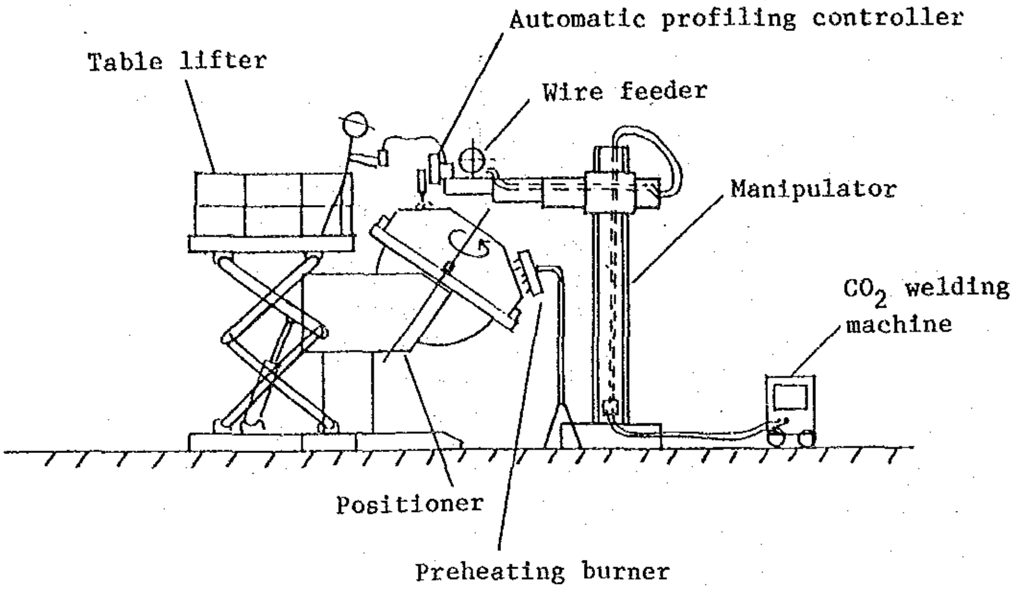


Figure 3.3.3-3 Structure of Automatic Welding System

As can be seen from the above figure, a product is rotated while its build-up welding section is kept horizontally by the positioner, and forcing the welding torch profile the product by the automatic profiling controller installed at the end of the manipulator arm, the build-up welding is carried out successively with the rotating speed of the positioner and feeding speed of the manipulator set constant. Further, the preheating burner is provided at the side for the purpose of preheating, temperature holding and after-heating. The external views and main specifications of the positioner, manipulator, automatic prefiling controller and table lifter are shown in Figure 3.3.3-4 through -7 and Table 3.3.3-4 through -7, respectively.

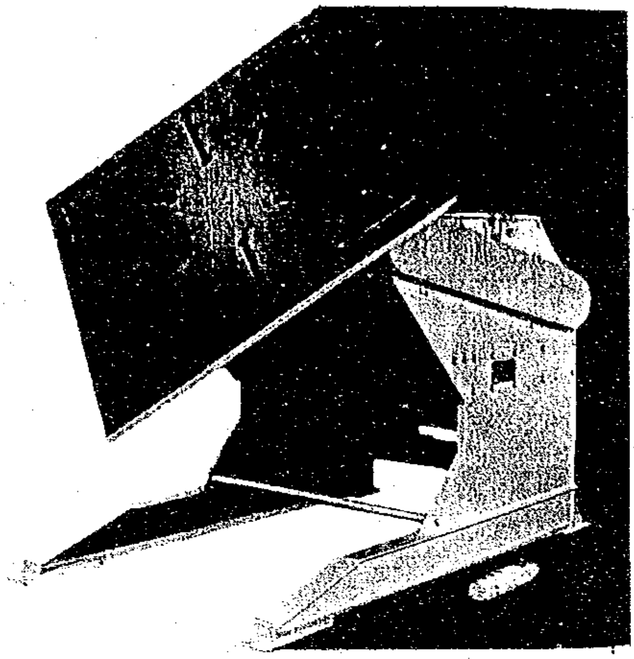


Figure 3.3.3-4 Positioner

Table 3.3.3-4 Main Specification of Positioner

Item	Specification
Loading capacity	15,000 kg
Speed of table	0.0125 to 0.25 r.p.m.
Tilting angle of table	0 to 135°
Size of table	2500 x 2500 mm
Dimensions	2,450 (H) x 2,500 (W) x 3,900 (L) mm
Weight	12,000 kg

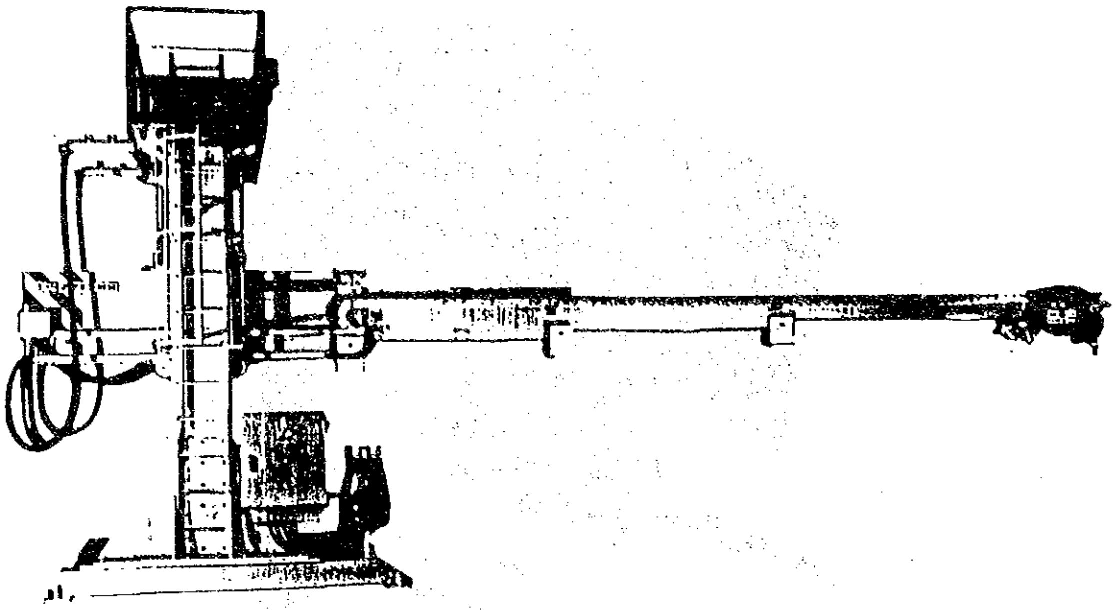


Figure 3.3.3-5 Manipulator

Table 3.3.3-5 Main Specification of Manipulator

Item	Specification
Horizontal moving distance	3,000 mm
Horizontal moving speed	150 to 1500 mm/min.
Vertical moving distance	3,000 mm
Vertical moving speed	500 mm/min.
Load on the end	Max. 150 kg
Dimensions (with the arm contracted)	900 (W) x 1200 (L) x 5060 (H) mm
Weight	5,500 kg

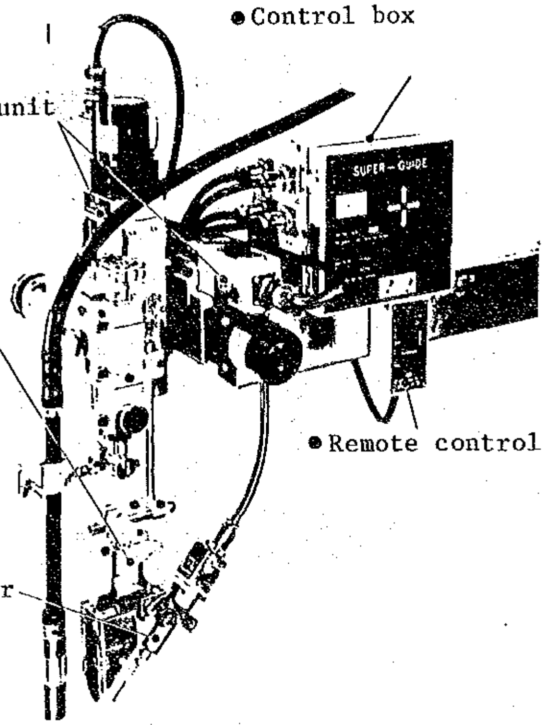


Figure 3.3.3-6 Automatic Profiling Controller

Table 3.3.3-6 Main Specification of Automatic Profiling Controller

Item	Specification
Loading capacity	75 kg
Momentary load	800 kg·cm
Tracing speed	120 mm/min.
Tracing range	Vertical : 150 mm Horizontal: 150 mm
Control function; Manual	Vertical & horizontal movement
Control function; Automatic	Left & right profiling, left profiling, right profiling, tack weld detection, work termination detection, sensor centering indication
Stage driving system	Special forwarding by motor driving
Driving motor	6W reversible motor
Weight	21 kg

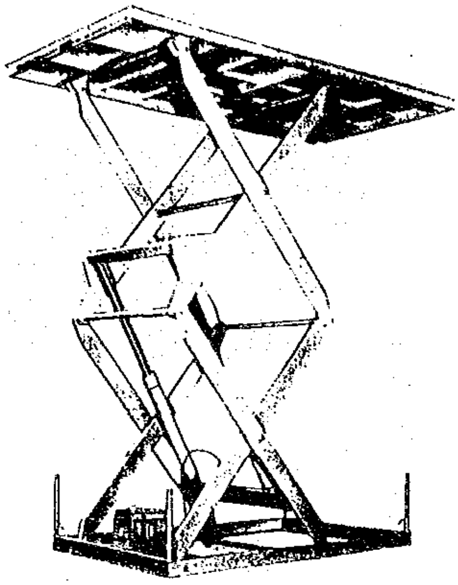


Figure 3.3.3-7 Table Lifter

Table 3.3.3-7 Main Specification of Table Lifter

Item	Specification
Max. load	1000 kg
Table size	1500 x 2500 mm
Lift	3000 mm
Min. height	700 mm
Overall height	3700 mm
Rising time	62 sec.
Motor	1.5 kw

c) CO_2 gas piping

As a result of the wide adoption of the CO_2 welding method, CO_2 gas consumption increases accordingly. The existing cylinder system takes much time as frequent carry-in and carry-out of CO_2 gas cylinders and change of hoses are required. Therefore, the CO_2 gas piping will be isntalled in the shop. Fortunately, there is a CO_2 gas generating yard in the foundry shop and the piping at this yard will be extended and a header will be provided to each pole at the welding yard in the plate shop. Further, purity of CO_2 gas must be above 99.5% (volume %) and moisture must be below 0.05% (weight %). The conceptual diagram of the CO_2 piping is shown in Figure 3.3.3-8.

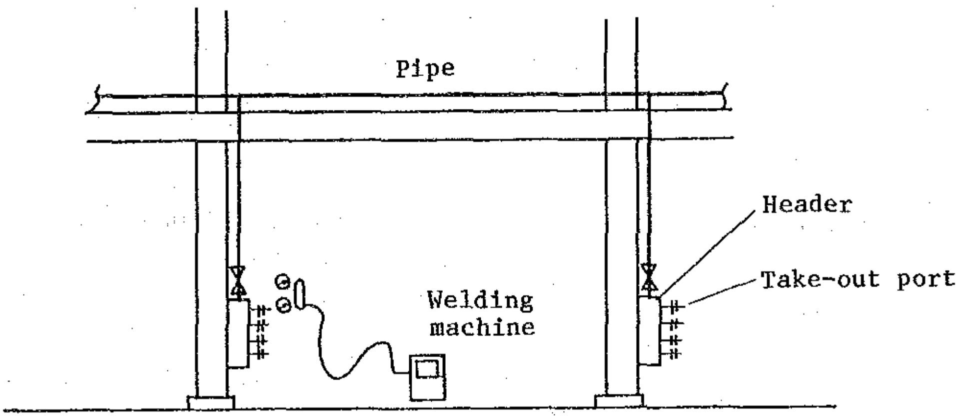


Figure 3.3.3-8 CO_2 Gas Piping Diagram

d) Submerged arc welding machine

A submerged arc welding machine will be introduced for high efficiency automatic butt welding and fillet welding of thick plates. The submerged arc welding machine is shown in Figure 3.3.3-9 and its main specification in Table 3.3.3-8.

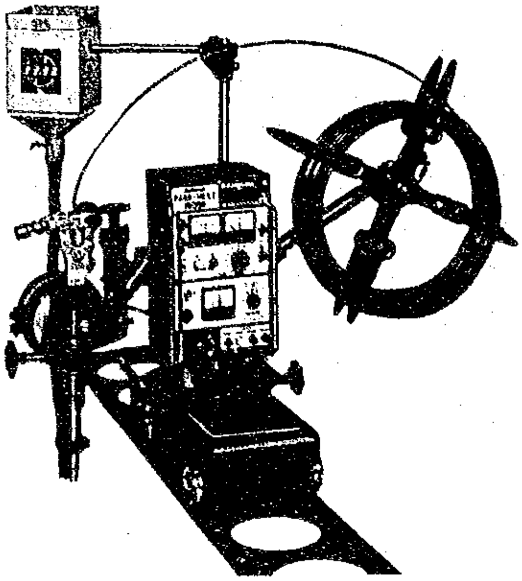


Figure 3.3.3-9 Submerged Arc Welding Machine

Table 3.3.3-8 Main Specification of Submerged Arc Welding Machine

Item		Specification
Power supply	Rated primary input Current regulating range Dimensions Weight	78 KVA 300 to 1200A 690(W) x 920(L) x 1320(H) mm 445 kg
Auto welding system	Applicable wire dia. Applicable wire coil Carriage travelling speed Dimensions Weight	4.0, 4.8 and 6.4 ϕ mm 12.5 kg and 25 kg winding Low speed : 12 - 120 cm/min. High speed: 50 - 360 cm/min. 585(W) x 1100(L) x 916(H) mm 70 kg

e) Electrode desiccator

At present, coated electrodes used for manual welding are used without being dried. However, to secure acceptable welding quality, electrodes must be well dried. At this shop, low hydrogen type electrodes are used. This type of electode must be especially protected from moisture absorption. Therefore, an electrode desiccator will be introduced to maintain electrodes in proper condition. The electrode desiccator is shown in Figure 3.3.3-10 and its main specification in Table 3.3.3-9.

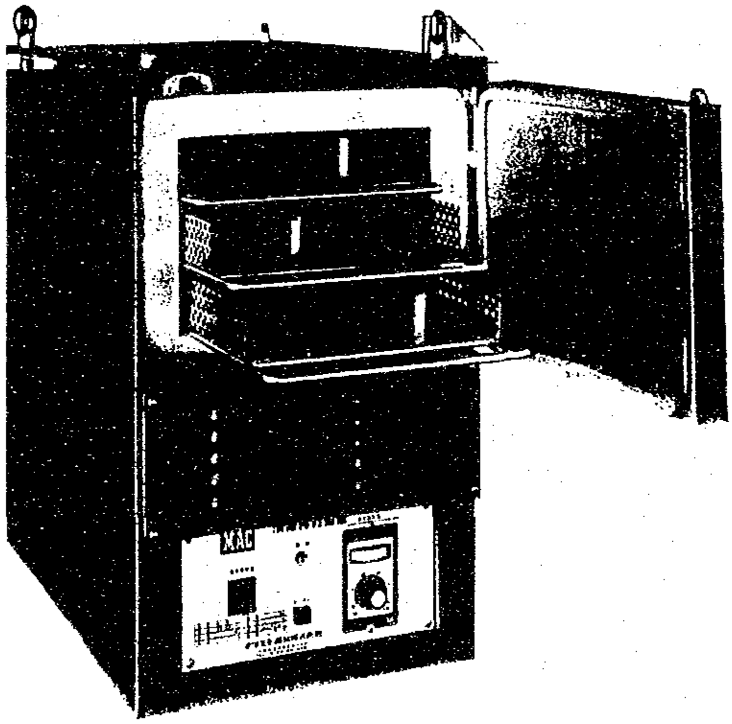


Figure 3.3.3-10 Electrode Desiccator

Table 3.3.3-9 Main Specification of Electrode Desiccator

Item	Specification
Desiccating volume	50 kg
Max. working temperature	400°C
No. of shelves	3 shelves
Max. power consumption	2.7 KW
Temperature regulator	Electronic type
Max. length of electrode	550 mm
Outer dimensions	635(H) x 400(W) x 680(L) mm
Inner dimensions	200(H) x 300(W) x 580(L) mm

f) Assembly and welding surface plate

The present plate shop has a concrete floor in 2 m wide extending north and south at the center of the shop with a rail located at its center and all other floors are covered with 130 mm square lumbers. This type of floor cannot restrict movement of large steel structures such as freight car sufficiently at time of assembly and welding and furthermore, is unstable and undersirable from the viewpoint of quality and safety. For this reason, a concrete surface plate with a shape steel frame embedded will be installed at the assembly and welding yard. This shape steel frame also serves as an earthing plate at time of welding. This surfacing plate with an embeded frame is shown in Figure 3.3.3-11.

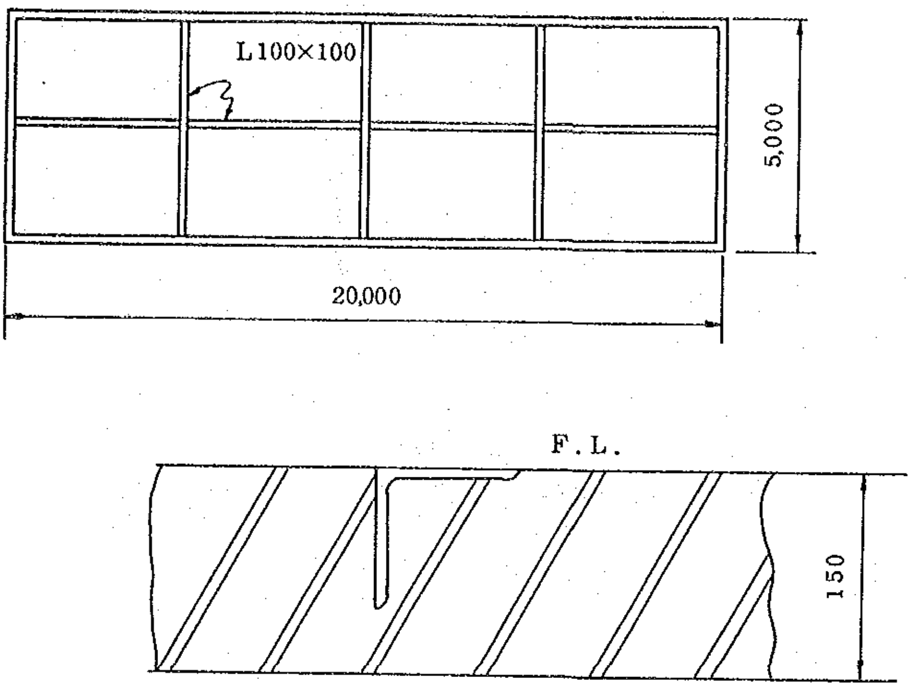
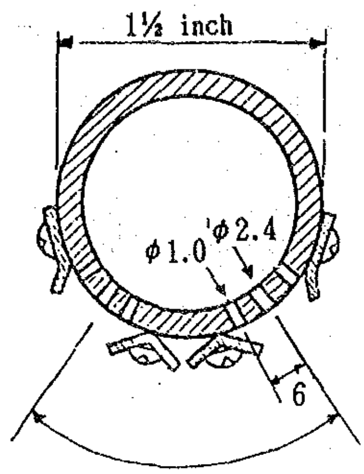


Figure 3.3.3-11 Embedding Assembly and Welding Surface Plate

g) Preheating burner

If a large burner is used, it is necessary to keep temperature constant but control of temperature is difficult and furthermore, a burner operator is required to change a location of the burner all the time, and it is also uneconomical to use a large burner from the viewpoint of fuel consumption. Instead of this large type burner, a burner for exclusive use for preheating purpose with many small nozzles arranged will be introduced. This burner, made of $\phi 1''$ gas tube, can be bent to fit shapes of products, has a wide caloric force adjusting range and once set, it is not required to control caloric force, and labor saving as well as energy saving can be thus achieved. This preheating burner is shown in Figure 3.3.3-12.



Sectional View of Burner 80°

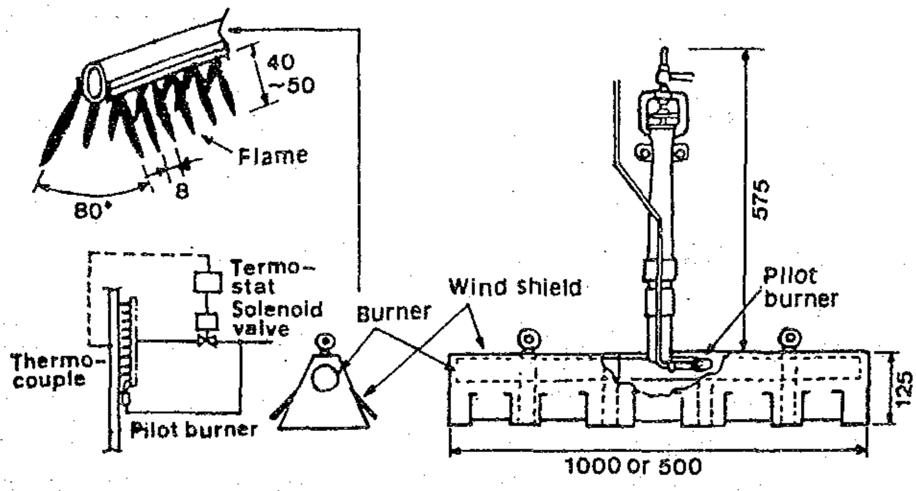


Figure 3.3.3-12 Preheating Burner

(3) Layout of facilities

Facilities will be installed at the current locations welding work. Out of these facilities, assembly and welding surface plate will be a fixed equipment as it is installed with concrete. All others are movable (by a crane or forklift truck) and are therefore relocated as necessary according to progress of product processing. The layout of facilities is shown in Figure 3.3.3-13.

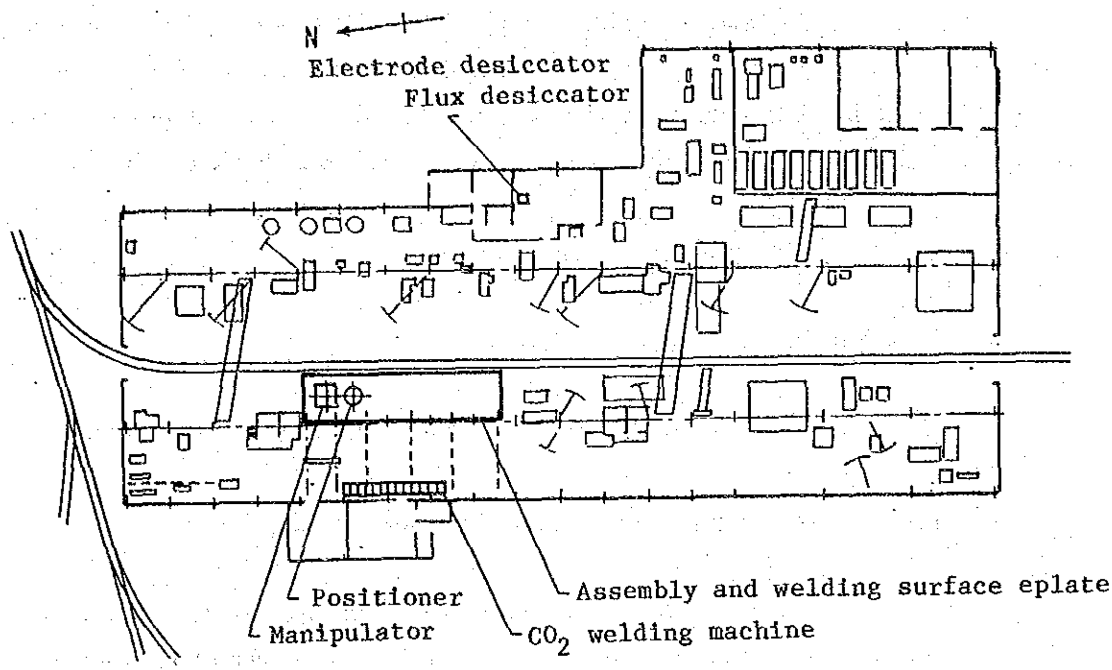


Figure 3.3.3-13　Layout of Facilities in Plate Shop

2)　Desirable future shop plan

When the modernization of the facilities looking ahead the future welding process is considered, improvement of welding technoligies, improvement of work flow mainly in transportation management and environmental inprovement from the aspect of safety and sanitation may be required. As to the improvement of welding technologies out of these imprevements, if the modernization programs established as mentioned in the above are implemented, improvement of technological level as well as substantial improvement of productivity can be expected and it is considered there will be no large problem to progress introduction of new technologies and facilities toward the technical progress in the future. However, as to the improvement in other two areas, as pointed out in the current production facilities in Chapter 2, drastic improvement is required.

However, the matter is concerned with not only the welding process but also the entire plate shop and at the same time, the improvement has to be so extensive that it becomes necessary to rebuild the plate shop itself. Therefore, presented here in a plan proposed as a reference material when an overall reviews is made on the entire plate shop in the future.

(1) Entire shop layout plan

a) Problems in the current shop layout

There are following problems in the material flow in the plate shop:

(a) Relationship between road in the yard and shop layout

The plate shop is surrounded with the machine, foundry and electric shops on three sides and they are all in close vicinity each other. Therefore, the materials and products carry-out ports are limited to the south side, causing congestion of flow of materials and products in the shop.

Further, the road at the south side of the shop is running around the material yard and is inconvenient for carrying large size products in and out of the shop.

(b) Layout of the main shop and subsidiary shops

The sand blasting shop, shape steel cutting shop and painting shop belong to the plate shop in addition to the main shop. Those shops are located away from the main shop and materials and products have to be transported or handled by carriage, forklift truck or wrecker truck, and transporting efficiency is adversely effected.

Further, heat treatment after welding is performed using No. 4 furnace in the foundry shop, which is also far away from the plate shop and it is necessary to take welded products in and out of the furnace with a wrecker truck.

(c) Layout of facilities in the mainshop and building structure

The main shop consists of a 15 m wide main building equipped with an overhead travelling crane, with an approx. 7.5 m wide building attached at both sides. The main building is the center of this shop and facilities are satisfactorily arranged in the building along flow of process and movement of large size products. However, a large bending roller with low working ratio is installed at the central part of the shop, thus impeding flow of large size products and also, a shape cutting machine, which is used in the initial process, and a press brake are located at the center of the shop. It is considered necessary to improve the layout of these machines.

Further, processings of small size products are performed in the attached buildings but a wall crane that has a narrow working range is used and flow of products in the attached buildings as well as flow of products to/from the main building are not satisfactory.

b) Desirable entire shop layout

The desirable entire shop layout plans for solving the above-mentioned various problems involved in the current shop layout are shown in Figure 3.3.3-14 and -15. However, likewise the entire foundry shop layout plan, this layout intends to solve current problems and therefore, when implementing these layout plans (relocation, modification or new installation), it is necessary to thoroughly examine them totally as the plans for the entire work shops together with the future long range production programs.

The contents of the layout plans are described in the following.

(a) Rearrangement of the shop building and improvement of peripheral environments

The work flow in the plate shop is straightened to a consistent flow of material carry-in cutting bending assembly welding product carry-out. The existing building is moved to a location about 25 m south and a road for carrying out products is provided at the north side. In keeping with this, the existing electric shop, X-ray room, etc. are rearranged and the outdoor material storage yard is readjusted. Further, the wire net and casted products working yards currently existing in the plate shop are handling products differing from these of the plate shop and are also using different machines and therefore, they will be moved into a new shop to be constructed together with the maintenance shop at a location adjacent to the plate shop.

As a whole, the shops, peripheral roads, material storage yard, etc. are arranged parallelly and at right angle to improve flow of works.

(b) Arrangement of facilities

Facilities are arranged along with flow of works in order of material charge from the south side of the shop, cutting, bending, assembly and welding. In particular, as it is difficult to move the eye tracer, bending roller, press brake and other large size facilities when once installed, they will be installed near the attached buildings as much as possible so as not to impede the flow of works at the center. Further, a carriage type annealing furnace for use in build-up welding, etc. will be installed at the north side to allow loading by a crane in the shop. If welding structures become more thicker and more higher class in the future, this annealing furnace will become indispensable.

(2) Imprevement from the aspect of safety and sanitation

If the work flow described in the above is improved, safety is also considered to improve. Recent production of large ladles weighing 15 tons, exceeding the plate shop crane capacity of 10 tons is another problem and overload must be avoided. It is, therefore, necessary to solve these problems by increasing capacity of the building and crane at the same time of the shop rearrangement. It is also necessary to make the floor to a smooth concrete floor and secure the working passages by clearly drawing white lines on the floor and at the same time, to create a easy to work environment by constantly cleaning and keeping the work place in good order.

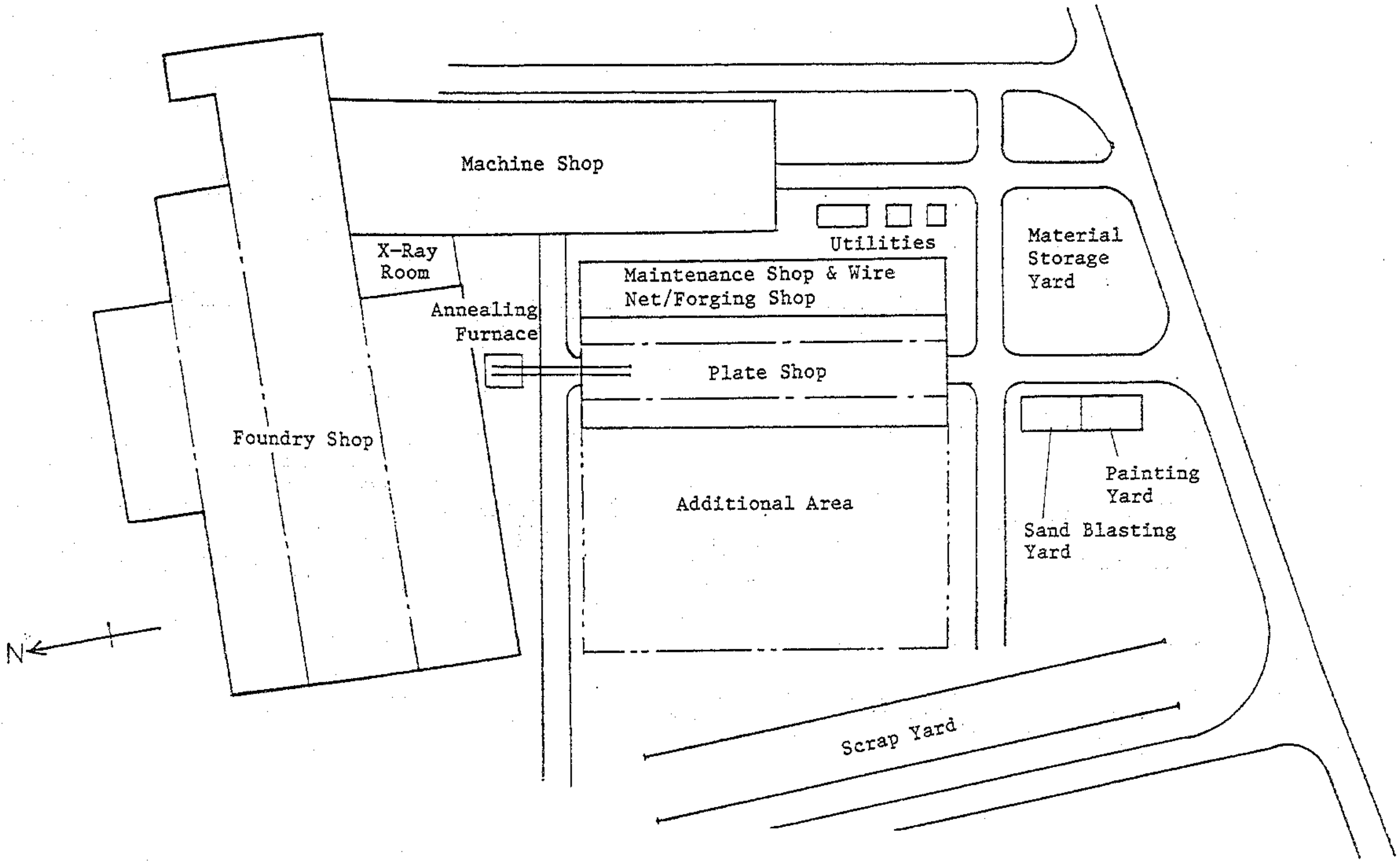


Figure 3.3.3-14 Entire Plate Shop Layout Plan

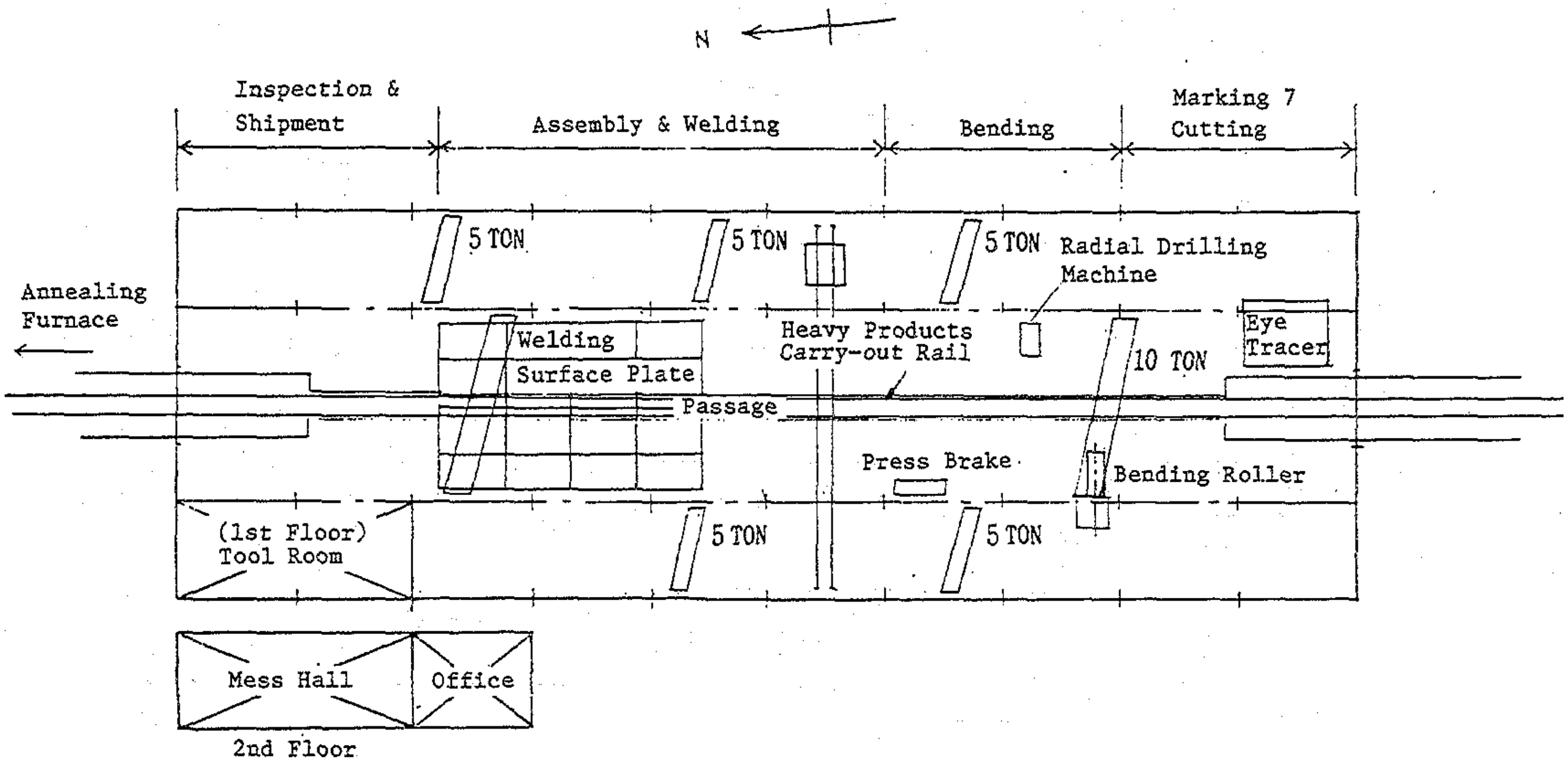


Figure 3.3.3-15 New Plate Shop Layout Plan

3.4 Management

3.4.1 Personal Arrangement Program

As mentioned in 3.1.2, Production Program, the production is planned to be increased in the future. In order to attain this program for increasing production, it is now planned to modernize the production techniques and facilities mainly in the finishing process (foundry shop) and the welding process (plate shop) as mentioned in 3.2 and 3.3.

Table 3.4.1-1 shows the personnels required in the execution of the modernization program. The total number of personnels was calculated on the following assumption:

- The numbers of personnels to be increased in some processes and jobs other than the finishing and welding processes to be modernized are the numbers required to attain the production targets in the production program with the present facilities.

- The present numbers of personnel remain unchanged in the departments which are not influenced by the production increase shown in the production program.

Table 3.4.1-1 List of Personnel

Department \ Job	Managerial and Technical Staff	Clerical Workers and Specialists	Factory Workers	Total
Plant manager and staff	3	2	0	5
Calcination plant	2	9	7	18
Production planning dept.	4	15	0	19
Quality control dept.	5	14	4	23
Production dept.	1	1	0	2
Foundry shop	6	68	124	198
Workshops (Maestranza)	8	140	89	237
Maintenance shop	2	36	23	61
Total	31	285	247	563

3.4.2 Process Control

1) Foundry shop

With regard to the production program and result, it is so arranged that a computer records the consumption (weight) and quantity of each cast part. The program list which is punched by computer and the process list (card) for each part are forwarded to the site for proceeding with every process.

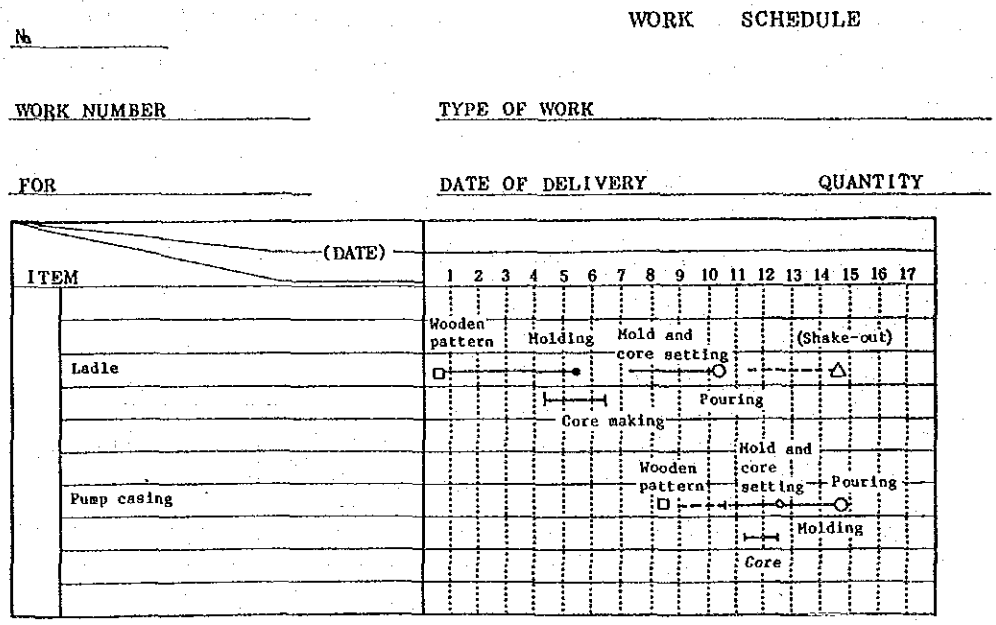
These lists produced by the computer are filled with figures and are suitable for data tabulation for cost control, etc. in the production control department, but it is difficult at the production site to understand the whole image of products at a glance of these lists. Also, since the process control must be carried out so as to deliver planned products most rationally and economically until the designated time, the key process of each part must be concretely scheduled (or planned) to keep the promise. From this point of view, this control system has some room for improvement.

(1) Preparation of daily sheet by bar chart

When the scheduling is shown by bar chart, it is quite easy to understand the details of process and the daily schedule.

For example, in the molding process (until pouring), bar charts for molding, core making, mold and core setting, and pouring are made out as shown in Table 3.4.2-1 after receipt of pattern by each part.

Table 3.4.2-1 Molding Schedule



This chart clearly shows the relations of molding timing between mold and core, and time and type of products to be poured. For making out such a bar chart, it is necessary to make arrangements in advance as to the time when patterns are delivered. It is recommended to make out plans, taking the delivery date into account, so that as many castings as possible of same material can be poured together. This type of schedule shall be made out by means of bar chart for each process in the manufacturing order even in the finishing department. In this case, it is important for the effective use of the heat treatment furnace to make arrangements so that as many castings as possible of same material can be heat treated together.

Foremen, section leaders and process controllers shall trace actual process taken with red line on the charts to check if the processes are proceeding as scheduled. When a plan includes such a time series process check, real control can be carried out.

(2) Schedule sheet and schedule control by process controller

The process controller (for the whole casting process) shall make out the schedule sheet covering the all schedules of the above various sections to understand the whole flow for process control. Or, he shall make out a list showing important dates for respective processes to check if products are passing through each process as scheduled.

Table 3.4.2-2 Process Check List

	Pat-tern	Mold-ing	Pour-ing	Shake-out	Heat Treat-ment	Finish-ing	Inspec-tion	Ship-ment
. Ladle . Mantle . Pump casing	4/3	9/3	10/3	15/3	20/3	23/3	25/3	26/3

The process controller checks the process everyday according to the check list, but it is recommended to have a meeting on schedule with related sections once a week at least. The meeting on schedule is divided into the one for the processes up to pouring and the one for finishing and shipment processes.

In the former meeting, progress of molding, modification of schedule, procurement of casting material, etc. are fully studied, and the information is forwarded to the later process of finishing.

(3) Production control at site

Each part is produced according to the schedule sheet, and both the poured and the finished quantities increase. These results can be naturally compared with the respective estimated quantities in figure everyday. But it is difficult only by comparing figures to judge if these quantities are above or below their estimated quantities and how they change in the future. In this case, use a graph showing the time series production changes, and the judgement can be made rather easily. Though such graphs are not found in the room of the site chief, it is recommended to make out these graphs and plot them every day, since they are effective to understand the tendency of the whole process.

For example, in the molding section, the completion of pouring is regarded as the completion of production. So, the total weight of poured products shall be plotted as shown in Figure 3.4.2-1 so as to know the changes everyday.

Such graphs shall be made out in the finishing section as well, and these graphs shall be posted up on a wall so that every person concerned can see these graphs any time.

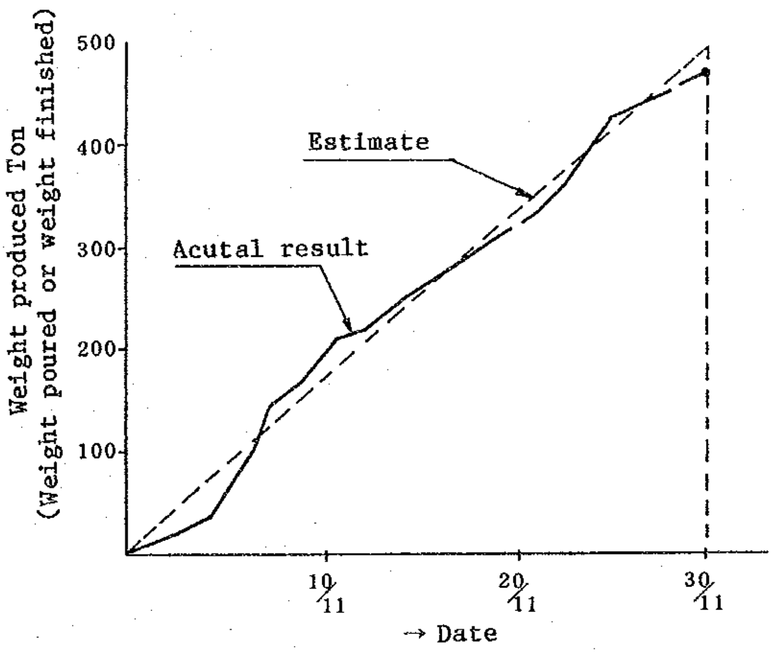


Figure 3.4.2-1 Control Chart of Production Changes

(4) Progress card

Croquis (rough sketch) are not contained usually in the progress chart but make it easy to understand progress as shown in Table 3.4.2-3. This drawing shows a wheel, but when judging shapes by name, it generally occurs that even products of same nomination have different shapes sometimes and, in a case, are quite different from what is imagined.

Though products can be identified by respective drawing numbers, the croquis are very convenient for searching for the products, in communication and meetings as well. So, it is recommended to include croquis in progress chart.

Table 3.4.2-3 Example of Progress Card (Croquis) of Casting

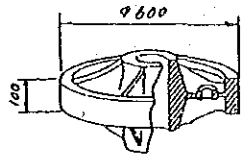
Progress Card of Casting *(3) Molding, Pouring Report*

Croquies

Rejection piece

Acceptance piece

Inspector's Certification Stamp



Issued Year Month Day

Schedule / Process	Schedule: Schedule	Schedule: Result	Manhour: Schedule	Manhour: Result	Name of Worker's Group
Pattern	/	/	/	/	
Pattern Delivery Schedule Year Month Day					
Pattern Delivery Actual Year Month Day					
Molding	/	/			
Core Making	/	/			
Drying Mold	/	/			
Mold Setting	/	/			
Pouring Date Schedule Year Month Day					
Shake Out	/	/			
Annealing	/	/			
Rough Machining	/	/			
Shipping Date Schedule Year Month Day					

Casting Shop: Sign of Chief	Casting Shop: Sign of Foreman	Sign of Chief

Section Issued: Sign of Chief	Section Issued: Sign of Staff / Checked By	Sign of Staff

Specification ______

Witness ______

Test Piece ______

Necessary Quantity ______

Test Piece No. ______

Material in Accounting	Name of Ordered Job	Name of Drawing	Customer's Address	Iron Casting / Steel Casting
		Wheel		
	Customer's Identification Number	Number of Drawing	Material to be Poured	

84060

Production Schedule Table No.	Accounting Code No.	Code for Rejected Product	Work Order No.	Classifying No.	Planned Molding Hour	Actual Mold Hour

Weight by Drawing (kg)	As Cost Weight Planned (kg)	Actual As Cast Weight (kg)	Actual Weight After Rough Machining (kg)	Contracted Weight (kg)	Store House	Stock Yard	Quantity	Actual Molding Hour

Weight/Piece	Weight/Piece	Weight/Piece	Weight/Piece	Weight/Piece	Actual Pattern Delivery Date	Actual Pattern Returned Date
					Month Day	Month Day

(5) Grasp of man-hour

Man-hours are not filled in the progress charts returned to the production control department. Castings are of job-shop type production, and it is very troublesome to totalize man-hours of all items. Also, man-hours are not accurate and reliable, and in most cases the total man-hour does not agree with the whole man-hour taken. Therefore, many foundry shops employ the process cost system. In this plant, monthly direct and indirect man-hours shall be reported from the molding, finishing and other sections to the production management department. However, it is desirable from the technical point of view at site and from the point of productivity improvement to record man-hours per item or per lot as much as practicable. Foremen and section leaders at site can surely record them. Being very important as the data for estimation of new products, man-hour reduction and revision of standard production time, actual man-hours should be recorded.

(6) Process control of important or urgently required products

This plant has a cast parts service section for mining machinery, and therefore, it is considered that the plant should produce urgently required repair parts and spare parts. Some parts among them may be very important or may be required to pass severe inspection. When producing such products, make a proper plan at the beginning keeping the proverb "More haste, less speed" in mind. Before producing casting, the technical group shall make out a flow chart like the example shown in Table 3.4.2-4, and the process controller shall decide the important date in schedule in the discussion with workers concerned at site in advance for pursuing the process without omission. This type of procedure should be applied to all products in the end, but for the time being, only to principal items with gradual expansion in view. Table 3.4.2-5 shows an example of the production procedure.

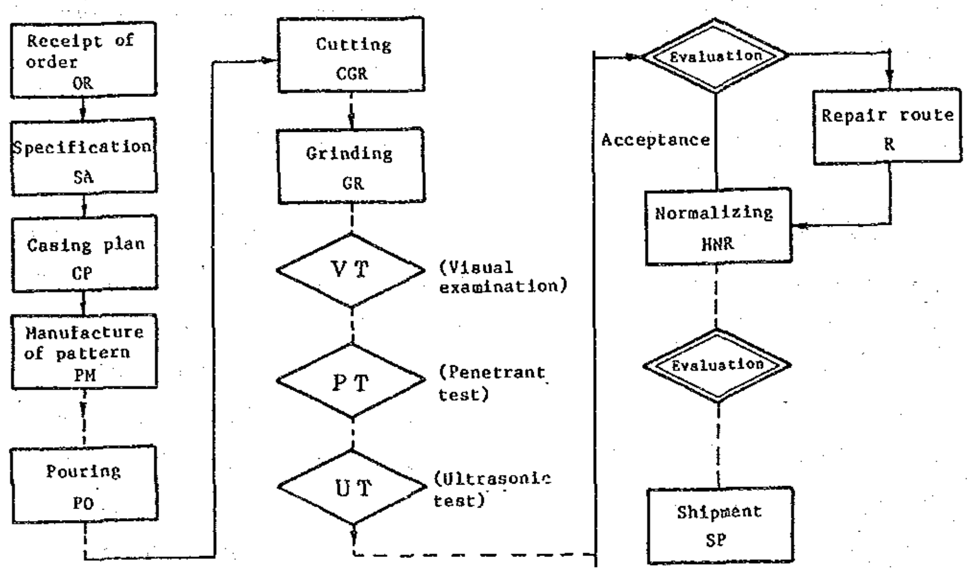
We have explained the process control with some proposals and expect this will help to improve the process control. Good control cannot be expected without any clear and accurate schedule.

Table 3.4.2-4 Flow Chart and Outline of Process Check Sheet

① Flow chart

This is to show a flow of processes for the production of casting using conventional symbols.

Example of a flow:



② Process check sheet

This is to show which manual or instructions should be applied for respective processes, whether records are required or not, which section is responsible for respective processes, etc. in order to check works in respective processes.

The flow chart ① and the process check sheet ② are practically combined to a form.

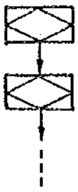
Flow	Witness	Record	Manuals	Instructions	Section in Charge	Date of Work, Signature	No.	Remarks
Example 	o	o	IS-PK-3045	–	Quality Control G	Staff A	xx	
			IS-PK-3046	–	Quality Control G	Staff B		

Table 3.4.2-5 (1/4) Example of Flow Chart (combined with the process check sheet)

	Flow Chart (PSD)	No. CPSD-80-006	Rev 1	1/6

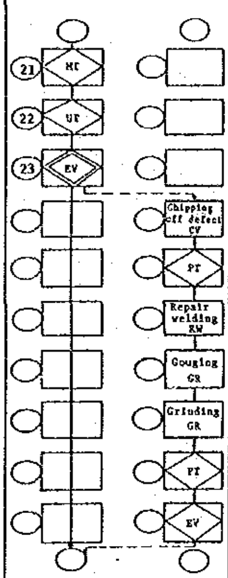
8153-017	Job No. M/S B.H.E.L	Name of Part Valve door	Drawing No. 0212-02-11001 Rev.1	Material 1.5MmSC	Weight x Quantity x 3

Item	Details		
1. Flow chart	1.1)	This flow chart applies to the subject item, cast valve door.	
2. Explanation of symbols	2.1)	VT	Visual test
	2.2)	DT	Dimensional check
	2.3)	PT	Penetrant test
	2.4)	MT	Magnetic particle examination
	2.5)	UT	Ultrasonic test
	2.6)	EV	Evaluation

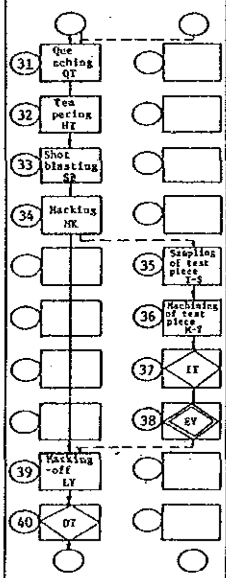
Table 3.4.2-5 (2/4) Flow Chart

Process Sequence	Whi-ness	Rec-ord	Procedure No.	Rev.	Instruction No.	Rev.	Section in Charge	Date	Operation Signature	Record No.	Remarks
1 Receipt of order OK							Production control department				
2 Specification SA			H/S B.HEL PS10556-B				Production control department				
3 Casting plan CP		®					Technical group				
4 Manufacture of pattern PM							Pattern shop				
5 Sand preparation MS							Molding shop				
6 Molding MO					CPND 80-0040	0	Pattern shop				
7 Mold setting MOS							Pattern shop				
8 Melting ME		®	H/S B.HEL PS10556-B				Melting shop				
9 LA	I	®	H/S B.HEL PS10556-B				Quality control section				
10 Pouring PO							Molding shop Melting shop				
11 Shake out OF							Finishing shop				
12 Core knock out CK							Finishing shop				
13 Cutting CGR							Finishing shop				
14 Annealing HA	®				COA 80-004	0	Finishing shop				
15 Shot blast SB							Finishing shop				
16 Chipping							Finishing shop				
17 Gauging GU							Finishing shop				
18 Grinding GR							Finishing shop				
19 DI							Finishing shop				
20 FT		®					Quality control section				

Table 3.4.2-5 (3/4) Flow Chart

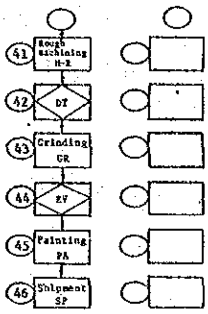


Process Sequence	Whi-ness	Rec-ord	Procedure No.	Rev.	Instruction No.	Rev.	Section in Charge	Date	Operation Signature	Record No.	Remarks
	Q	®	ASTM-138 E125-63, Degree 2				Quality control section				
	Q	®	ASTM-A609 Level 2				Quality control section				
							Quality control section				
							Finishing shop				
			CCH-70-1 KE-70-1, Class 2				Finishing shop				
							Finishing shop				
							Finishing shop				
							Finishing shop				
			CCH-70-1 RE-70-1, Class 2				Finishing shop				
							Quality control section				



Process Sequence	Whi-ness	Rec-ord	Procedure No.	Rev.	Instruction No.	Rev.	Section in Charge	Date	Operation Signature	Record No.	Remarks
		®			CQA-80-004	0	Finishing shop				
		®			CQA-80-004	0	Finishing shop				
							Finishing shop				
	C						Quality control section				
					CQA-80-004		Quality control section				
			M/S B.HEL No. PS-10556-B				Quality control section				
	C	®	M/S B.HEL No. PS-10556-B		CQA-80-004		Quality control section				
	C						Quality control section				
			DWG No. D-212-02-11001	0			Machining shop				
							Machining shop				

Table 3.4.2-5 (4/4) Flow Chart

Process Sequence	Whitness	Record	Procedure No.	Rev.	Instruction No.	Rev.	Section in Charge	Date	Operation Signature	Record No.	Remarks
											
			M/S D.HBL No. PS-10556-B				Machining shop				
	C	®	IS, 7897 -1976- Class 2				Machining shop				
							Quality control section				
							Finishing shop				
	C						Quality control section				
					In compliance with CPI-79-011.	0	Finishing shop				
							Finishing shop				

2) Plate shop

(1) Form of schedule sheet

The IBM scheduling system which has been employed in the plate shop is almost perfect, but in the workshop there are some situations which do not comply with the scheduling system (for example, there are many works in processes.)

This is attributed to the followings:

a) Delay in release of design drawing
b) Delay of raw materials and purchased items
c) The schedule is set so as not to meet the actual situation in the workshop.
d) Excess from the predetermined time due to insufficient accuracy
e) Inefficient expediting, insufficient understanding of working situations in previous and later processes by persons responsible for the schedule and workers in the related shop, and also insufficient adjustment of the schedule based on sufficient understanding of the working situations.

Div. E1 Teniente is responsible for a) and b), but no delay of schedule has been caused by these so far. Therefore, as a solution of c) and d), especially of e), we would like to propose the making-out of a process chart, with which workers can visually understand the current situations in the process. In the other words, the process chart can be utilized by means of bar chart which makes visual control possible. It is difficult to understand influence of a delay in a process on the whole production process due to the digital display of the IBM scheduling system. But the schedule sheet of bar chart method makes it possible to understand the situations of the whole production process and take proper measures in broad perspective.

The following explanation is made about an example of a schedule sheet for the production of 10 mine cars: The general production plan of mine cars (Table 3.4.2-6) shows the detailed schedules from the commencement of production of 10 mine cars to the shipment, i.e., date for charging materials, production period, inspection date and shipping date.

The production plan of mine car (Table 3.4.2-7) shows the detailed production schedule of one mine car based on the above general production plan, i.e., machining processes of single materials of all parts per block, fit-up and welding process, total assembling process, coating process, final inspection and trial operation and shipping date.

In addition, this schedule sheet may be used by detailing monthly, bi-weekly and weekly schedules.

This explanation is only for one example, and if necessary, detailed schedules per block may be made out. The work schedule can be used to know the progress of each work at a glance, for example, if it is checked for the progressed extent periodically at the expediting meeting.

When applying the example process sheet, the followings should be noted:

: Make out the schedule so as to be understood visually.
: Enter the progress of a process clearly showing the date distinctly. For example, use red pencil for the first time and black pencil for the second time.
: Keep all schedule sheets, on which progresses are completely entered (after completion of product), for future reference.
: Schedule sheets shall be posted at necessary places where attract attentions of persons concerned (including workers in the workshop) so as to let them know the current situations and consider things to be done individually.

If shall be recommended to elaborate the optimum schedule for the situations of the plate shop by carefully referring to the above explanations and proposals on schedule sheets and to use it effectively together with the IBM scheduling system.

(2) Control chart

As mentioned in the paragraph concerning the foundry, it is necessary to draw control charts to grasp the progress in each process by entering actual result each week or each ten days against the estimated production curve and to take proper measures for the process.

Also, as the control chart of productivity, a H/T curve which showes the time consumption per ton of production weight of direct workers in the plate shop, a KG/H curve which shows the consumption of welding material (kg.) per hour of welders, and another H/T curve which shows the learning effect in producing same structures repeatedly and the feedback effect during the production (Figure 3.4.2-2, showing changes of efficiency in producing welded structures of a same shape in Japan as an example) shall be drawn.

These curves will indicate the current efficiency of this shop, the measures to be taken in the future, and the effect obtained as the result of measures taken.

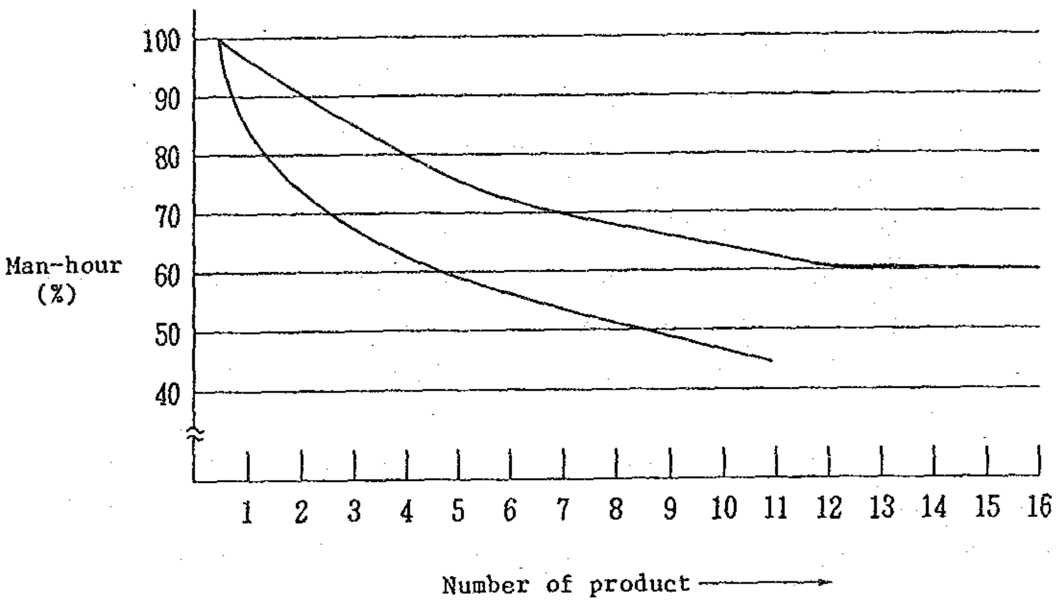


Figure 3.4.2-2 An Example of Changes of Efficiency in Producing Same Welded Structures

Work Schedule

Distri-bution	Cus-tomer	Sales Sec-tion	Produc-tion Arrange-ment	Manage-ment	Planning	Design	Spare

No. Table 3.4.2- ____________

Prepared on ____________

Section ____________

Work No. ____________ Type of Work: General Production Plan of Mine Car Quantity ____________

Dept. Manager	Section Chief	Person in Charge

For ____________ Delivery Date ____________ Point of Delivery ____________

	1	2	3	4	5	6	7	8	9	10	11	12	1	2
No. 1 Mine Car	●		×	SP ○										
No. 2 Mine Car			●		×	SP ○								
No. 3 Mine Car				●	×	SP ○								
No. 4 Mine Car					●	×	SP ○							
No. 5 Mine Car						●	×	SP ○						
No. 6 Mine Car							●	×	SP ○					
No. 7 Mine Car								●	×	SP ○				
No. 8 Mine Car									●	×	SP ○			
No. 9 Mine Car										●	×	SP ○		
No. 10 Mine Car											●	×	SP ○	

Remarks

● Charging of material　○ Trial operation

× Loading on bogie　SP Shipping

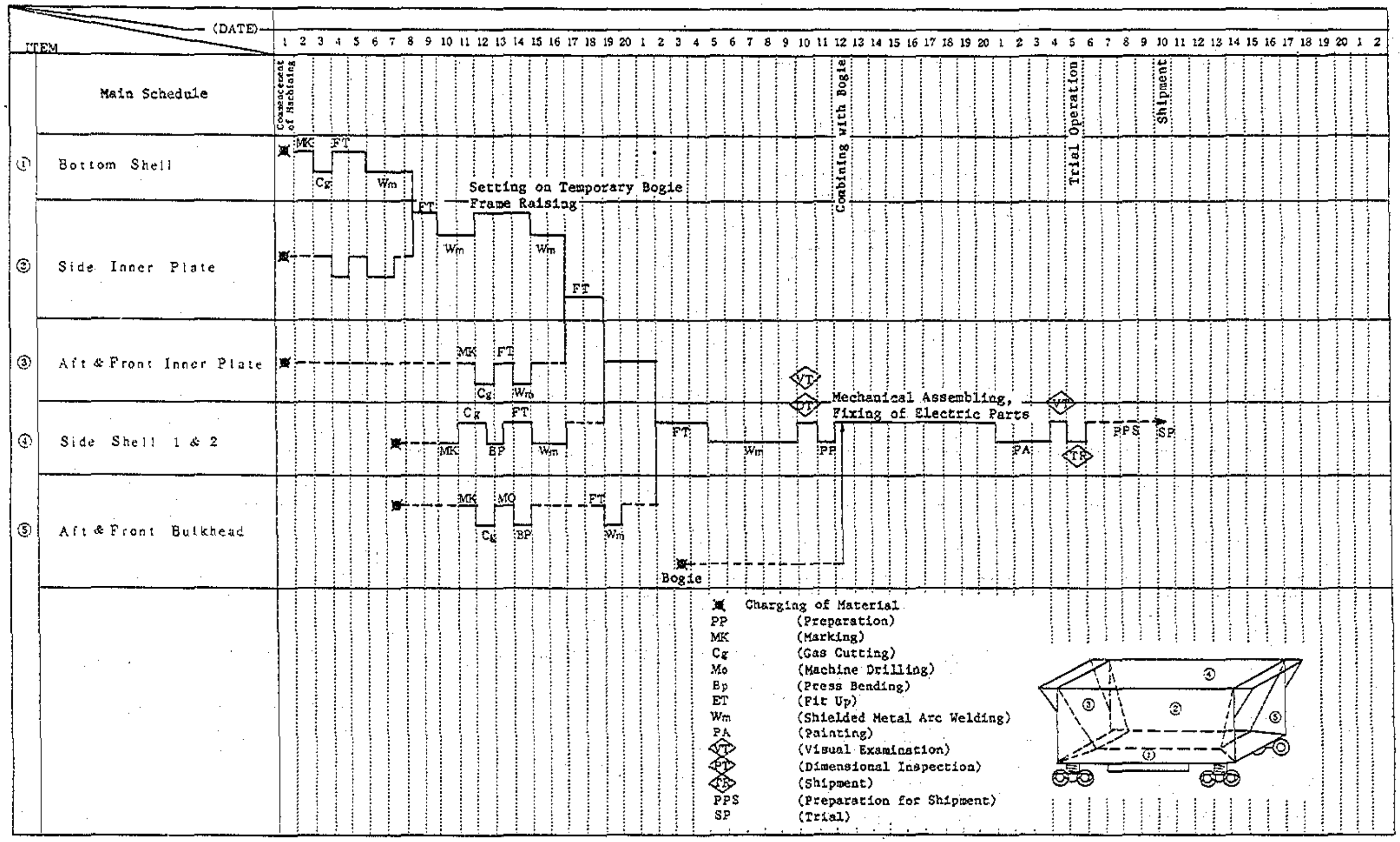
Table 3.4.2 Detailed Work Scheduled for Operation

WORK SCHEDULE

No. ______

WORK NUMBER ______ TYPE OF WORK No. 3 ______ PREPARED AS OF ______

FOR ______ DATE OF DELIVERY ______ QUANTITY ______



3.4.3 Quality Control

1) Foundry shop

The quality control in the foundry shop is provisionally complete in the quality control system, because the quality control department is organized as a shop organization to the production department. The quality control department assumes the engineering related activities with the trial manufacture of castings, and such so-called inspection activities as checking the mechanical properties of materials and analyzing the material quality become the main constituents.

The quality control can, of course, not be left in the hands of quality control department only, and is closely related with the technical and functional controls of each manufacturing process. For the purpose to deliver the products credible by customers, however, we believe that the quality control department should specifically establish the policies on how the quality in this shop is to be controlled and assured, along which the quality control should be promoted.

As discussed in para. 2.5.3 above, the current status indicates a high percent defective of castings, whose trend is also increasing year by year. This tells you that there are many improvement requirements in the ways of quality control. To manufacture the castings of high quality and reasonable price, it is indispensable to control the manufacturing processes with the backup of technologies.

This means that if the castings are manufactured, whether the techniques to be applied thereat are those firmly established as the company's technologies or not, or whether they are strictly observed or not, becomes a great keypoint for determining the technical abilities. Viewing from such a standpoint, this shop can be assumed still remaining a margin of improvements. To manufacture an article by many employees, there must have the specific, technical indexes. It is also important for every individual worker to have aspirations of how to do for manufacturing good things at a low cost. In this regard, this shop needs:

① to orderly establish the standards (for operation, processes, inspection, etc.) to become the basis of manufacture, and

② to positively exercise the quality control activities by demonstrating the comprehensive force with the full force of all employees, instead of carrying out by a certain number of specific people.

(1) For completing the standards, first, clarify every manufacturing or inspection process per product, as shown in Table 3.4.3-1 to 3.4.3-5 below, then, prepare the lists of items to be controlled per process, i.e. the QC flow charts.

The QC flow charts as given with this case consist of the following items, i.e. the design is made to control the following items per process along the manufacturing process flow.

- What are the machines and equipment to be used?
  Ex: Shake-out process = Shake-out machine

- What are the quality characteristics to be controlled?
  What are the standards to be used for this control?
  How important are these characteristics to be positioned in the manufacturing processes?
  Ex: Melting process:
  Control item = Adding quantity of deoxidant
  Standard = Al at 0.3 to 1.0 kg/ton
  Importance = A

- What are the production control characteristics to be specified for production control items per process? What is a control level for it? How important is this control in each manufacturing process?
  Ex: Shot blasting process
  Control item = Shot blasting time
  Control level = Equal to or more than 15 minutes
  Importance = B

- What are the measuring instruments and methods to be applied to control these processes?
  Ex: Pouring process (pouring time)
  Measuring instrument = Stopwatch
  Method = Measurement by a measuring operator

- What is the control technique, total quantity or sampling? What are the sampling technique and rate?

  Ex: Casting sand procurement:

  Control technique = Sampling

  Sampling technique and rate = One per receiving

- Who is the competent controller?

  Ex: Molten metal tapping process (tapping temperature):

  Temperature check = Operator

  Judgement at an emergency = Foreman (Team leader)

- What are the standards applicable to perform the said process? In another word, under what standards should it be worked out?

  Ex: Heat treatment process:

  Standards = Heat treatment operating standards

- What are the control means to be applied, check sheet, control chart, performance sheet or daily report?

  Ex: Casting sand mixing process:

  Control means = Control chart

- How to deal with an emergency?

  Ex: Casting process; Casting temperature below the standard

  Action = Discontinue the pouring work

- Specify other remarks and precautions, as required.

The foregoing represent a summary of descriptions to be specified in the QC flow chart. Listing them in the process order results in clarifying what and how are to be controlled and what standards are required as well. These standards should be prepared by examining the further detailed quality and control characteristics based on the QC flow charts, but they should not be too ideal to run out of the actual present abilities. Thoroughly grasping the actual situation of present shop, standardize them at a maximum and best manner. For the theoretical requirements, however, no current condition, if it deviates from the theory, can be accepted. If 1,450°C is theoretically required for casting temperature, for example, the actual condition of 1,400°C, cannot straightly be adopted, even though it is so insisted by reason of actually doing so. It is an urgent requirement to first improve and bring the techniques to a posture that they should be originally.

For the operation manuals, it is better to stipulate the procedures and methods by intensifying them into the best understandable ways in this shop, including the job instructions of intuitions and know-how together with the illustrations, figures, etc. It is also advised to provide the cautions with respect of safety of jobs. The standards so prepared must sufficiently be used in the manufacturing processes. For this purpose, it is necessary to pay attention to the following.

a) These standards are to be prepared for such closely related departments as technical, production and inspection departments. It is necessary for every department to maintain all standards and to thoroughly understand the contents. It should be avoided that the foundry shop has no inspection standard, for example, because of no direct necessity.

b) Thoroughly disseminate the prepared standards to all concerns to train the workers so that they should be observed. This is a link with the worker training. Workers will understand why is necessary to do so. Such an effect may also be demonstrated that workers may pay various considerations to jobs which they have worked merely as instructed till now.

c) Modern technologies advance very fast. They may, therefore, often move to completely new technologies within a few years. These standards, if they are once prepared, cannot be said that this is it. Many improvement requirements ought to come out of the daily work. Upon adopting the better procedures and methods, the standards must also be revised. Unless the standards are properly maintained, they become a simple decoration. For this purpose, it is necessary to organize an audit group to conduct a regular audit and to control them so that they may be the live standards at all times. For the preparation of standards, five examples of QC flow chart samples are given as follows.

Table 3.4.3-1: QC flow chart of cast steel molding

Table 3.4.3-2: QC flow chart of arc type electric furnace dissolution for castings

Table 3.4.3-3: QC flow chart of high manganese cast steel finish

Table 3.4.3-4: QC flow chart of heat-resisting cast steel finish

Table 3.4.3-5: QC flow chart of cast stainless steel finish

Table 3.4.3-1 Green Sand Molding—From Receiving of Casting Sand to Shake-out (1/2)

Responsibility symbol		
	✓	Check or plot
	△	Reporting (at emergency)
	○	Action

(Company)
Address and Tel No.
Writer's name and section

Process No. and Symbol	Process Name	Machine Equipment	Quality Characteristic: Importance Class	Quality Characteristic: Control Item	Quality Characteristic: Standard	Production Control Characteristic: Importance Class	Production Control Characteristic: Control Item	Production Control Characteristic: Control Level	Measuring Instrument and Method	Control Technique: Total Q'ty	Control Technique: Sampling	Control Technique: Sampling Technique and Rate	Responsible Person: Worker	Responsible Person: Inspector	Responsible Person: Foreman or team leader	Responsible Person: Section chief or supervisor	Responsible Person: Section manager	Standards: Operation standard	Standards: Technical standard	Standards: Inspection standard	Standards: Purchase standard	Standards (Standard No.)	Check sheet	Control chart	Report and record sheet	Time series data	Daily report and journal	Check Sheet, Control Chart, Inspection Record, etc. (Applied book name)	Emergency Treatment	Remarks
◇ 1	Receiving of casting sand		A	Chemical components	SiO_2 ≥ 94%				Checking the specification sheet		○	Once per receiving		✓	△	○					○	Purchase standards			○			Purchase book	Lot change or return	
			A	Grain size	JIS G5901 No.48 or equivalent				Low tap sieving machine (JIS Z2602)		○	↑		✓	△	○					○	↑			○			↑	↑	Accuracy control as per the examination standards of test equipment
▽ 2	Storing of casting sand					B	Location	No mixture	Visually	○		At storing	✓		○ △		○					Operating standards							Checking the stored location	
					Facing sand / Backing sand																									
③	Sand preparation	Mix muller (Simpson type)	A	Moisture (%)	3.6 ±0.7 / 3.6 ±0.8				Moisture tester (JIS Z 2605)		○	Twice/day	✓		△	○		○	○			Operating standards, Technical standards		○			○	Daily report, Control chart	Remeasurement, checking of mixing quantity	Accuracy control as per the examination standards of measuring instruments
			A	Compression (kgf/cm^3)	0.8 ±0.3 / 0.8 ±0.4				Sand testing equipment (JIS Z 2604)		○	↑	✓		△	○		○	○			↑		○			○	↑	↑	Accuracy control as per the examination standards of test equipment
			A	Permeability	200 ±95 / 200 ±95				Permeability gauge (JIS Z 2603)		○	↑	✓		△	○		○	○			↑		○			○	↑	↑	Accuracy control as per the examination standards of measuring instruments (Permeability and Compactability)
			A	Compactability (%)	48 ±8 / 48 ±8				C.B. measuring instrument		○	↑	✓		△	○		○	○			↑		○			○	↑	↑	
						A	Mixing q'ty	Instructed q'ty ±1%	Weighing scale or measure	○			✓		△	○		○	○			↑					○	Daily report		Accuracy control as per the examination standards of weighing scale
						A	Mixing order	As per operating standards		○			✓		△	○		○				Operating standards					○	↑		
						B	Mixing time	↑	Synchronized with a timer	○			✓		△	○		○				↑					○	↑	Adjust the timer at emergency	
④	Holding	Jolt-squeeze machine	A	Surface stability	No ragging sand				Touching test	○			✓		△	○		○				Operating standards					○	Daily report	Sand-green property measurement	
			A	Damage of mold	NG				Visually	○			✓		○ △			○				↑					○	↑	Repair or reject	
			A	Mold dimensions	As per casting plan instructions				Special gauge		○	Once/specific mold	✓		△	○		○				↑					○	↑	Rechecking and repair of mold	Accuracy control as per the examination standards of dimensional measuring instruments
			B	Indication of charge no. and lot no.	Exact and clear				Visually	○			✓		○ △			○				↑					○	↑		
			B	Mold hardness	Plane ≥ 80 Side surface ≥ 70				Hardness tester		○	Once/change of preparation	✓		○ △			○				↑					○	↑	Readjustment of sand quantity and squeeze	Accuracy control as per the examination standards of measuring instruments
			B	Filling density	To be sensed				Visually	○			✓		○ △			○				↑					○	↑		
						A	Mold damage and wear	NG	↑	○			✓		△	○		○				↑	○					Inspection report	Pattern repair	
						A	Wear of mold flask pins and bushes	Pin 0 to 0.1mm Bush +0.1 to 0mm	Special gauge		○	Once/day	✓		○ △			○				↑	○					↑	Exchange of pin and bush	Accuracy control as per the examination standards of dimensional measuring instruments
						A	Wear of mold flask pins and bushes	Pin 0 to 0.2mm Bush +0.2 to 0mm	Special gauge		○	Once/before work	✓		○ △			○				Operating standards	○					Inspection report	Exchange of pin and bush	Accuracy control as per the examination standards of dimensional measuring instruments
						A	Looseness of pattern and plate	NG	Visually		○	Once/change of preparation	✓		○ △			○				↑	○					↑	Pattern repair	
						B	Thickness of facing sand	20 to 50mm	Special gauge		○		✓		○ △			○				↑					○	Daily report		Accuracy control as per the examination standards of dimensional measuring instruments
						B	Jolt pressure and time	3.5 to 7 kgf/cm^3 5 to 20 sec	Pressure gauge and timer	○			✓		△	○		○				↑					○	↑	Readjustment	Accuracy control as per the examination standards of measuring instruments
						B	Position and size of gas vent hole	As per casting plan instructions	Visually	○			✓		○ △			○	○			Operarting standards Technical standards					○	↑	Repair	

(Note) Process symbols: ◇ = Mainly for processes requiring inspection
▽ = Storage and storing process
○ = Operating process

Table 3.4.3-1 Green Sand Molding—From Receiving of Casting Sand to Shake-out (2/2)

Responsibility symbol	
✓	Check or plot
△	Reporting (at emergency)
○	Action

(Company)
Address and
Tel No.
Writer's name
and section

Process No. and Symbol	Process Name	Machine Equipment	Quality Characteristic: Importance Class	Quality Characteristic: *Control Item*	Quality Characteristic: Standard	Production Control Characteristic: Importance Class	Production Control Characteristic: *Control Item*	Production Control Characteristic: Control Level	Measuring Instrument and Method	Control Technique: Total Q'ty	Control Technique: Sampling	Control Technique: Sampling Technique and Rate	Responsible Person: Worker	Responsible Person: Inspector	Responsible Person: Foreman or team leader	Responsible Person: Section chief or supervisor	Responsible Person: Section manager	Standards: Operation standard	Standards: Technical standard	Standards: Inspection standard	Standards: Purchase standard	Standards: (Standard No.)	Check Sheet, Control Chart, Inspection Record, etc.: Check sheet	Control chart	Report and record sheet	Time series data	Daily report and journal	(Applied book name)	Emergency Treatment	Remarks
						B	Chill	No rust as per casting plan instructions	↑	○			✓		○ △			○	○			↑					○	↑	Recleaning or replacement	
						B	Mold leaving time	As per operating standards		○			✓		△	○		○				Operating standards								
						B	Drawing horizontally	Gauge gap ≤ 0.5mm	Special gauge		○	Once/ before work	✓		○ △		○					↑	○					Inspection report	Readjustment	Accuracy control as per the examination standards of dimensional measuring instruments
⑤	Core setting					A	Core movement and fall	Within 0.5 mm	Special gauge	○			✓		○ △			○				Operating standards					○	Daily report	Reset	Accuracy control as per the examination standards of dimensional measuring instruments
						A	Mold inside cleaning	Neither free from sand nor foreign matter	Visually	○			✓		○ △			○				↑					○	↑	Cleaning by compressed air	
						B	Position and material of *Chaplet and* insert chill	As per casting plan *instructions*	↑	○			✓		○ △			○	○			Operating standards, Technical standards					○	↑	Repair	
						B	Gas vent connection	↑	↑	○			✓		○ △			○	○			↑					○	↑	↑	
⑥	Mold setting	Mold setting machine				A	Wear and bending guide pins	Wear ≤ 0.2mm Bending NG	Gauge and visually	○			✓		○ △			○				Operating standards						Daily report	Pin exchange	Accuracy control as per the examination standards of dimensional measuring instruments
						B	Clamping	Uniformly	Visually	○			✓		○			○				↑					○	↑	Mold resetting	
						B	Matching between pouring cups and sprues		↑	○			✓		○ △			○				↑					○	↑	↑	
⑦	Pouring	Ladle				A	Pouring temperature	1535 to 1585°C As per operating standards	Dipping temperature thermometer or optical pyrometer		○	Once/before pouring	✓		△	○		○	○			Operating standards, Technical standards					○	Daily report		Accuracy control as per the examination standards of dimensional measuring instruments
						A	Pouring time	As per operating standards	Stopwatch		○	For specific castings only	✓		△	○		○	○			↑					○	↑		
						B	Casting order	↑	Visually	○			✓		○ △			○	○			↑					○	↑		Cast the high quality products intermediately
						B	Riser height	As per casting plan instructions	↑	○			✓		○ △			○	○			↑					○	↑		
						B	Applied quantity of riser insulation material		Visually count the number of bags	○			✓		○ △			○	○			↑					○	↑		
						B	Nozzle diameter	As per casting plan instructions	Visually	○			✓		△	○		○	○			Operating standards, Technical standards					○	Daily report		
⑧	Shake-out	Shakeout machine				A	Cooling time of keeping in mold inside or product temperature	As per operating standards	Watch and thermocouple	○			✓		○ △			○				Operating standards					○	Daily report		Indicate a time of leaving in the mold for specific products

Table 3.4.3-2 Melting Process by Arc Type Electric Furnace—From Receiving of Raw Materials to Tapping (1/2)

Responsibility symbol	
✓	Check or plot
△	Reporting (at emergency)
○	Action

(Company)	
Address and Tel No.	
Writer's name and section	

Process No. and Symbol	Process Name	Machine Equipment	Quality Characteristic: Importance Class	Quality Characteristic: Control Item	Quality Characteristic: Standard	Production Control Characteristic: Importance Class	Production Control Characteristic: Control Item	Production Control Characteristic: Control Level	Measuring Instrument and Method	Control Technique: Total Q'ty	Control Technique: Sampling	Control Technique: Sampling Technique and Rate	Responsible Person: Worker	Responsible Person: Inspector	Responsible Person: Foreman or team leader	Responsible Person: Section chief or supervisor	Responsible Person: Section manager	Standards: Operating standard	Standards: Technical standard	Standards: Inspection standard	Standards: Purchase standard	Standards (Standard No.)	Check sheet	Control chart	Report and record sheet	Item entries data	Daily report and journal	Check Sheet, Control Chart, Inspection Record, etc. (Applied book name)	Emergency Treatment	Remarks
◇ 1	Receiving of raw materials (steel scraps)		A	Impurities (nonferrous)	Mixing = NG				Visually or with an analyzer		○	Once/receiving	✓		○ △						○	Purchase standards					○	Purchase book	Return	Accurate control as per examination standards of analyzer
			A	Size and shape	As per purchase standards				Visually		○	↑	✓		○ △						○						○	↑	Return or recutting	It is preferable to use JIS G 2401 Class-A No.1 for carbon steel and low alloy cast steel
	Receiving of raw materials (alloy iron)		A	Chemical composition	As per JIS				Composition analysis check	○		At receiving		✓	○ △						○	Purchase standards			○			Purchase book	Return of items out of the standards	
▽ 2	Material storage		A	Mixture of different materials	NG				Visually		○	Once/week	✓		○ △			○				Operating standards							Prohibited use of materials mixed with different materials	
○ 3	Issuance of materials					B	FIFO (First-IN, First-OUT)	FILO (First-IN, First-OUT) = NG	Visually	○		At issuance	✓		○ △			○				Operating standards					○	Issue book		
○ 4	Material mixing	Lifting magnet, weighing bucket				B	Weight of main raw material	As per operating standards (Indicated quantity ± within the allowable range)	Weighing scale	○			✓		○ △			○				Operating standards					○	Daily melting report		Accurate control as per examination standards of weighing scale
						B	Weight of steel scraps	↑	↑	○			✓		○ △			○				↑					○	↑		
						B	Weight of returned scraps	↑	↑	○			✓		○ △			○				↑					○	↑		
						B	Weight of ground chips	↑	↑	○			✓		○ △			○				↑					○	↑		
○ 5	Material charging					A	Alloy mixing	As per operating standards (Indicated quantity ± Within the allowable range)	Weighing scale	○			✓		○ △			○				Operating standards					○	Daily melting report		Accurate control as per examination standards of weighing scale
						B	Charging order	As per operating standards	Visually	○			✓		○ △			○				↑					○	↑		
○ 6	Melting	Arc furnace (basic)				A	Melted C-quantity	0.3 to 0.6%	Analyzer (Quant-back) or visually check the fracture	○		At melting		✓	○ △			○		○		Operating standards, Technical standards					○	Daily melting report	Carburization in case of low carbon	Accurate control as per examination standards of analyzer
						A	Oxygen blowing temperature	≥ 1580°C	Dipping temperature thermometer	○		At blowing	✓		○ △			○				Operating standards					○	↑		Accurate control as per examination standards of temperature gauge
						A	C-quantity after oxygen blowing	0.10 to 0.15%	Analyzer (Quant-back)	○		After blowing		✓	○ △			○		○		Operating standards, Technical standards					○	↑	Reblowing in case of high	Accurate control as per examination standards of analyzer
						B	Removed sludge quantity	≥ 90%	Visually	○			✓		○ △			○				Operating standards					○	↑		
						B	Melting voltage	As per operating standards	Voltmeter	○			✓		○ △			○				↑					○	↑		Accurate control as per examination standards of measuring instruments
						B	Refining voltage	As per operating standards	Voltmeter	○			✓		○ △			○				Operating standards					○	Daily melting report		Accurate control as per examination standards of measuring instruments
◇ 7	Component check		A	Chemical composition	As per intracompany specifications or JIS				Analyzer (Quant-back)	○		Before tapping		✓	○ △			○		○		Operating standards, Technical standards		○			○	Control chart, Daily melting report	Readjustment at an emergency	Accurate control as per examination standards of analyzer

(Note) Process symbols: ◇= Mainly for processes requiring inspection
▽= Storage and storing process
○= Operating process

Table 3.4.3-2 Melting Process by Arc Type Electric Furnace—From Receiving of Raw Materials to Tapping (2/2)

Responsibility symbol		
✓	Check or plan	(Company)
△	Reporting (at emergency)	Address and Tel No.
○	Action	Writer's name and section

Process No. and Symbol	Process Name	Machine Equipment	Quality Characteristic: Importance Class	Quality Characteristic: Control Item	Quality Characteristic: Standard	Production Control Characteristic: Importance Class	Production Control Characteristic: Control Item	Production Control Characteristic: Control Level	Measuring Instrument and Method	Control Technique: Total Q'ty	Control Technique: Sampling	Control Technique: Sampling Technique and Rate	Responsible Person: Worker	Responsible Person: Inspector	Responsible Person: Foreman or team leader	Responsible Person: Section chief or supervisor	Responsible Person: Section manager	Standards: Operation standard	Standards: Technical standard	Standards: Inspection standard	Standards: Purchase standard	Standards (Standard No.)	Check sheet	Control chart	Report and record sheet	Time series data	Daily report and journal	Check Sheet, Control Chart, Inspection Record, etc. (Applied book name)	Emergency Treatment	Remarks
⑧	Killing check		A	Killing	No blister				Metal mold for killing check or visually	○		Before tapping	✓		○ △			○				Operating standards					○	Daily melting report	Add deoxidant or refine again in case of deoxidation shortage, and reject of molten metal in case of substantial blister.	
⑨	Tapping	Ladle				A	Added deoxidant quantity	Al 0.5 to 1.0 kg/t	Weighing scale	○		Before tapping	✓		○ △			○				Operating standards					○	Daily melting report		Accurate control as per examination standards of weighing scale
						B	Ladle temperature	≥ 800°C	Visually	○		↑	✓		○ △			○				↑					○	↑		
			A	Tapping temperature	As per intra-company standards				Dipping temperature thermocouple	○		↑	✓		○ △			○				↑					○	↑	Killing after receiving molten metal in case of too high temperature	Accurate control as per examination standards of temperature gauge
			A	Ladle analysis value	As per intra-company specifications or JIS				Analyzer (Quant-back)	○		After receiving molten metal		✓	○ △					○		Inspection standards		○			○	Control chart Daily welding report	Suspend the casting in case of a deviation from the intra-company specifications or JIS	Accurate control as per examination standards of analyzer

Table 3.4.3-3 High Manganese Cast Steels (1/2)

Responsibility symbol	
✓	Check or plot
△	Reporting (at emergency)
○	Action

(Company)
Address and Tel No.
Writer's name and section

Process No. and Symbol	Process Name	Machine Equipment	Quality Characteristic: Importance Class	Quality Characteristic: Control Item	Quality Characteristic: Standard	Production Control Characteristic: Importance Class	Production Control Characteristic: Control Item	Production Control Characteristic: Control Level	Measuring Instrument and Method	Control Technique: Total Q'ty	Control Technique: Sampling	Control Technique: Sampling Technique and Rate	Responsible Person: Worker	Responsible Person: Inspector	Responsible Person: Foreman or team leader	Responsible Person: Section chief or supervisor	Responsible Person: Section manager	Standards: Operating standard	Standards: Technical standard	Standards: Inspection standard	Standards: Purchase standard	Standards: (Standard No.)	Check Sheet, Control Chart, Inspection Record, etc.: Check sheet	Control chart	Report and record sheet	Time series data	Daily report and journal	(Applied ordinary name)	Emergency Treatment	Remarks
①	Shake-out	Shake-out machine				A	Cooling time keeping in mold flask	As per operating standards	Watch	○			✓		△	○		○				Operating standards					○		Revise the standards	
②	Cleaning	Shot blast				B	Degree of sand sticking	A degree available to remove the riser, and ingate	Visually	○			✓		△	○		○				Operating standards					○		Re-execution	
③	Heat treatment	Heat treatment furnace				A	Loading method	As per operating standards	Visually	○			✓		△	○		○				Operating standards	○				○		Heat retreatment	
	(Water toughening)	Water tank				A	Temperature rising rate	↑	Automatic temperature recorder	○			✓		△	○		○				↑			○		○	Heat treatment chart		
						A	Retaining temperature	1050 to 1100°C	↑	○			✓		△	○		○				↑			○		○	↑		
						A	Retaining temperature	1.5 hr/inch	↑	○			✓		△	○		○				↑			○		○	↑		
						A	Water temperature	40°C or below	Mercury temperature gauge	○			✓		○ △			○				↑					○			
						A	Surface temperature right after drawing out of water	150°C or below	Surface temperature gauge		○	Anytime	✓		△	○		○				↑					○			
④	Cutting (Cutting)	Gas cutting machine	A	Too much cut	NG				Visually and scale	○			✓		△	○		○				Operating standards					○		Review the cutting method	
						A	Cutting position	As per drawing	↑	○			✓		△	○		○				↑					○			
	(Gouging)	Arc air gouging devices	A	Extra thickness	NG				Visually	○			✓		△	○		○				↑					○			
⑤	Finishing	Arc air gouging devices	A	Degree of surface defect	As per inspection standards				Visually	○			✓		△	○		○		○		Operating standards Technical standards					○		Repair	
		Grinder	B	Degree of grinding off fins and mold shift	None				↑	○			✓		○ △			○		○							○		Repair	
			B	Unevenness of as-casted surface	Degree up to not substantially impairing appearance				↑	○			✓		○ △			○		○							○			
◇6	Inspection (As-cast)		A	Appearance	As per inspection standards				Visually	○				✓		△	○			○		Inspection standards			○		○	Inspection certificate	Repair	
			A	Shape and dimensions					Measuring tools like scale	○				✓		△	○			○		↑			○		○		↑	
			A	Crack (traces after removing the riser, runners, etc.)					PT	○				✓		△	○			○		↑			○		○		↑	
			A	Indication					Visually	○				✓		△	○			○		↑			○		○		↑	
◇7	Defect removal	Arc air gouging devices and grinders	A	Degree of defect removal	Complete removal of cracks All others as per inspection standards				Visually, PT	○			✓			△	○		○		○	Inspection standards, Technical standards					○	Defect record		

(Note) Process symbols: ◇ = Mainly for processes requiring inspection
▽ = Storage and storing process
○ = Operating process

Responsibility symbol	
✓	Check or plot
△	Reporting (at emergency)
○	Action

(Company)
Address and Tel No.
Writer's name and section

Table 3.4.3-3 High Manganese Cast Steels (2/2)

Process No. and Symbol	Process Name	Machine Equipment	Quality Characteristic: Importance Class	Quality Characteristic: Control Item	Quality Characteristic: Standard	Production Control Characteristic: Importance Class	Production Control Characteristic: Control Item	Production Control Characteristic: Control Level	Measuring Instrument and Method	Control Technique: Total Q'ty	Control Technique: Sampling	Control Technique: Sampling Technique and Rate	Responsible Person: Worker	Responsible Person: Inspector	Responsible Person: Foreman or team leader	Responsible Person: Section chief or supervisor	Responsible Person: Section manager	Standards: Operating standard	Standards: Technical standard	Standards: Inspection standard	Standards: Purchase standard	Standards (Standard No.)	Check Sheet, Control Chart, Inspection Record, etc.: Check sheet	Control chart	Report and record sheet	Time series data	Daily report and journal	(Applied book name)	Emergency Treatment	Remarks
(8)	Welding repair	Ac arc welding equipment				A	Type of welding rod	As per operating standards	Visually	○			✓		△	○		○	○			Operating standards, Technical standards					○	Repair procedure and record	Rewelding	
		Dryer				A	Drying temperature and time of welding rods	↑	Strength gauge	○			✓		△	○		○	○			↑					○	↑	Rebaking	
						A	Current	↑	Ammeter		○	Anytime	✓		△	○		○	○			↑					○	↑		
						A	Interlayer temperature	↑	Surface temperature gauge		○	↑	✓		△	○		○	○			↑					○	↑		
(9)	Inspection (Portion repaired)		A	Welding defect	NG				Visually, PT	○			✓		△	○						Inspection standards			○		○		Repair welding	
(10)	Machining	Lathe turning machine	A	Dimensions	As per drawings				Scale and other measuring tools	○			✓		△		○		○			Operating standards	○				○		Remachining	For those with machining specifications
(11)	Inspection		A	Dimensions	As per inspection standards					○				✓		△	○			○		Inspection standards				○	○	Inspection certificate	Repair or remachining	
	(Machined parts)		A	Defect degree	↑					○				✓		△	○			○		↑				○	○			
(12)	Painting		B	Coating thickness	As per operating standards				Visually		○		✓			△	○		○			Operating standards					○		Repainting	Rust prevention of machined surfaces
(13)	Shipping		A	Wrong item	NG				Manufacture no. check	○			✓		△	○											○	Transportation request		
			B	Rust on machined surfaces	None				Visually	○			✓		△	○														
						B	Packaging	As per operating standards	↑	○			✓		△	○			○			Operating standards								

Table 3.4.3-4 Heat Resistance Cast Steels (1/3)
(Martenstic Series: SCH1, 3 Ferritic Series: SCH2)

Responsibility symbol		(Company)
✓	Check or plot	Address and Tel No.
△	Reporting (at emergency)	Writer's name and section
○	Action	

Process No. and Symbol	Process Name	Machine Equipment	Quality Characteristic: Importance Class	Quality Characteristic: Control Item	Quality Characteristic: Standard	Production Control Characteristic: Importance Class	Production Control Characteristic: Control Item	Production Control Characteristic: Control Level	Measuring Instrument and Method	Control Technique: Total Q'ty	Control Technique: Sampling	Control Technique: Sampling Technique and Rate	Responsible Person: Worker	Responsible Person: Inspector	Responsible Person: Foreman or team leader	Responsible Person: Section chief or supervisor	Responsible Person: Section manager	Standards: Operation standard	Standards: Technical standard	Standards: Inspection standard	Standards: Purchase standard	Standards (Standard No.)	Check Sheet, Control Chart, Inspection Record, etc.: Check sheet	Control chart	Report and record sheet	File series data	Daily report and journal	(Applied book name)	Emergency Treatment	Remarks
①	Shake-out	Shake-out machine				B	Cooling time keeping in mold flask	As per operating standards	Watch	○			✓		△	○		○				Operating standards					○	Shake-out record		Special molten metal <200°C
②	Shake-out	Shot blast				B	Degree of sand sticking	Degree available to remove the riser and ingate	Visually	○			✓		△	○		○				Operating standards							Re-execution	
③	Heat treatment	Heat treatment furnace				A	Temperature rising rate	≦ 100 to 150°C/hr	Temperature recorder	○			✓		△	○		○				Operating standards					○	Heat treatment record		
	(Annealing)					A	Retaining temperature	850 to 930°C	↑	○			✓		△	○		○				↑					○	↑		
						A	Retaining temperature	1 hr/in > 0.5	↑	○			✓		△	○		○				↑					○	↑		
						A	Cooling method	Furnace cooling	↑	○			✓		△	○		○				↑					○	↑		
						A	Loading method	As per operating method	Visually	○			✓		△	○		○				↑								
④	Cutting																													
	(Cutting)	Powder cutting machine	A	Too much cut	None				Visually	○			✓		△	○		○				Operating standards					○	Daily cutting report		
						A	Cutting position	As per drawings	↑	○			✓		△	○		○				↑					○	↑		
						A	Preheat temperature	200 to 350°C	Surface temperature gauge	○			✓		△	○		○				↑					○	↑		
	(Gouging after cutting)	Carbon arc DC machine	A	Extra thickness	As per operating standards				Visually	○			✓		△	○		○				↑					○	↑		
⑤	Descaling	Shot blast	B	Scale sticking	NG				Visually	○			✓		△	○		○				Operating standards								
⑥	Finishing	Grinder	A	Degree of surface defect	As per inspection standards				Visually	○			✓		△	○				○		Operating standards					○	Daily finish report		
			B	Degree of sand burn-in and fins					↑	○			✓		△	○				○		↑					○			
			B	Casting surface roughness					↑	○			✓		△	○				○		↑					○			
			A	Dimensions	As per drawings (generally as per JIS medium roughness)				Vernier calipers and scales	○			✓		△	○				○		↑					○			
⑦ (◇)	Inspection		A	Degree of surface defect	Customer specifications and inspection standards				Visually and limit samples	○				✓	△	○	○			○									Repair or refabrication	
	(Appearance and dimensional non-destructive)		A		Drawings				Vernier calipers, gages and straight scale																				↑	See JIS B 0012

(Note) Process symbols: ◇ = Mainly for processes requiring inspection
▽ = Storage and storing process
○ = Operating process

Table 3.4.3-4 Heat Resistance Cast Steels (2/3)
(Martenstic Series: SCH1, 3 Ferritic Series: SCH2)

Responsibility symbol	
✓	Check or plot
△	Reporting (at emergency)
○	Action

(Company) Address and Tel No.
Writer's name and section

Process No. and Symbol	Process Name	Machine Equipment	Quality Characteristic: Importance Class	Quality Characteristic: Control Item	Quality Characteristic: Standard	Production Control Characteristic: Importance Class	Production Control Characteristic: Control Item	Production Control Characteristic: Control Level	Measuring Instrument and Method	Control Technique: Total Q'ty	Control Technique: Sampling	Control Technique: Sampling Technique and Rate
		(MT)(PT)	A	Degree of surface defect	Customer specifications and inspection standards				Visually and limit samples			
		(RT)	A	Degree of internal defect	↑				Film and visually			
(8)	Defect removal	Grinder	A	Harmful defect	Complete removal of cracks				Visually, PT, MT	○		
		Gouging	A	Small defect	Round-off				Visually			
(9)	Welding repair	DC welding equipment				A	Current and voltage	Operating standards	Meters	○		
						A	Pre-heating and after-heating	↑	↑			
						A	Interlayer temperature	↑	↑			
						A	Type of welding rods	↑	Visually			
						A	Drying temperature of welding rods	250 to 350°C	Temperature gauge			
						A	Drying time of welding rods	≥ 30 min.	Watch			
(10)	Heat treatment					A	Charging temperature	Operating standards	Automatic temperature recorder	○		
	(Solution treatment)					A	Temperature rising rate	≤ 150°C	↑			
						A	Retaining temperature	1050 to 1100°C	↑			
						A	Retaining time	1 hr/in	↑			
						A	Cooling method	Operating standards	↑			
◇(12)	Inspection (Machined parts)	(Same as Step ◇(7) above)										
(13)	Heat treatment (Stress removal annealing)	(Same as Step (3) above)										
◇(14)	Inspection											
	(Appearance)		A	Degree of surface defect	As per standard cast face photographic book and inspection standards				Visually	○		
	(Dimensions)		A	Dimensions	As per JIS B 0417 and drawings				Scale, vernier caliper and micrometer	○		

Process No. and Symbol	Process Name	Responsible Person: Worker	Responsible Person: Inspector	Responsible Person: Foreman of team leader	Responsible Person: Section chief or supervisor	Responsible Person: Section manager	Standards: Operating standards	Standards: Technical standards	Standards: Inspection standards	Standards: Purchasing standards	Standards (Standard No.)	Check Sheet, Control Chart, Inspection Record, etc.: Check sheet	Control chart	Report and record sheet	Time series data	Daily report and journal	(Applied book name)	Emergency Treatment	Remarks
																		↑	
																		↑	
(8)	Defect removal	✓			○	○	○											Re-removal	
(9)	Welding repair	✓			○	○	○											Re-repair	
(10)	Heat treatment	✓			△	○												Heat retreatment	
	(Solution treatment)																		
◇(12)	Inspection (Machined parts)																		
(13)	Heat treatment (Stress removal annealing)																		
◇(14)	Inspection																		
	(Appearance)		✓	△	○				○		Specifications and inspection standards								
	(Dimensions)		✓	△	○				○		↑						Dimensional inspection record		

Table 3.4.3-4 Heat Resistance Cast Steels (3/3) (Martenstic Series: SCH1, 3 Ferritic Series: SCH2)

Responsibility symbol	
✓	Check or plan
△	Reporting (at emergency)
○	Action

(Company) Address and Tel No.
Writer's name and section

Process No. and Symbol	Process Name	Machine Equipment	Quality Characteristic: Importance Class	Quality Characteristic: Control Item	Quality Characteristic: Standard	Production Control Characteristic: Importance Class	Production Control Characteristic: Control Item	Production Control Characteristic: Control Level	Measuring Instrument and Method	Control Technique: Total Q'ty	Control Technique: Sampling	Control Technique: Sampling Technique and Rate	Responsible Person: Worker	Responsible Person: Inspector	Responsible Person: Foreman or team leader	Responsible Person: Section chief or supervisor	Responsible Person: Section manager	Standards: Operating standard	Standards: Technical standard	Standards: Inspection standard	Standards: Purchase standard	Standards: (Standard No.)	Check sheet	Control chart	Report and record sheet	Time series data	Daily report and journal	Check Sheet, Control Chart, Inspection Record, etc. (Applied book name)	Emergency Treatment	Remarks
	(Nondestructive)	Nondestructive test equipment							Visually, PT, RT					✓		△	○			○		↑			○			Nondestructive test record		Upon request only
	(Material tests)	Tensile strength test equipment and hardness test equipment	A	Material strength	JIS and customer specifications									✓		△	○			○		↑			○			Material inspection certificate		
⑮	Shipping		A	Indication of stamps and product No.	Shipping instructions				Visually	○			✓		△	○		○				Operating standards								
			A	Wrong item	NG				↑	○			✓		△	○		○				Packaging standards					○	Product invoice Transportation request		

Table 3.4.3-5 Cast Stainless Steels (Precipitation Hardening Type: SCH2C) (1/3)

Responsibility symbol	
✓	Check or plot
△	Reporting (at emergency)
○	Action

(Company)
Address and Tel No.
Writer's name and section

Process No. and Symbol	Process Name	Machine Equipment	Quality Characteristic: Importance Class	Quality Characteristic: Control Item	Quality Characteristic: Standard	Production Control Characteristic: Importance Class	Production Control Characteristic: Control Item	Production Control Characteristic: Control Level	Measuring Instrument and Method	Control Technique: Total Q'ty	Control Technique: Sampling	Control Technique: Sampling Technique and Rate	Responsible Person: Worker	Responsible Person: Inspector	Responsible Person: Foreman or team leader	Responsible Person: Section chief or supervisor	Responsible Person: Section manager	Standards: Operation standard	Standards: Technical standard	Standards: Inspection standard	Standards: Purchase standard	Standards (Standard No.)	Check Sheet, Control Chart, Inspection Record, etc.: Check sheet	Control chart	Report and record sheet	Time series data	Daily report and journal	(Applied book name)	Emergency Treatment	Remarks
①	Shake-out	(Hammer, shake-out machine)				B	Cooling time keeping in mold flask	Operating standards	Watch	○			✓		△	○		○												
②	Cleaning	Core knockout machine				B	Degree of sand sticking	Operating standards	Visually	○			✓		△	○		○											Retreatment	
						B	Shot blast time	≥ 15 minutes	Timer	○																				
③	Heat treatment	Heat treatment furnace				A	Charging temperature	Operating standards	Automatic temperature recorder	○			✓			△	○	○											Heat retreatment	
	(Solution treatment)					A	Temperature rising rate	≤ 250°C	↑																					
						A	Retaining temperature	1050 to 1100°C	↑																					
						A	Retaining time	1 hr/in	↑																					
						A	Cooling method	Operating standards	↑																					
④	Cutting (Cutting)	(Powder cutting machine, Grind cutting machine)	A	Cut-in	None				Visually	○			✓		△	○		○											Welding repair	
	(Gouging)	Carbon arc DC machine	A	Slip-cut	None				↑																					
			A	Accurate shaping height	≤ 2 m/m				↑																				Re-refining	
⑤	Descaling	Shot blast				B	Grain size	Operating standards		○			✓		△	○		○											Retreatment	
						B	Shot blast time	≥ 15 minutes	Timer																					
⑥	Finishing	Fixed grinder	A	Degree of flaw	Operating standards				Visually and limit samples	○			✓		△	○		○											Retreatment	
		Hand grinder	A	Degree of burning	↑				↑																					
		Swing grinder	A	Casting surface roughness	↑				↑																					
			A	Cutting state	↑				↑																					
⑦	Inspection		A	Degree of surface defect	Customer specifications non-destructive				Visually and limit samples	○				✓		○	○			○									Repair or refabrication	
	(Appearance and dimensional nondestructive)		A		Drawings				Vernier caliper, pass and straight scale																				↑	See JIS B 0012
		(MT)(PT)	A	Degree of surface defect	Customer specifications and inspection standards				Visually and limit samples																				↑	
		(RT)	A	Degree of internal defect					Film and visually																				↑	
⑧	Defect removal	Grinder	A	Harmful defect	Complete removal of cracks				Visually, PT, MT	○			✓			○	○	○											Re-removal	
		Gouging	A	Small defect	Round-off				Visually																					
⑨	Welding repair	DC welding equipment				A	Current and voltage	Operating standards	Meters	○			✓			○	○	○											Re-repair	
						A	Pre-heating and after-heating	↑	↑																					

(Note) Process symbols: ○ = Mainly for processes requiring inspection
▽ = Storage and storing process
○ = Operating process

Table 3.4.3-5 Cast Stainless Steels (Precipitation Hardening Type: SCH2C) (2/3)

Responsibility symbol	
✓	Check or plan
△	Reporting (at emergency)
○	Action

(Company) Address and Tel No.
Writer's name and section

Process No. and Symbol	Process Name	Machine Equipment	Quality Characteristic: Importance Class	Quality Characteristic: Control Item	Quality Characteristic: Standard	Production Control Characteristic: Importance Class	Production Control Characteristic: Control Item	Production Control Characteristic: Control Level	Measuring Instrument and Method	Control Technique: Total Q'ty	Control Technique: Sampling	Control Technique: Sampling Technique and Rate	Responsible Person: Worker	Responsible Person: Inspector	Responsible Person: Foreman or team leader	Responsible Person: Section chief or supervisor	Responsible Person: Section manager	Standards: Operation standard	Standards: Technical standard	Standards: Inspection standard	Standards: Purchase standard	Standards: (Standard No.)	Check sheet	Control chart	Report and record sheet	Time series data	Daily report and journal	(Applied book name)	Emergency Treatment	Remarks
						A	Interlayer temperature	↑	↑																					
						A	Type of welding rods	↑	Visually																					
						A	Drying temperature of welding rods	250 to 350°C	Temperature gauge																					
						A	Drying time of welding rods	≥ 30 min.	Watch																					
⑩	Heat treatment					A	Charging temperature	Operating standards	Automatic temperature recorder	○			✓			△	○												Heat retreatment	
	(Solution treatment)					A	Temperature rising rate	≤ 150°C	↑																					
						A	Retaining temperature	1050 to 1100°C	↑																					
						A	Retaining time	1 hr/in	↑																					
						A	Cooling method	Operating standards	↑																					
⑪	Heat treatment	Heat treatment				A	Charging temperature	Operating standards	Automatic temperature recorder	○			✓			△	○	○											Heat retreatment	
						A	Temperature rising rate	≤ 250°C/hr	↑																					
						A	Retaining temperature	≤ 480°C	↑																					
						A	Retaining time	1 hr/in	↑																					
						A	Cooling method	Cooling air	↑																					
⑫	Descaling	Sand blast Shot blast				B	Grain size	Operating standards		○			✓			△	○	○											Retreatment	
						B	Blast time	≥ 15 minutes	Timer																					
⑬	Pickling	Pickling tank				A	Liquid concentration	Operating standards		○			✓			△	○		○										Retreatment	
						A	Dipping time	↑	Watch																					
⑭	Distortion removal	Press machine	A	Distortion and warp	Drawings and specifications				Vernier caliper, pass and straight scale	○			✓			△	○		○										Recorrection	
⑮	Inspection (Dimensions)		A	Length, thickness	Drawings Specifications				Vernier caliper, pass and straight scale	○			✓			△	○		○										Repair	
⑯	Machining	Lathe turning machine, drilling machine	A	Machining range Dimensions, Roughness					Visually, straight scale and vernier caliper	○			✓			△	○		○										Remachining	
⑰	Inspections (Dimensions)		A	Length, thickness	Drawing, specifications				Vernier caliper, pass and straight scale	○				✓		△	○			○									Repair and recheck	
	(Appearance)		A	Surface defect rays	Inspection standards				Visually and limit samples																					

Table 3.4.3-5 Cast Stainless Steels
(Precipitation Hardening Type: SCH2C) (3/3)

Responsibility symbol	
✓	Check or plot
△	Reporting (at emergency)
○	Action

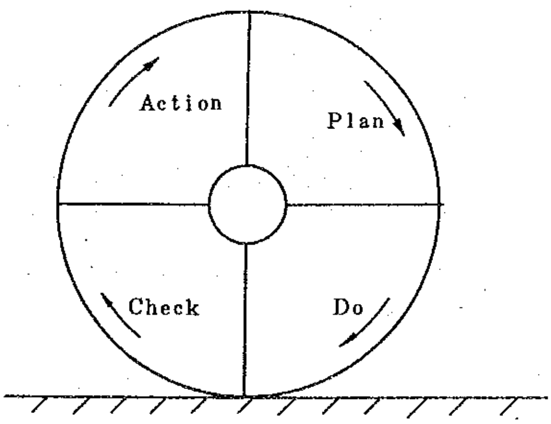
(Company)
Address and Tel No.
Writer's name and section

Process No. and Symbol	Process Name	Machine Equipment	Quality Characteristic: Importance Class	Quality Characteristic: Control Item	Quality Characteristic: Standard	Production Control Characteristic: Importance Class	Production Control Characteristic: Control Item	Production Control Characteristic: Control Level	Measuring Instrument and Method	Control Technique: Total Q'ty	Control Technique: Sampling	Control Technique: Sampling Technique and Rate	Responsible Person: Worker	Responsible Person: Inspector	Responsible Person: Foreman or team leader	Responsible Person: Section chief or supervisor	Responsible Person: Section manager	Standards: Operation standard	Standards: Technical standard	Standards: Inspection standard	Standards: Purchase standard	Standards: (Standard No.)	Check Sheet, Control Chart, Inspection Record, etc.: Check sheet	Control chart	Report and record sheet	Time series data	Daily report and journal	(Applied base name)	Emergency Treatment	Remarks
│	(Non-destructive)		A	Surface defect Internal defect					Visually, limit samples and films																					
↓	(Mechanical tests)		A	Mechanical strength	JIS, ASTM and specifications																									
18	Shipping		A	Wrong item	NG				Invoice	○			✓		△	○		○												

(2) Encouragement of quality control activities

The foregoing discussed that the basis of quality control activities lies first in completing the necessary standards. Since the operating conditions in the work fields are always changing, therefore, it is a keypoint how to control these dispersions within the objective setting ranges. For this purpose, it is important for you how faithfully circulate the PDCA cycle at all time, which is a basis of the quality control.

This PDCA cycle means, as shown in Figure 3.4.3-1 below, that the plan first needs to be firm, that it is then executed, that the results are checked and that the improving measures are determined and tried. If the improvements resulted in the favorable effect, standardize them. If the design needs to be changed, reflect it upon the design stage to apply the improved processes to the following manufacture.



Concept making much of quality

Sense of responsibility to quality

Figure 3.4.3-1 PDCA Cycle

For these activities, the factual recognition of current quality status must be correct. It is, therefore, necessary to collect data available to conduct the analyses for improvements in the daily activities. It is quite obvious that the causes must be analyzed to take actions based on the reliable data. It is, therefore, desired for the quality control of castings to strictly do the following.

a) Data collection and analysis

Not to speak of the percent defective data of castings, if what data are once determined to be controlled in the processes, they must always be collected and analyzed. Although the data control is determined to be executed for characteristics control of casting sand, for example, it is almost not practiced, in fact. This allows us to say nothing is controlled. If it is excusable by reason of no occurrence of any critical issue at present or short manpower, the significance of quality control is not basically understood. Such control techniques as sampling frequency, etc. may be simplified, if the product quality is stable, but a condition must be avoided to stop the control activities completely.

We assume that many ways have been tried to collect the statistics of castings. Nevertheless, there are a few real defectives by all means. The top three of defective phenomena are also always same. Such cases may often be divided into the difficult solution without knowing of causes or the simple solution by determining the causes through analysis and by taking appropriate actions. If a same product is repeatedly manufactured in a same manner, in fact, the causes of defectives may often be determined intuitively like "that's it!"

To avoid this, first:

(a) Collect the correct data.

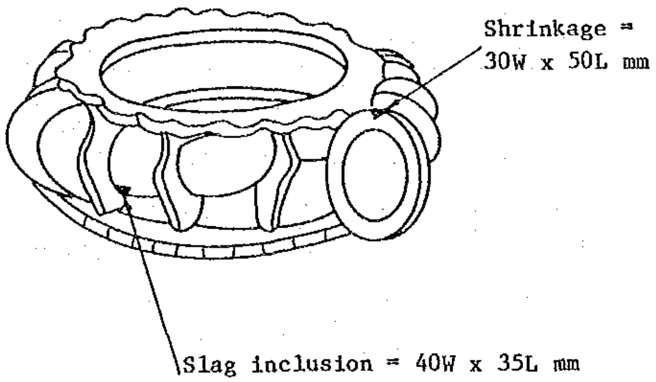
If a defective occurs, correctly determine the defect phenomenon (for example; distinguish clearly between sand inclusion and slag, or between pinhole and shrinkage porosity). Also, record the positions, sizes, etc. of defects with sketches. As a case may be, it is better to take its photograph. They will become the important data later for examining the quality. An example of defect phenomena recording sheet is given in Table 3.4.3-6 below.

Table 3.4.3-6 Defect Phenomena Recording Sheet

Approval stamp   No.

Distributed to:
Ordering customer
Design division
Engineering division
Workshop division
Workshop division
Production control division
Inspection division
File copy
Total

Ordering customer	Work No.	Drawing No.	Date of issue
Delivery to:	Material		Date of inspection
Name of work	Quantity		Place of inspection
Name of parts		Defect phenomenon	



Approval
Checker
Planner

(b) Data analysis

The percent defective of castings needs to be analyzed from such various angles as per part, per material, per molding process, etc., but it is not limited to the overall percent defective only. We assume that they are executed to a certain extent. It is, however, necessary for you to analyze more deeply why the shrinkage, cracks, etc. happen so frequently, in fact. It is advised for you to analyze more particular data, for examples, to see whether there is a correlation depending upon parts or not, materials, processes, molding processes, casting process, secular relationship, etc. If such an analysis results in concluding, for example, that shrinkage is caused due to a low pouring temperature, this leads you to determine whether the standards were followed or need to be revised, and to take necessary actions. Though it is closely related with the pouring temperature, if no data is collected, first collect the data. Standardize it, if necessary, and provide the temperature gauges as well. Anyway, you have to enforce the workers to be liable for measurement.

b) Meeting to discuss the countermeasures against defectives

Upon the happening of a defective, it is natural to take actions immediately then, as a case may be. While, it is quite effective to hold the quality meeting weekly, monthly or annually based on the quality trend. For the work fields, it is one of the ways to hold a weekly QC meeting between the personnel in charge of quality control and the foundry shop concerns to have an opportunity of discussing the problems and solutions.

In this case, in order to avoid mistaking the factual recognition, it is important for everybody involved to review the foregoing defect phenomena recording sheets (with illustrations) and actual defectives to obtain the correct factual recognition. It is also important to determine who will do what, by when and how and to check to see what were the results and up to what step the measure were progressed, every meeting. These meetings also need to invite the field workers concerned and to analyze the actual manufacturing processes completely. The monthly QC discussion meeting should invite the shop manager to review the quality trend from the overall viewpoint and to discuss the countermeasures to improve the current quality trend so as to direct correctly.

The quality control department should preside these meetings, and prepare the minutes of meetings without fail, in which it is necessary to clearly state the improvement measures and the results therefrom. These minutes are very useful to avoid the recurrence of a same fail in establishing the improvement measures, as well as in improving the technologies.

c) Pre-examination

This shop has a trial manufacturing section and the system is established to manufacture a prototype to solve the problems and then to enter the actual production. This is very good. However, this is exercised for new parts, but the parts which have already been manufactured are sent directly to the production fields for reproduction.

For the recurrent or repeatedly flowing products, reviewing what problems can be expected before entering the production and executing the production by taking such review results into consideration could fairly reduce the occurrence of defectives. The original quality control is not following what have already been produced, but should conduct a precise review before production. For this purpose, it is preferable for you to summarize the record on what quality problems have been experienced with the previous lots and on what points are to be noticed, and to issue such records as an instruction.

The production department should thoroughly review and check such instructions together with the foremen and team leaders, and make themselves read for the same. It is quite obvious to generate a great difference in the result between working continuously with a problem consciousness as above and producing the quantity only of products assigned.

If you prepare the list of expected defects and failure factors as a pre-examination document, it will help you for quality prediction. A sample of such a factor list is given hereunder.

Table 3.4.3-7 Casting Defects and Failure Factors (1/4)

Quality characteristics of castings / Defect	Intermediate characteristics (Substitute characteristics)	Mold properties: Molding sand properties: Reclaimed sand properties: Full clay portion	Activated clay portion	Sand grain size	Flammables quantity	Moisture	Permeability	Compression strength	Compactability	Rapid thermal expansion	Surface stability	Drying strength	Coke, lump quantity	Mold strength (hardness)	Coated mold cleanliness	Coated mold state	Coated mold dry state	Dimensional accuracy: Mold dimensions	Assembly accuracy	Flask accuracy	Weight/upper mold positional relation	Pallet mold positional relation	Gas vent hole condition	Assembly condition	Mold seal/mold position		Control method
Dimensions	Pattern defectives (casting mold defect)																	◎									Check the weight, thickness and dimensions of products. → Control chart
	Core moving																		◎								
	Mold shift																			◎							
	Poor care																										
	Short thickness																										
	Core break																										· Dimensional accuracy information form the cast finishing process
	Body swell							○	◎					◎							◎	◎					
	Core warp																		Δ	Δ							· Daily control of percent
	Target defect																										
Material	Material defect																										· Daily control of percent defective
	Hardness defect																										· Product hardness measurement Control
	Chill															Δ											
Casting Failure	Slag inclusion															Δ											· Defect information from the cast finishing process
	Sand inclusion	○	○			◎		○			◎		◎	○	◎	○					Δ		○	○			
	Sand burn-in			◎	○	○	○		○				○	○		◎											· Daily control of percent defective
	Coated mold defect	○														◎											
	Scab	○	○	Δ	◎	◎	○	○	○	◎		◎		◎			◎										
	Main mold damage (including drop)	○	○			○		○	○				◎	◎				○	○	○	◎	◎					

Table 3.4.3-7 Casting Defects and Failure Factors (2/4)

Quality characteristics of castings / Defect	Intermediate characteristics (Substitute characteristics)	Mold properties: Molding sand properties: Reclaimed sand properties: Full clay portion	Activated clay portion	Sand grain size	Flammables quantity	Moisture	Permeability	Compression strength	Compactability	Rapid thermal expansion	Surface stability	Drying strength	Coke, lump quantity	Mold strength (hardness)	Coated mold cleanliness	Coated mold state	Coated mold dry state	Dimensional accuracy: Mold dimensions	Assembly accuracy	Flask accuracy	Weight/upper mold positional relation	Pallet mold positional relation	Gas vent hole condition	Assembly condition	Mold seal/mold position		Control method
Casting Failure (cont'd)	Core damage																	○	△	△	○	△		△			
	Metal leakage from mold flask																	○		◎							
	Short pours																										
	Molten metal split onto core print													○				○	◎	◎	◎				◎		
	Misrun																										
	Shrinkage							○						○									△				
	Pinhole					○																					
	Gas			○	○	○	○									○	○					△	◎				
	Crack																										
	Fin																		◎	◎	○						
Process																										Standard (quality associates)	Control method
Sand mixing and reclaiming	Weighing and charging sand	○	○	○	○	○	○	○	○	○	○	○		○												Sand mixing, preparation and weighing work standards	Regular weighing check and record
	Bentonite	◎	◎					○			○	○		○												" " "	"
	Coal powder	○			◎			△		○																" " "	"
	α-strach				○			△		○				△												" " "	"
	Dextrin				○			△			△			△												" " "	"
	Water					○	○	○	○		○	○		○				○								" "	Daily check

Table 3.4.3-7 Casting Defects and Failure Factors (3/4)

Quality characteristics of castings / Defect \ Intermediate characteristics (Substitute characteristics)		Mold properties: Molding sand properties: Reclaimed sand properties: Fall clay portion	Activated clay portion	Sand grain size	Flammable quantity	Moisture	Permeability	Compression strength	Compactability	Rapid thermal expansion	Surface stability	Drying strength	Coke, lump quantity	Mold strength (hardness)	Coated mold cleanliness	Coated mold state	Coated mold dry state	Dimensional accuracy: Mold dimensions	Assembly accuracy	Flask accuracy	Weight/upper mold positional relation	Pallet mold positional relation	Gas vent hole condition	Assembly condition	Mold seal/mold position		Control method
Process																										Standard (quality associates)	Control method
Sand mixing and reclaiming (cont'd)	Mixing; Mixing time setting			○			○	○				○	○	○				○								Sand mixing	Daily check (Timer setting)
	Relining			○			○	○	○				○													Blow replacement working standards	Daily check and replacement
	Mixer cleaning					○	○	○	○																		Daily cleaning
	Reclaiming; Breaker screen	○											◎														Regular check
	Fine particle drain	○	○		○	○																					
Molding	Molding machine; Pattern cleaning											○															〃
	Sand charging (Facing sand)	○	○		○	○												○								Facing sand work	Trial mold setting
	Jolt													◎				○								Molding	Total quantity check (alignment)
	Squeeze																										Regular check
	Pattern drawing																				◎						〃
	Sand scraping; Sand scraping																				◎						
	Gas vent opening / Cleaning														○											Pouring sprue work standards	
	Coated mold / Coated mold														○	△										〃	
	Drying																○									〃	

Table 3.4.3-7 Casting Defects and Failure Factors (4/4)

Intermediate characteristics (Substitute characteristics) / Quality characteristics of castings / Defect		Mold properties																Dimensional accuracy									Control method
		Molding sand properties																									
		Reclaimed sand properties																									
		Full clay portion	Activated clay portion	Sand grain size	Flammables quantity	Moisture	Permeability	Compression strength	Compactability	Rapid thermal expansion	Surface stability	Drying strength	Coke, lump quantity	Mold strength (hardness)	Coated mold cleanliness	Coated mold state	Coated mold dry state	Mold dimensions	Assembly accuracy	Flask accuracy	Weight/upper mold positional relation	Pallet mold positional relation	Gas vent hole condition	Assembly condition	Mold seal/mold position		
Control Method and data	Control chart	○	○	○	○	○	○	○	○	○																	
	Measurement record										○	○															
	Check																										

The following gives a flow chart of quality development as discussed up to here.

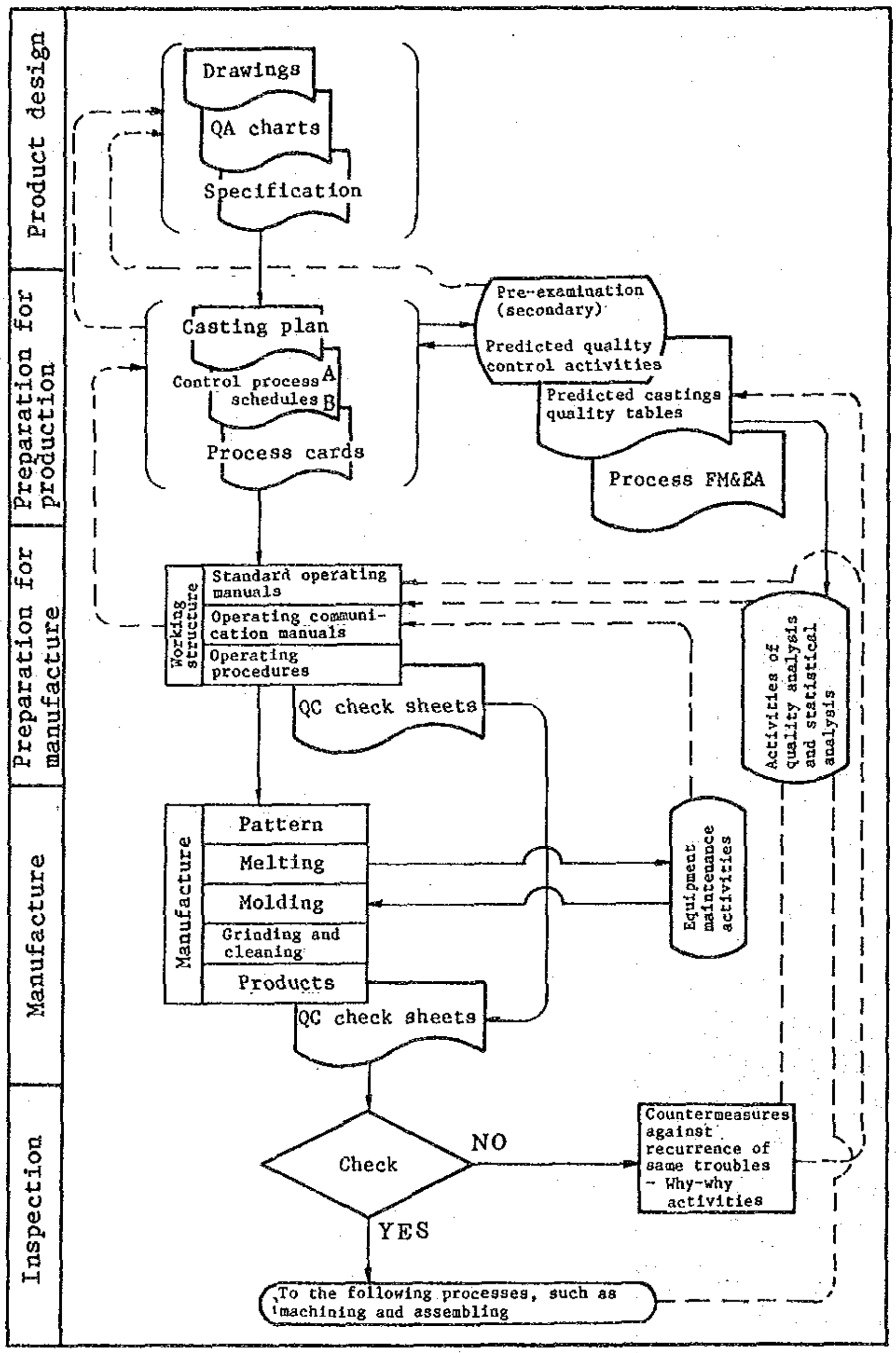


Figure 3.4.3-2 Quality Development in the Production Processes

The following gives a flow chart of casting defectives recurrence preventive activities.

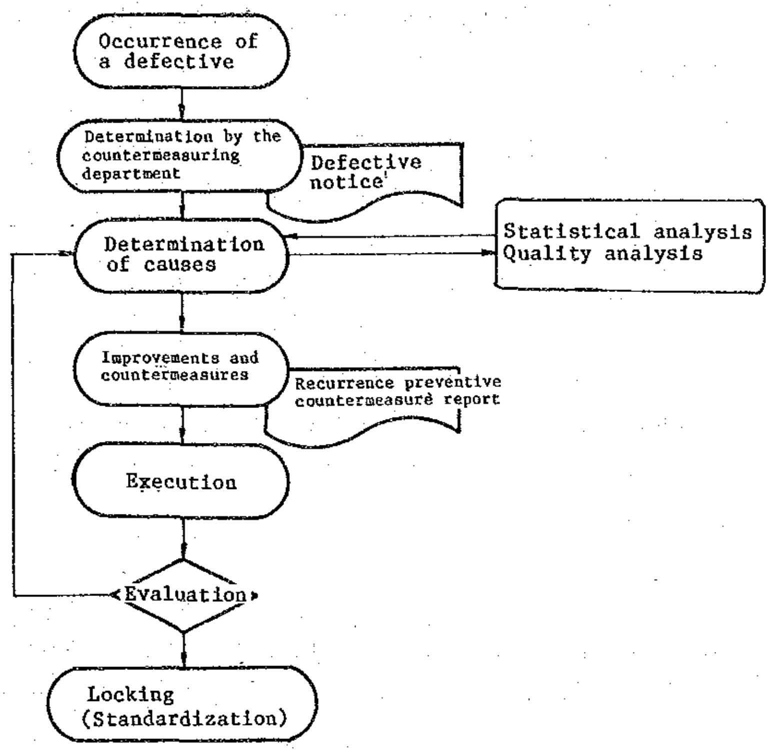


Figure 3.4.3-3 Flow Chart of Casting Defectives Recurrence Preventive Activities

d) Small group activities

Castings are manufactured under a collaborated work of many workers. Like a proverb that "many a mickle makes a muckle," the integration or multiplication effect of everyone's capabilities results in a very great power. Human beings have aspirations, and volution desired to do even a same job in this way. In another word, if the capabilities held by everyone could successfully be drawn out, a very great work can be achieved. In this context, we believe that it is quite effective to improve the quality through the QC activities of small groups. Fortunately, this shop also shows a rise of tendency to introduce the small group activities with reference to the TQC campaign in Japan, so that we wish it would be made successful by all means. It is, however, necessary for you to foster this campaign over a long term without expecting an excessive result to begin with. It is important for the managers and supervisors to understand this campaign thoroughly, to hold a prepared mind to continue this campaign with belief, and to take care of well consulting with the members of small group activities, if they hold a pain.

It is important for this campaign to establish an organization, but it is also essential to do things first what you can do.

You'd better form 5 to 10 people per group.

You'd better, therefore, form the groups of mechanical molding, manual handling of small articles, core molding, etc., for examples, in the molding department, or you may contrive to divide the pattern making group into such two groups as A and B.

For the themes to be picked up, you'd better encourage every member in the group to speak up freely, and try to select the themes related with all members in the group. It is advised you to select the simple themes which you may likely thank favulous, rather than the difficult ones from the beginning. For example, try to pick up an ordinary theme like "no body takes a day off without prior notice."

Each group should pick up a few themes. Too many themes you pick up leads you to the impossible execution. Limit to 3 to 4 themes. The following are the examples in the work fields.

Pattern:	To reduce to 8% from 10% in the generation percentage of residual pieces after manufacturing patterns.
Molding:	To reduce to 15 damages of molds per month from 20 damages.
Melting:	To reduce the electric power consumption for melting from 750 kW/ton to 730 kW/ton
Finishing:	To reduce the cracks by riser removal from 10 pieces per month to 6.

To reduce the grinder setting time by 5% from the currently spent time.

Since the time schedule to achieve the objectives differ depending upon the themes you selected, discuss this also among the group members to determine the goals to 3 or 6 months in advance.

Write these objective themes on the large papers per group, which you should then put on a wall to allow you to enter the actual progress in terms of bar graph. Each group should monthly summarize the progress results to review and discuss the improvement. Such processes require any improvement. It is recommended that the corporation should establish an incentive award program and system to officially commend such contrivances and improvements with an award (with any subprize in this case).

For this purpose, the improvement suggestion format is to be established, in which everybody can enter any improvement idea to submit to the improvement suggestion examination committee, whereby examining, classifying, ranking and scoring the improvement suggestions submitted. The annual total scores of these suggestions per group is calculated, according to which the corporation should officially commend the groups. Some small gifts (e.g., a cake of soap, etc.) should be presented to all individuals whose improvement suggestions are adopted by the corporation. For the most outstanding suggestion, corporation should separately commend it. It would be important for corporation to appreciate the worker efforts as above.

The success in creating the joyful work fields being worth working by the workers would consequently bring the improvement of quality and productivity inevitably without fail. It is preferable as a future posture that the QC circle activities should be particularly be developed with an integrated policy from the management top down to the end workers. An example of these QC activity systems is given in Figure 3.4.3-3 below.

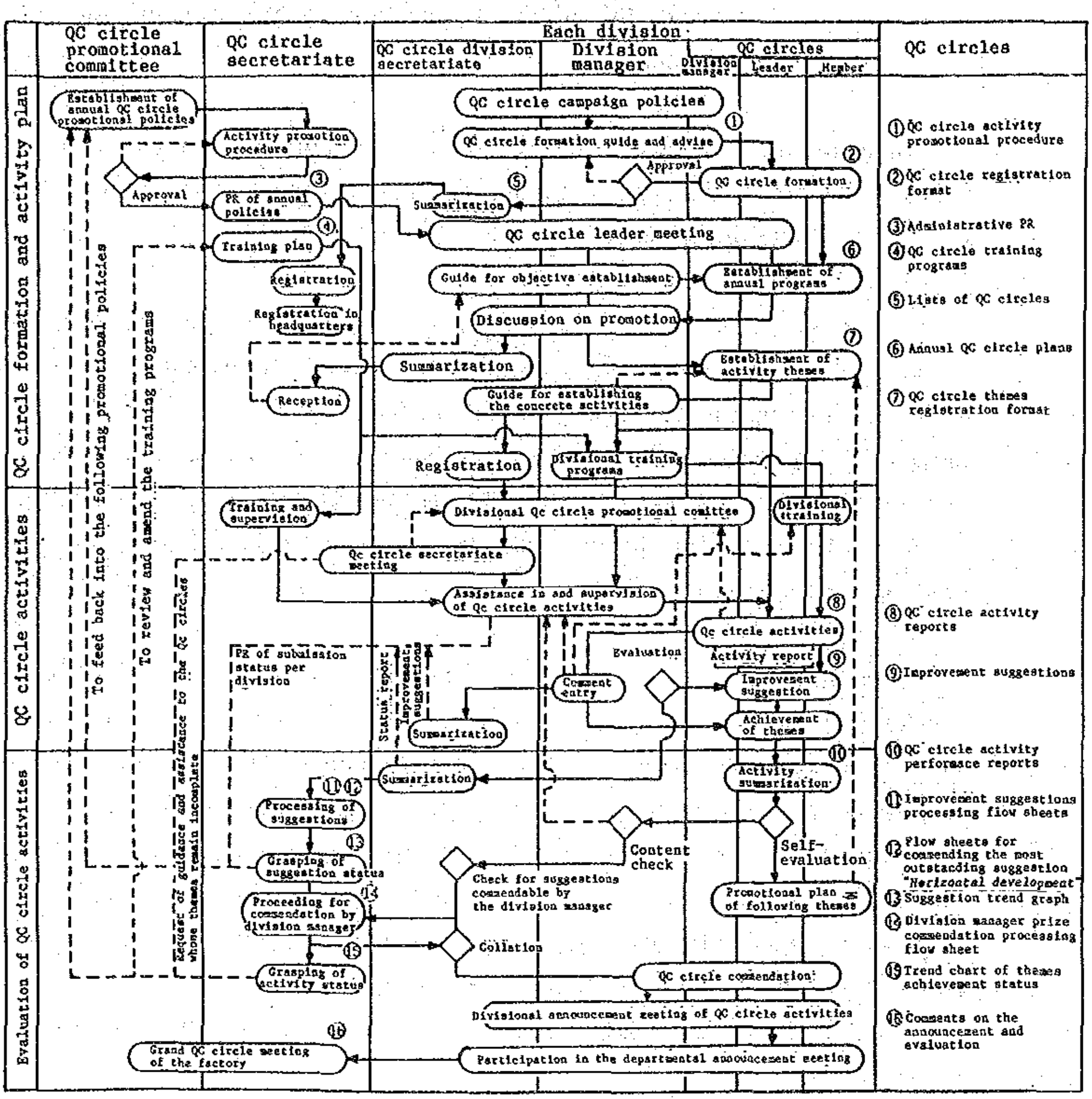


Figure 3.4.3-3 QC Circle Activity System

2) Plate shop

Since the basic, concrete measures (small group activities, etc.) are same as for the foundry shop, described hereunder center at the special additions to the plate shop.

Even if new techniques and equipment are introduced for modernizing the welding processes, so far as the important welds remain at low workmanship (gas cut roughness, gap, etc. of welded surfaces), the expected productivity and quality cannot possibly be attained. Rather, new techniques and equipment should be introduced after the following quality control activities could have demonstrated the sufficient performance. Since the production increase is an urgent in this modernization plan, however, the quality control system is to be established in parallel with the introduction of new equipment. Our survey on the quality control functions of plate shop resulted in finding a fair repletion of inspection functions among all other quality control functions, but it is no exaggeration to say that almost no quality control activity of plate shop itself is carried out. The major problems and improvement requirements are discussed as follows.

(a) Almost no standard (quality standards, operating standards, etc.)
(b) Insufficient quality control activities

(1) Completion of standards

As mentioned previously, the inspection functions centering in the inspection division are fairly repleted, but there are many improvement requirements in the future, such as gas cut roughness, weld gaps, drying of low hydrogen series welding rods, etc. in the plate shop. We assume that the causes of such nonconformances depend greatly upon the insufficient completion of standards. Since the basis of quality control begins with completion of standards, the execution of quality control is impossible without standards. The quality standards must be prepared at a high reliability backed up not only with experiences, but also with theory and actual performance.

In the shipbuilding industry manufacturing the products just similar to this plate shop, the "Japan Shipbuilding Quality Standards" are issued by No. 1 subcommittee of the Japan Shipbuilding Research Committee. From this standard, a few examples are given in Table 3.4.3-8 below. Additionally, you are available to obtain a copy book of this standard upon request to the Japan Shipbuilding Institute. With reference to this standard, it is preferable for us to establish your own standards to meet the actual situation of the plate shop. For the operating standards, it is advised for you to prepare them by taking the foregoing standards into consideration as well, as mentioned in subpara. 2.5.1.2 "work engineering management (plate shop)" above.

(2) Activation of quality control activities

The improvement of product quality depends greatly upon the skills and quality consciousness of workers who engage the actual jobs, as well as the tackling posture of shop key personnel.

Since the QC circle campaign is fortunately introduced, it is advised for you to achieve the activation of quality control activities through the best use of this campaign. Developing this campaign gives rise to claims (feedback). The immediate solution of these claims leads to the activation of QC circle campaign to improve the quality and productivity.

Further, it is judged that the QC process charts remain still at an early stage, in view of the actual situation of this plate shop. It is advised for you to study this as a future theme.

Table 3.4.3-8 An Example of Quality Standards (1/3)

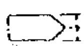
Major Class		Gas Cutting			Unit = mm, unless otherwise specified
Middle Class	Minor Class	Item	Standard Range	Allowable Limit	Remarks
Rough-ness	Free end of members	Important portion Internal work External work Unimportant portion Internal work External work	 100μ (2nd class) 150μ (3rd class) 100μ (2nd class) 500μ (out-of class)	 200μ (3rd class) 300μ (out-of-class) 200μ (3rd class) 1000μ (out-of class)	Figures in parentheses represent a class established by the Gas *Work Committee*. 50 microns or below = 1st class 50 to 100 microns = 2nd class 100 to 200 microns = 3rd class 200 microns or above = out-of-class
	Welded joint	Important portion Internal work External work Unimportant portion Internal work External work	 100μ (2nd class) 400μ (out-of class) 100μ (2nd class) 800μ (out-of-class)	 200μ (3rd class) 800μ (out-of class) 1500μ (out-of class) 1500μ (out-of class)	. Wherever requires a special treatment like grinder finish, etc., take appropriate actions, instead of following this standard. . The cast steels in the internal work shall comply with the standard range and allowable limit for external work.
Gas notch	Free end of members	(1) Upper edge of shear strake (2) Edge of opening to be made on the powerful deck and shell between 0.6L x marks. (3) Especially important, longitudinal members		No notch	Smooth finish with a grinder. Filling by welding, as required, subject to care to cause no short bead. "Notch means a concave more than 3 times a roughness."
		Important horizontal and longitudinal strength members, etc.		1 m/m or less	
		Others		3 m/m or less	
	Welded joint	Butt-welded joint: Shell and upper deck with 06L x marks		2 m/m or less	Correct notches with a grinder, gouging, etc. to shape free from causing any welding defect.
		Butt-welded joint: Others		3 m/m or less	
		Fillet-welded joint		3 m/m or less	
Cutting size	Plate earing straightness	Automatic welding Semiautomatic welding and manual welding	±0.4 ±1.0	±0.5 ±2.5	
	Grooving depth		±1.5	±2.0	

Table 3.4.3-8 An Example of Quality Standards (2/3)

Gas Cutting — Unit = mm, unless otherwise specified

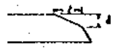
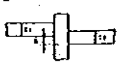
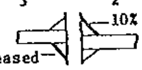
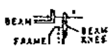
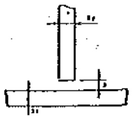
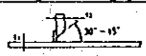
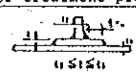
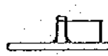
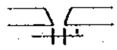
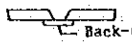
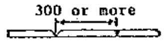
Major Class		Item	Standard Range	Allowable Limit	Remarks
Middle Class	Minor Class				
Cutting size	Grooving angle	Automatic welding Semiautomatic welding and manual welding	±2° ±2°	±4° ±4°	
	Taper length	 (ℓ to a positive size)	±0.5d	±1.0d	
	Member size	Member shape to a positive size	±3.5	±5.0	
			±2.5	±4.0	For those requiring a special accuracy, such as double-bottom floor, girder depth, etc.
		Width of face bar to a positive size	±2.0	-3.0 to +4.0	
Connection accuracy	Connecting deviation of fillet-welded joint  a=Deviation t=Plate thickness t1 t2	Important members		$a \leq \frac{1}{3}t2$	$\frac{1}{3}t2 \leq a \leq \frac{1}{2}t2$  10% increased leg 10% increased leg $a > \frac{1}{2}t2$ Reconnection
		Others	$a \leq \frac{1}{2}t2$	$a \leq \frac{1}{3}t2$	$a > \frac{1}{2}t2$ Reconnection
	Deviation between the beam and frame		$a \leq 3$	$a \leq 5$	Indicate a range capable of welding by pulling without removing the welds of beam and frame.
	Gap at connection	For fillet weld 	$a \leq 2$	$a \leq 3$	. 3 m/m < a ≤ 5 m/m Specified leg + (a-2) increased leg . 5 m/m < a ≤ 16 m/m 1) Chamfering weld or 2) Liner treatment Chamfering welding procedure  30° to 45° groove in webs and weld by patching a chill plate, then, back weld after removing the chill plate. Liner treatment procedure  . 16 m/m < a 1) Liner treatment or 2) Partial change Partial change procedure  300 or more

Table 3.4.3-8 An Example of Quality Standards (3/3)

Major Class		Gas Cutting			Unit = mm, unless otherwise specified
Middle Class	Minor Class	Item	Standard Range	Allowable Limit	Remarks
		For butt weld  (Manual welding)	$2 \leq a < 35$	$a \leq 5$	. $5 < a \leq 16$ m/m After a backup metal welding, remove the backup metal to back weld.  . 16 m/m $< a < 25$ m/m After the filling shaping, weld or change part of the base material.  . 25 m/m a Partial change of base material
		Butt weld (Automatic welding)			. Place the sealing beads, if melting drops can be expected.
		1. Both-side sub-merge arc welding 	$0 \leq a \leq 0.8$	$0 \leq a \leq 5$	
		2. Submerge arc welding combined with manual or carbon dioxide welding 	$0 \leq a \leq 3.5$	$0 \leq a \leq 5$	. Conform to the manual fillet weld in case of $a > 5$ mm.