2.7 Safety Control

2.7.1 General Descriptions on Safety Control

1) Basic policies of safety control

The safety and sanitary activities of the workshops are exercised under the statutory Act of the Republic of Chile and the policies of Div. El Teniente. The statutory Act was enacted in 1968 to clarify the enterprise responsibility and to grant the rights to workers to receive the medical treatments and economical aids, from the idea that the society itself should hold the resonsibility on the safety, because if an incident happens, the families and enterprise receive the influence, which in turn leads to the influence upon the society itself.

Div. El Teniente established the following basic policies in accordance with this law.

- The managers to execute the work must fully be liable for it upon accepting the delegation of rights to protect the life and health of all subordinate employees and to maintain their welfare.
- Every employee has a responsibility to protect the healthy body of himself and fellow workers and to observe the regulations and standrds stipulated for each production activity.
- Any work should not be executed without measures required to conduct an consistent preliminary study and to control the hazardous prevention on the expectable hazards.

2) Safety control systems

The safety control of the shops is positioned as a link with the safety control of Div. El Teniente, and exercised under the policies of safety and hygiene department belonging directly to Div. El Teniente. The organization of safety and hygiene department is as shown in Figure 2.7.1-1 below.

The safety and hygiene department consists of a division to conduct the medical treatments, a division to conduct the training and satistics, and safety and hygiene division together with each staff segment of security department in each factory. The safety and hygiene division assigns the specialists qualified for safety control profession per area of mines, mineral processing works, refining works and service shops (including the workshops) to provide the advices and recommendations with respects to the previous prevention of hazards, environmental hygiene and employees' health management, enhance of safety consciousness, promotion of safety education, etc. per area. In the factory, the line supervisors become the people in charge of safety and sanitation to promote the safety control activities in cooperation with the safety and hygiene division.

3) Safety control activities

The 1986 safety control activity plan and annual schedule were established and are now under implementation. The particulars are as shown in Tables 2.7.1-2 and 2.7.1-3 below. Although not being witnessed during this study period the safety patrol is exercised three times a year by five men in total consisting of the representatives from the factory key personnel, personnel in charge of safety and workers for the purpose to check the implementation status of these activities, as well as the monthly patrol by the safety division.

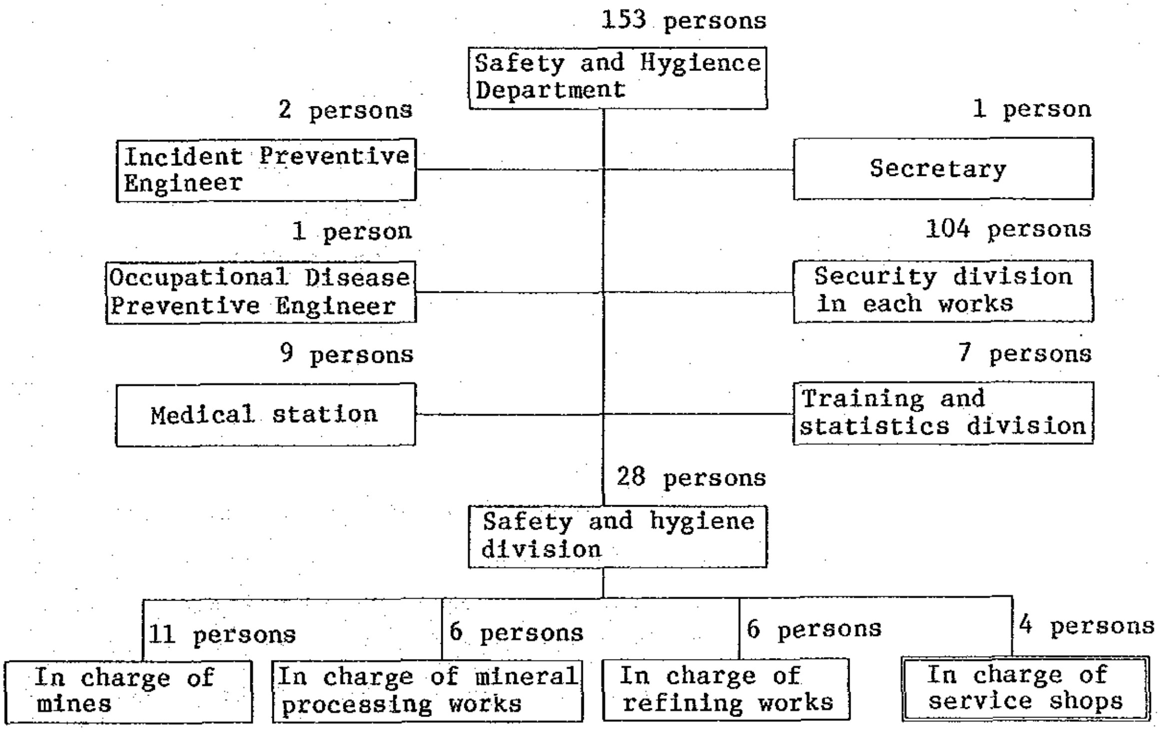


Figure 2.7.1-1 Organization Chart of Safety and Sanitary Department

Table 2.7.1-2 1986 Workshop Safety Control Activities

No.	Item	Description
1	Completion of standards	. To review all jobs from the safety's point of view on all production activities having an expectable hazard and to prepare the operating standards. . To regularly review the regulations of safety department.
2	Inspection and investigation	. Review of safety control plan . Inspection of equipment and machines from the safety's point of view . Investigation of incidents with physical damages . Investigation of troubles
3	Training	. Integrated safety training by the basic training groups . Lectures by the safety and sanitary division and factory manager . 5-minute training by the supervisors . Safety competition (by group) . Special safety training
4	Activity follow-up	. Analysis of safety accomplishments . Audit . Progress status of corrective action effects . Progress status of training programs
5	Communication	. Repeated meeting by basic safety training groups . Repeated meeting with the safety chief These are incorporated in the annual safety activity plan per department and executed.

Table 2.7.1-3 Annual Safety Control Activity Schedule (1986)

PROGRAMA DE SEGURIDAD 1986 DEPARTAMENTO TALLERES ANEXO Nº 1
Pág. 1 de 4

PROGRAMACION DE ACTIVIDADES

ACTIVIDADES	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SET	OCT	NOV	DIC	OBSERVACIONES
1.-FUNCION NORMATIVA													
1.1. Elaborar Procedimiento de Seguridad													
- Selección Proced. Seg. a elaborar			X										
- Preparación				X	X	X	X	X					
- Revisión y aplicación								X	X	X	X	X	
1.2. Completar revisión Reglamento Seguridad Depto. Talleres.			X	X	X	X	X	X					
2. FUNCION INSPECTIVA													
2.1. Inspecciones Programadas													
a)Supte. TA con Jefe Depto. SH.				X						X			
b)Jefe Gral.TA. con Jefe Seg. Serv.													
- Control de Calidad y Desarrollo de Productos		X						X					
- Fundición		X				X				X			
- Maestranzas				X				X				X	
- Planta de Cal			X				X				X		
c)Grupos Base de Seguridad													
- Control de Calidad y Desarrollo de Productos				X						X			
- Moldeo y Almas			X			X			X			X	
- Moldeo Mecanizado y Planta Arena		X			X			X			X		
- Fusión				X			X			X			
- Modelería			X				X				X		
- Terminaciones			X			X			X			X	
- Planta de Cal					X				X				
- Maestranza # 1		X			X			X			X		
- Maestranza # 2			X			X			X			X	
- Maestranza # 3			X			X			X			X	
- Mantención y Servicios		X			X			X			X		

4) *Incident statistics*

The incident statistics are very well analyzed from various angles, of which some statistic data expressing the current status of this factory are discussed hereunder.

(1) Frequency trend per department (1978~1985)

Table 2.7.1-4 below gives the frequency trend per department, indicating a great dispersion by year in every department, but a high frequency as a whole, especially a very high frequency in the finishing process beyond all others. This is a question, together with worsening the last year safety accomplishment in the most departments. Further, there was no incident with a human death during this period. For reference, this indicates more than 10 times the frequency in Japan, i.e. in 1985 about 4.5 for *foundry industry and about 2.0 for construction and mining machine manufacture industry.*

Further, the frequency in the Republic of Chile is expressed in terms of the following formula, differing from the frequency used internationally. Since the FE was zero during a period in Table 2.7.1-4 below, the frequency resulted in the same.

$$\text{Frequency} = (\text{No. of human death and hurt by labor incidents } (F+CTP+FE)) \div \text{Cumulative total workhour} \times 10^6$$

where:

F = Number of fatality
CTP = Number of physical harm to rest for more than a day
FE = Number of physical harm without rest, but impossible to return to work *immediately (FE is not included in the international frequency.)*

(2) Incident occurrence status per job classification (1985)

Table 2.7.1-5 below gives the 1985 incident occurrence status per job classification, finding that the finishing workers and welders are the top, 15.5% of the entire factory, respective which were the main subject processes to this study, followed by 12% of mechanical and 8.6% of plate workers.

(3) Incident occurrence status per where is hurt (1985)

Table 2.7.1-6 below gives the 1985 incident occurrence status per where is hurt in human body, finding that the physical damage is especially concentrated to fingers, legs and feet to occupy about 60% of total.

(4) Incident occurrence status per unsafe factory (1985)

Table 2.7.1-7 below gives the 1985 incident occurrence status per unsafe factor, indicating the incidents at "no-hazardous condition" is the top, that is one-third of total, followed by the conditions at an unsafe method, procedure and place in this order. However, this "no hazardous condition" was explained to mean the carelessness and absent-mind of workers. In view of the current status that the 16 incidents with rest have happened, we ought to say that the factor analysis still remains in easy-going. No incident occurs from a real safe condition, and it should be recognized that there could be no real safe condition.

(5) Incident occurrence status per unsafe action (1985)

Table 2.7.1-8 below gives the 1985 incident occurrence status per unsafe action, indicating that the determination as no unsafe action is merely 5% (3 incidents), while the incidents due to no hazardous prevention, improper use of hands and legs and without protective equipment are 38% (22 incidents), 21% (12 incidents) and 16% (9 incidents), respectively, to occupy three-fourths of total. This table indicates an incident factor analysis of all incidents occurred in this year, viewing from the actions of workers. The comment of safety and division to this was that "it is necessary to have workers correct their actions through the amendment of operating methods and strengthening the supervisor control." There was no factor analysis at the controller and supervisor sides, which was onesided. This is one of the problems for progressing the safety control in the future.

(6) Other statistic data

The incident occurrence status per age and per service length are analyzed, indicating a frequency incident of 30 to 45 ages and 6 to 20 years of service. This also corresponds to the age configuration of employees in this factory. The incident occurrence ratio per year of service is also 6 to 8%, not so much difference.

Table 2.7.1-4 Frequency Trend Per Department

DEPARTAMENTO TALLERES

TF. D. 40 por Centro Administrativo

CENTRO ADMINISTRATIVO	1979	1980	1981	1982	1983	1984	1985
4-313 0 Quality control and production control	0	0	0	23.0	0	19.7	
4-322 Molding shop	18.7	26.7	15.2	37.7	22.7	0	45.3
4-323 Dismantling (shake-out) process	13.0	31.7	55.2	0	47.1	0	33.3
4-324 Modeling shop	25.8	0	0	30.9	55.8	0	23.5
4-326 Cast finishing shop	71.1	59.6	52.5	46.3	37.4	17.6	73.9
4-330 Coal shop	16.4	0	23.9	0	0	0	29.9
4-342 Machine shop				21.4	16.2	17.1	53.1
4-343 Assembling shop	4.0	14.5	16.6	3.8	7.7	5.6	9.0
4-344 Plate shop	17.7	13.0	21.4	0	25.6	34.7	32.3
4-345 Maintenance shop	0	8.8	18.9	27.2	21.0	19.3	0
TOTAL TA.	14.2	16.4	19.8	14.9	21.0	11.7	28.3

ORA/1pm

Table 2.7.1-5 Incident Occurrence Status Per Job Classification (1985)

OCUPACION	ACCIDENTES					
	F	CTP	CREH	STP	TOTAL	%
Plate Worker	-	1	-	4	5	8.62
Ladle Operator	-	1	-	1	2	3.45
Foundry Shop Worker	-	3	-	-	3	5.17
Crane Operator	-	1	-	1	2	3.45
Miscellaneous Worker	-	3	-	1	4	6.90
Cast Finishing Worker	-	3	-	6	9	15.52
Skilled Worker	-	2	-	1	3	5.17
Milling Machine Operator	-	1	-	1	2	3.45
Mechanical Worker	-	3	-	4	7	12.07
Sand Molding Worker	-	1	-	2	3	5.17
Operator	-	2	-	-	2	3.45
Welder	-	4	-	5	9	15.52
Others	-	6	-	1	7	12.07
Factory Total	-	31	-	27	58	

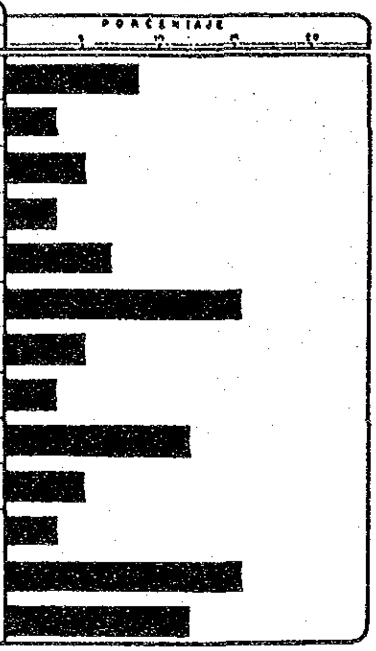


Table 2.7.1-6 Incident Occurrence Status Per Where is Hurt in Human Body (1985)

PARTE DEL CUERPO	ACCIDENTES					%
	F	CTP	CREH	STP	TOTAL	
Head	-	2	-	3	5	8.62
Face	-	1	-	3	4	6.90
Eyes	-	-	-	5	5	8.62
Body	-	3	-	-	3	5.17
Arms	-	-	-	-	-	-
Hands	-	-	-	2	2	3.45
Fingers	-	7	-	6	13	22.41
Legs	-	6	-	5	11	18.96
Feet	-	8	-	2	10	17.24
Ears	-	2	-	1	3	5.17
Each part	-	2	-	-	2	3.45
Body Systems	-	-	-	-	-	-
Parts of Body	-	-	-	-	-	-
Factory Total	-	31	-	27	58	

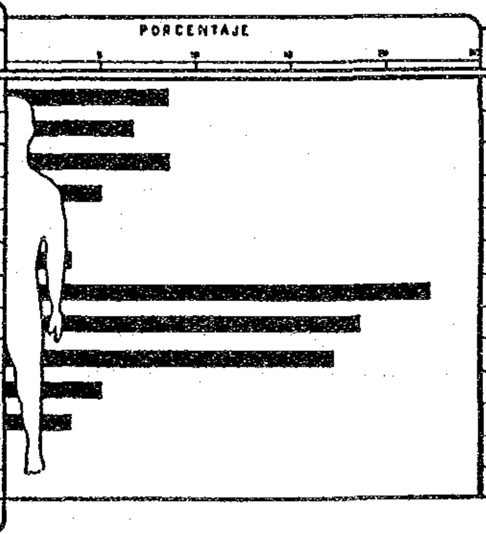


Table 2.7.1-7 Incident Occurrence Status Per Unsafe Factor (1985)

CONDICION PELIGROSA	ACCIDENTES					
	F	CTP	CREH	STP	TOTAL	%
Mistake by Representatives	-	5	-	3	8	13.79
Hazard Due to Clothes	-	-	-	2	2	3.45
Environmental Hazard	-	-	-	4	4	6.90
Hazardous Method and Procedure	-	6	-	7	13	22.41
Place Hazard	-	4	-	5	9	15.52
Improper Protection	-	-	-	2	2	3.45
Hazard Out of Work Fields				-	-	-
Hazard Out of Factory	-	-	-	-	-	-
Hazardous Condition	-	-	-	-	-	-
Insufficient Instruction		-	-	-	-	-
No-Hazardous Condition	-	16	-	4	20	34.48
Factory Total	-	31	-	27	58	

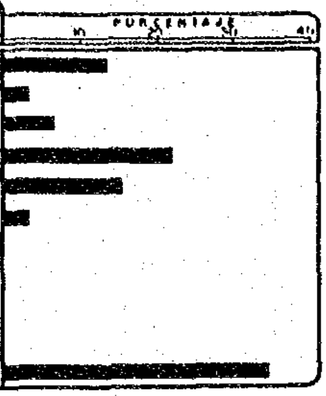
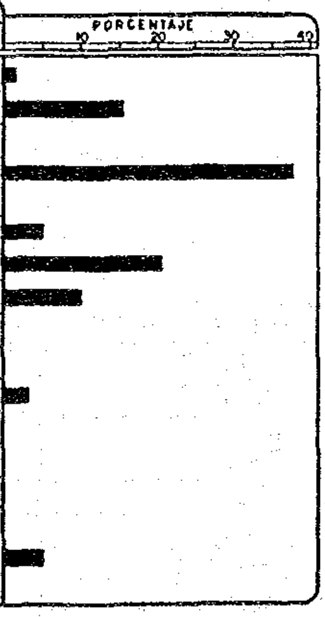


Table 2.7.1-8 Incident Occurrence Status Per Unsafe Action (1985)

ACTO INSEGURO	ACCIDENTES					
	F	CTP	CREH	STP	TOTAL	%
Repair, lubrication and cleaning of driving machines	-	1	-	-	1	1.72
Without protective equipment	-	2	-	7	9	15.52
Wear of unsafe clothes	-	-	-	-	-	-
No hazard prevention	-	11	-	11	22	37.93
Joking and kidding	-	-	-	-	-	-
Improper use of tools	-	2	-	1	3	5.17
Improper use of hands and legs	-	8	-	4	12	20.69
Carelessness to surroundings	-	4	-	2	6	10.34
Making the safeguards unoperable	-	-	-	-	-	-
Working at an unsafe speed	-	-	-	-	-	-
Action at a hazardous position	-	2	-	-	2	3.45
Wrong action	-	-	-	-	-	-
Placing and mixing at an unsafe method	-	-	-	-	-	-
Use of an incomplete tool	-	-	-	-	-	-
Unsafe action	-	-	-	-	-	-
No unsafe action	-	1	-	2	3	5.17
Others	-	-	-	-	-	-
Factory Total	-	31	-	27	58	



2.7.2 Current Safety Control in Foundry Shop

As mentioned in para. 2.7.1 "General Descriptions on Safety Control," the safety control systems are completed orderly, but observing the actual situation in the work fields in the foundry shop resulted in finding the scattering of phenomena seemed as an unsafe factor.

1) The pattern shop has a little of incidents, but cutting a hand with a saw happened. This shop is provided fully with the work machines and tables to narrow the work space, so that the work would frequently be carried out at an unnatural posture. It is necessary for this shop to consider a layout to reserve the sufficient safety passages and work space. A few examples of equipment are listed hereunder, which are desired to take safety measures.

   - No brake for emergency stop is provided to the hand feed planer.
   - A front cover for saw teeth needs to be provided to the band saw machine.
   - The double-end grinder needs to control the gap between the grind stone and tool post within 3 mm.

2) There is a fairly long pit in the molding shop, but the installation of hand rails for it is not good.

It is noticed that part of them remained removed even when the pit was not used. No sign to indicate during work in the pit is provided. There is a possibility to lead to a critical incident, if anything is dropped during transportation above the pit.

"During work" should clearly be signified by installing a red flickering lamp on the pit. The name tags of workers then working in the pit should be hung on at the descending step entrance into the pit. Such are same for the pit in the sand treatment plant as well. The pits where are not usually used must be taken care of the irrespirable atmosphere (lack of oxygen and full of toxic gas).

For the molding work, wire ropes or chains are often used. The control of applying them cannot be said good. Wires are often left especially without correcting kinks. Workers should severely be trained to correct kinks without fail, to check fiber cutting off and out-of-oil, and to orderly put back to where to be stored, after completion of using the wire ropes.

The molding flask stock yard in the molding shop is found fairly messed up, and cannot be said where is orderly set. The way of stacking up the molding flask is also messed up, and there is a too high stacking of them as well. Others include a lack of controlling the ways of placing the scaffold boards. They must be placed at a stable, fall-free way of storage. The safety passages and work aisles are also insufficiently reserved in the molding shop. Sand slingers are provided to the manual sand lines, longitudinally passing through the molding shop, in which a passage is provided. It is advised to reserve a space of 200 mm at the both outsides of the sand slingers, whereby marking a white line, and to pave the passage with concrete.

It is also advised to make all floor surfaces with concrete in the molding shop, and to separate the area where is to be used for casting, over where sand is to be laid. The work field should always be kept clean with such identifications. If the floor is all kept with sand likely at present, tobacco stubs and dust are carelessly scattered around, thus disordering the area.

For the patterns placed on the small molding machine lines, what are not immediately needed should be sent to the warehouse so that the work field may be put in order.

It should always be kept in mind that no good product can be made from a messed up, disordered work field.

3) The melting shop is messed up before the furnace, where should be placed with concrete, and put in order. The safety hand rails of the pit before the furnace should also be made good to prevent any from falling down.

The S-loop is used for transporting the ladles, which seems to be made by the shop. The eye-bolt type forged hook should be used for this purpose. Use of the S-loop causes an extension, which is dangerous. Anyway, whatever is used at present should regularly be examined by a nondestructive method and checked for dimensional extension. Inspection of, the trunnions and lift lugs of ladles should also regularly disassembled and checked. The ladles are preheated with a fuel oil burner beside the passage. A location far away from the passage should be allocated to do this job.

Since the applied ladles remain fairly hot on the outer shell, there is a fear of burning upon contact. Consideration needs to be taken to warn out that the ladles still remain hot, by hanging down a sign board of such indications.

Since the melting shop often receives the arc sparks and splashes of molten metal at receiving it into a ladle, workers need to strictly observe the wear of protective glasses and mask, heat-resisting clothes, etc. against burning.

The crane operators in the melting shop need to firmly wear the protective glasses, mask, etc.

4) The finishing shop has had a fairly frequent occurrence of incidents this year, which are caused mainly by reason of human actions, e.g., fragments hitting to human body upon chipping off casting fins, splashing frangments to hit the nearby people upon cutting the riser, sprain of feet due to unstabilization upon handling articles, etc.

The finishing shop handles many of complexed shapes.

Since the casted products have the risers, sprues and runners, or the fins are generated irregularly, they tend to be unbalanced at transportation. Therefore, troubles may often be caused in handling articles. In this regard, it is advised for workers to observe the slinging and basic actions for transportation without grudging the trouble of doing so. Nevertheless, looking at the current situation of finishing shop resulted unfortunately in finding a fair amount of unsafe jobs and in feeling that incidents happen as expected as they should happen. For shake out, sand remains fully in and around the shakers as well. Such conditions may cause a trouble, because the stepping base is unstable. Such sand should immediately be collected to keep the area clean.

The castings are transported to the finishing shop via transfer car, but the way of stacking them is also unstable and messed up. No fall-down protective fence is also provided. If such a way of transportation is permitted, this is a question of basic policies to the safety. The outside passage of transporting them is also bumpy without pavement. This is also a matter of question.

The basis of safety starts with the orderly clean settlement of work fields. Looking at the current situation of finishing shop resulted in finding, for example, a mountain of sand taken off the castings before the shot blast area so that no article may be placed orderly thereat. Since the products themselves are unstable, ways of placing them stably should moreover be contrived to use the lockers with spacers, sleeping lumbers, etc. The current situation is strongly impressed as articles are just left around.

For lifting a load, for example, a square liner is also lifted up with a single chain. If this is slipped out, this would lead to a critical incident to damage the feet of workers, etc.

Although people ought to know of such already, the basis is not observed, in fact. Even though the regulations are provided, they become vain, if they are not observed. This is just an example, but this could simultaneously be said telling the entire image of this shop. With recognition that why the field workers do not practice is because the education and training by the supervisors are bad, efforts need to be made to progress the safety control steadily.

For the safety protective equipment, workers wear the safety helmets, but it is strange for us that no helmet is provided with jaw strings. This may halfly reduce the effect of safety helmets. Although workers wear the protective glasses, no worker wear the dust protective mask as a countermeasure against particle dust. Since this shop has much particle dust of sand and grinder, the dust protective mask should be worn by the workers. The working clothes vary greatly, such as sweater, jumper, etc. Workers should wear a close-fitted working clothes, because this shop has sparks, and uses such rotary tools as grinder, etc.

For the chains to be used for slinging work, if the chain is slung as a links remain twisted, there is a danger of cutting it. Many cases were seen to use the chains in such a manner without paying attention to this regard. For the chain control, neither daily nor regular inspection can be thought to be performed thoroughly, viewing from the current application status. Differing from the wire ropes, chains may suddenly be cut to cause a critical incident after they are fairly worn out, because of a difficulty to find out where is worn out, at a glance (as a crack progresses gradually). They must, therefore, be controlled by conducting such daily and periodic inspections of hammer lock and link deformation so that no unexpected incident may be generated.

Since molten metal splashes around at gas cutting the risers, etc., consideration should be taken to completely surround the area with fences so that nothing may splash around. The current situation is no more than merely having a partition partly.

The particle dust from the swing grinder are collected by the cyclone, but incomplete. Not matching the suction opening with the grinder is also a matter of question, but it is advised to install a dust collector of high suction power and dry bag filter.

The work field should be drawn with white lines over all areas to specifically discriminate between the passages and work fields, and the floor should be paved with concrete to keep clean at all times.

2.7.3 Current Safety Control in Plate Shop

Similarly as in the foundry shop, the safety control in the plate shop was found to have the situations at many places seemed to be corrected, upon observing the actual situation of the work fields, which are discussed as follows.

1) Orderly settlement and cleaning

The orderly settlement and cleaning are basic to be said the first step of safety control. Improvement is desired first in this regard. The first is the outdoor material stock yard. Here, the steels, i.e. mainly the steel plates and sheets, semi-products, jigs, etc. are aligned in a wide area. The condition is that no zoning line is provided to discriminate the passages and each stock location, that the steels are placed so close that where is a passage for work cannot be identified and that no spacer is orderly placed to cause the stacks to be leaned or the packages likely to be damaged as well. The land surface remains as rough as it cannot be said sufficiently prepared, with the scattering of stones, steel pieces like scaps, wooden pieces, etc.

This causes a lack of passages for forklift and mobile crane trucks ad loading in-and-out the steels. Such dangerous conditions can also be assumed as difficulties in the slinging wire and hacker works, bad stepping base, package damage, etc.

Here must first be prepared completely. The locations should then be zoned for type and size of steels, reserving appropriate passages.

Indications should be provided simultaneously to them so that they can clearly be indentified. It is advised then to use spacers to meet the shapes and sizes and to horizontally stack the stocks by maintaining their parallelism and perpendicularity. Labeling the product name, dimensions and weight to the steels is best for steel stock control.

The second is the work fields in the shop. The areas around a high operating machine, benches and welding work are especially bad. The materials, in-process items and tools are placed on these areas as the space looks likely insufficient, conditioning that workers have to walk likely to meander among them. Conduct cables, air hoses, grounding lead wires, small tools, foreign matters, etc. are also scattered around on the floor. The safety passages in the shop are provisionally indicated with white lines, but they are almost likely disappearing. Materials come out to the passages or pallets are left on the passages. The narrower the shop are, the more the unneeded or not immediately required articles need to be settled in order, whenever it is found.

It is necessary for workers to strictly and thoroughly perform the "settlement in order per job."

It is advised to determine the routes for cables and hoses without meandering, to bundle them and to protect them by covering, etc.

2) Crane and slinging work

The crane and slinging work, if an incident happens once, may often be led to a critical incident, so that this is one of the especially important items on the safety control aspect. This work is already discussed in the previous section of foundry shop, the same is conditioned in the plate shop as well. Such are the examples that no lock for slinging wires is provided to the crane hooks, that the slinging wires are hung down in the wire storage as the kinks remain, etc.

During this study, it was witnessed that a steel plate of about 2×2 m (about 1 ton) was lifed up horizontally at two positions with pawl hackers, and transported above the ore carrier bogies at about 3 m height and under assembly. It was a very dangerous work that it might be turned over and dropped down immediately, if it got a contact with anything during transportation. This must really be warned out.

Another thing is the overload work. The shop is disciplined that the overload work is carried out by thoroughly examining the cranes electrically and mechanically and also by checking the safety through the load tests. It is, however, difficult to check the safety on all aspects. In order to avoid the occurrence of any unexpected incident, it is also advised to increase the capacity of cranes and building side.

3) Assembling work of ore carrier bogies

An ore carrier bogie for loading 100 tons was under assembling at the center of the shop to assemble the loading frames above the floor at the lateral posture, then to mount it onto the bench for assembling and to conduct the final welding. Since this loading frame becomes unstable upon directing laterally, four angle struts are installed for preventing it from falling as an anchor bar from the floor, but the method to fix them was insufficient, because the shop floor was laid with 130 mm square wooden plunks, i.e. metal anchors were hammered into the gaps between the wooden plunks, to which the angle strut ends are connected, so that this could not receive a big force. The purpose of preventing it from falling is not only to maintain the posture, but also it is necessary to hold the strength free enough from falling even upon receiving an external force, such as contact with a train, crane, etc., earthquake, etc.

Since the plate shop involves naturally in the occurrence of such assembling work to use the floor as above, it is preferable to modify the floor to a floor surface plate available to be reinforced by welding.

The welding work on the assembling bogies reaches about 4 m in height, which belongs to a job at a high location. For this welding work, the lift staircase, ladder and scaffold boards are used, but without hand rails. No safety belt is also used. The ladder was not bound and fixed. The scaffold boards acrossing between the scaffolds, which are installed internally, were also not bound and fixed, and the narrow, broken boards were also used.

This mineral bogies is planned to be manufactured and connected continuously with 16 trains of a same size. During this study, the 12th bogie was under welding. Based on the foregoing, the safety control of this work cannot help being said very poor. Naturally after the first bogie is completed, wherever are unsafe must be checked and improved, which must be reflected upon the following work. This is what is said control.

4) Safety protective equipment and others

For the safety protective equipment, such ordinary items as safety shoes, safety helmets, protective glasses, masks, gloves, ear plugs, etc. are provided, but the state of their use cannot necessarily be said good. First, no jaw string is provided to the safety helmets. This is so in the entire factory. This allows the safety helmets to easily run off the heads upon stumbling over anything or upon having the heads hit anything, thus impossibly assuming the role of safety helmets.

Also witnessed the workers moving without a safety helmet during work. The state of using the protective glasses, ear plugs, gloves etc. seemed good, but use of a dust protective mask was not found in the grinder, welding and gas cutting works where have much particle dust.

Since the efficacy is invisible, this tends not to use a mask at anywhere with grudging the trouble of doing so, but it is necessary to steadily and severely train and guide the workers for what purpose it is used to have them understand it thoroughly.

5) Safety measures for machines and tools

The plate shop has a few of high-speed operating machines, and takes no special measure like protective fence, but limiting to an extent to put a cover over the motors, gears, belts, etc.

However, a cover for cutting blades of shearing machines is necessary. We also saw that the air grinder cover remained removed and that the whetstones were left downward on the floor. The whetstones are weak against impact force and moisture. In order to prevent the incidents from occurring due to damage, the whetstones must be placed upward always with the cover.

2.8 Raw Materials

2.8.1 Foundry Shop

Principal materials used in casting are as shown in Table 2.8.1-1. Considerable quantities of these materials are imported. Materials used for pattern, moulding (moulding sand), melting and finishing are described hereunder.

1) Relative to pattern

Principal materials used for pattern are boards and veneer boards. As mentioned in the foregoing, white pine of Canada growth and that of home-growth are used at the rate of 60% and 40%, respectively. This white pine has no knot or crack and is easy to process, and is considered to have no special problem as ordinary wood pattern material. The following kinds of boards are currently in use:

- 12" wide×16" long×1-1/4", 2", 3" and 4" thick
- 18" wide×16" long×1-1/4" thick
- 20" wide×16" long×1-1/4" and 1-1/2" thick

Among these kinds, boards in 12" wide×16" long×1-1/4" (31.5 mm) are largely used. Consumption of these boards is approx. 5,000 sheets per year in terms of 12" wide×16" long×1-1/4" thick size. There are such home-grown wood materials as alamo, insigne (pine), etc. but they have knots and cracks, and yield is about 80%. In addition, there is a hard wood named rauli which is used for furnitures. Veneer boards are not of waterproof type. They are considered to be changed to waterproof type. Veneer boards in the following 4 sizes are used. They are all home made veneer boards.

- 1,500 mm wide×2,500 mm long×6 mm, 10 mm, 20 mm and 1" (25.4 mm) thick
  Of these boards, 1" (25.4 mm) thick veneer board is largely used.

2) Relative to moulding (moulding sand)

Sands used for moulding are silica sand, olivine sand, chromite sand and zircon sand.

Of these sands, silicon sand is domestic sand and all other sands are imported sands. Examples of components of these sands are shown in Table 2.8.1-2. There is a problem for the quality of silica sand out of these sands. This sand is gathered at Cartegena sandhill near San Antonio Port 100 km away from Rancagua. Silica content

(SiO) of this silica sand is about 86%, which is low for foundry use. This foundry shop is producing cast steels and is also producing considerably thicker castings.

Normally, sand with SiO content 95 to 97% is used for cast steel and sand with SiO content 93 to 95% for cast iron. It is therefore necessary to look for sand with more higher SiO content. Grain size of sand is around AFS50 and there is no problem.

3) Relative to melting

Melting is carried out in the electric furnace and raw materials used are steel scraps and returned castings. Some of steel plates are cut by a shearing machine but there are considerably large scrapped steels in the scrap yard. It cannot be said that sizes of materials to be melted are not well controlled. Further, a large quantity of sand is adhered to risers and other return materials. Those sands adversely affect melting yield and power loss.

Improving sand removal from castings leads to improvement of riser cutting, saving of finish grinding and improvement of melting yield, and it is therefore necessary to make efforts toward technical improvement in the aspect of moulding. Further, as to additives and alloy materials used in melting, it is considered there will be no problems to be noted especially.

4) Relative to finishing

Various types of grindstones; those for rough grinding, cutting, finishing, etc. are used for finishing of castings. Principal types of grindstones are shown in Table 2.8.1-3. Further, grindstones in various shapes are used; i.e., flat type, disk type, offset type, cut type, grindstone with a shaft. Those grindstones are imported from Austria, Swiss, U.S.A., etc. Especially, those of Austria made (TYROLIT) are largely used. The main reasons is that they are cheap in price. According to the result of cutting ratios of grindstones tested at this shop (refer to Table 2.3.1-3 in 2.3.1 Current Production Technologies), grindstones made by Norton Inc., U.S.A. for the swing grinder are more superior.

Since many of materials to be grind are cast steels and cast irons with a high degree of hardness, grindstones in rough particle size are used. Grindstones are principally composed of aluminium oxide (alumina) (AlO) and the binder is organic resinoid. Principal components of this resinoid are synthetic resins such as bakelite, having sufficient elasticity enough to withstand relatively high speed rotation. This resinoid type grindstones are used normally at peripheral speed 50 m/sec and some of them are used at max. 80 m/sec. This resinoid type grindstones are satisfactory for free grinding and some of them are normally used for remoting casting fins.

Table 2.8.1-1 Unit Price and Annual Consumption of Raw Materials used for Casting

Classification	Item	Unit Price			Annual Consumption	Remarks
		Unit	US$	Yen		
Materials for Pattern	White pine	PM	36.24	5,798	615	
	Veneer board	PL	7.74	1,238	36	
Materials for Moulding	Silica sand	Ton	40.0	6,400	161.2	
	Chromite sand	Ton	110.0	17,600	173.4	
	Zircon sand	Ton	70.0	11,200	18.4	
	Water glass	Kg	0.56	90	19,440	
	CO_2 gas	Kg	0.31	50	60,910	
	Alcohol	ℓ	0.91	146	18,800	
	Clay	Kg	0.10	16	24,400	
	Bentonite	Kg	0.45	72	317,760	

(cont'd)

Classification	Item	Unit Price			Annual Consumption	Remarks
		Unit	US$	Yen		
Materials for Melting	Steel scrap	Kg	0.06521	10.4	2,992	
	Return scrap	-	-			
	Fe-Si	kg	0.89	142	56,470	
	Fe-Mn (C_H)	Kg	1.35	216	389,100	
	Fe-Mn (C_L)	Kg	1.98	317	61,300	
	Fe-Cr (C_H)	Kg	0.62	99	78,950	
	Fe-Cr (C_L)	Kg	1.28	205	69,600	
	Ni-Shot	Kg	7.47	1,195	8,110	
	Electrolytic Ni	Kg	6.74	1,078	8,350	
	Fe-Mn	Kg	1.23	197	85,550	
	Ca-si	Kg	1.64	262	750	
	Graphite	Kg	0.42	102	34,530	
	Magnesia clincer	Kg	0.59	94	79,900	
	Graphite electrode 8 x 60"	Pcs	188.45	30,152	451	
	Graphite electrode 10 x 60"	Pcs	301.40	48,224	68	
	Refractory cement	Kg	2.45	392	1,080	
Materials for Finishing	Grindstone	Pcs	1.29	206	880	
	Mantle type grindstone	Pcs	119.34	19,094	350	
	Carbon rod	Pcs	0.56	90	700	
	Oxygen (O)	Kg	0.36	58	18,500	
	Acetylene	Kg	4.79	766	35	

Table 2.8.1-2 Components of Silica Sand (%)

	SiO_2	Al_2O_3	Fe	CaO	MgO	Na_2O	K_2O	Ti	P
Silica 0#	86.4	7.2	1.4	1.5	0.35	0.90	1.00	0.3	0.012
Silica 1#	83.9	9.0	1.4	1.4	0.32	0.85	0.90	0.3	0.011

Components of Olivine Sand (%)

FeO_3	CaO	SiO_2	MgO	Al_2O_3
8.65	1.0	41.40	41.50	2.2

Components of Zircon Sand (%)

ZrO	SiO_2	TiO_2	Fe_2O_3	Al_2O_3
65.5	34.0	0.20	0.03	0.95

Components of Bentonite (%)

	SiO_2	Al_2O_3	Fe	CaO	MgO	Na_2O	K_2O	Ti
Bentonite	49.0	22.7	4.4	0.9	1.46	0.65	0.65	0.95
	60.4	20.1	3.0	1.5	1.84	1.25	0.70	1.20

Table 2.8.1-3 Kinds and Annual Consumption of Principal Grindstones

	Use	Size	Bond	Symbol	Annual Consump-tion (Pcs)	Unit Price (US$/Pcs)
1	For grinding (For Mantle)	24"x12"x3"	Resinoid	A145-04-1B 83/50	348	128.56
2	For grinding	30x40 mm	Resinoid	A-16-205B-83	600	1.08
3	For grinding	2"x3$\frac{1}{2}$"x 5/8 with a shaft	Resinoid	4-16-R5B	300	3.25
4	For grinding	∅6"x2"x5/8	Resinoid	4-16 R5B Screw type	120	6.35
5	For grinding	8"x1"x5/8	Resinoid	M-112-A145-P5-B83	200	16.03
6	For grinding	36x40x5/8	Resinoid	A-16-205B-83 with the ∅16 shaft	288	1.61
7	For cutting (Riser)	9"x1/4"x7/8"	Resinoid	A30S-4B-47A-20F	547	1.98
8	For cutting (General use)	9"x1/ "x7/8"	Resinoid	A30S-4B-47A 20F	213	1.50
9	For cutting (Riser)	7"x1/4"x7/8"	Resinoid	A30RBF	100	1.48

2.8.2 Plate Shop

Raw materials used by the plate shop are broadly classified into two kinds; steel materials and welding materials.

1) Steel materials

Most of steel materials are purchased from CAP (COMP. ACERO DEL PACIFICO) of Chile. As listed in Table 2.2.1-9, the material standards for these steel materials are 40 kg/mm^2 class mild steel and 50 kg/mm^2 class high tensile steel. Steel plate consumption in 1985 was about 880 ton/year or 70 ton/month as shown in Table 2.8.2-1. Steel plates up to thickness 32 mm are home-produced in Chile (CAP made) and more thicker steel plates are imported. In addition, T-1 steel and stainless steel may be used in special cases. Further, shape steels are produced from steel plates as a rule because they are not rolled at the steel mill in Chile (CAP). Materials are purchased by the engineering and procurement departments of the division and delivered into the shop as required. The production schedule was never affected adversely by undelivery of materials so far. The material storage yard is the open space adjacent to the plate shop. Part of steel materials is stored vertically but the most part is laid horizontally in disorder without segregation by types or thickness. Thus, forklift trucks cannot travel as desired. This state of material storage may cause erroneous use and deformation of materials, and is very dangerous from the viewpoint of safety.

2) Welding materials

General electrodes for manual welding and some welding wires are imported from U.S.A. (Lincoln Inc.) and Canada (Utetic Inc.)

The greater part of electrodes for manual welding is of low hydrogen type (AWS E7018) and very small quantity of electrodes for manual welding of stainless steel and surface hardening is used. The majority of welding wires for semiautomatic and automatic weldings, except MIG welding, is of self-shielded type. As shown in Table 2.8.2-2, consumption of welding materials in 1985 was about 35 ton/year or a little under 3 ton/month. Welding materials purchased at the division side are delivered into the warehouse in the shop in response to the shop's request.

Delivered welding materials are stored in a tool room by type and issued when requested by welders. Low hydrogen type electrodes covering the majority of welding materials are used directly without being dried after unpacked. The moisture absorption state of low hydrogen type electrodes and influence given to the welding are described below for information.

Needless to say, influence of moisture given to low hydrogen type electrodes under the hot and humid climate in Japan differs largely from that in Chile under the nearly same temperature as Japan but in very dry condition. However, use of electrodes without drying is questionable.

(1) Weld crack due to hydrogen

As metallurgical factors for weld cracks, reduction of ductility of base metal by thermal effect, brittleness resulted from over-saturated hydrogen, presence of harmful impurities, etc. may be pointed out. Of these factors, brittleness by hydrogen is caused in such a way that hydrogen gas produced as a result of decomposition of organic matters and moisture contained in coating material enters (is dissolved) into deposited metal in molten condition at time of welding and this hydrogen enters (diffuses) into the heat-affected zone, thus making the weld zone hard and brittle. Since hydrogen exists in atomic state in steel and is able to pass through the atomic lattice of iron, not only the inside of deposited metal but also the heat-affected zone are made brittle. Hydrogen contained in steel tends to gather around the lattice defect and non-metallic inclusions or blow holes, and becomes one of large factors for causing cracks.

(2) Low hydrogen type electrode (AWS E7018)

a) Properties

This type of electrode is an electrode composed principally of such basic carbonate as calcium carbonate and fluorite, ferrosilicon, etc. added without containing organic matters and other sources of hydrogen in the coating material. Quantity of hydrogen generated from the coating material is less and CO_2 gas produced through decomposition of carbonate shields arc and therefore, quantity of hydrogen in deposited metal is extremely less than other types of coating as shown in Figure 2.8.2-1.

Therefore, not only mechanical properties but also notch toughness as well as crack resistance of deposited metal are most excellent among various types of coated electrodes. Accordingly, low hydrogen type electrodes are used for welding of thick plate, high tensile steel, and hard facing requiring high level of hardness.

b) Moisture absorption and drying

Moisture absorption of electrodes is taken place when they are left in the air. Factors causing moisture absorption are temperature and relative humidity, components of coating materials (especially, organic matters), particle size, thickness of coating, adequacy of packed condition, etc. An example of the relationship between time of electrodes left and absorbed moisture is shown in Figure 2.8.2-2. What is important as a caution when a low hydrogen type electrode is used is to protect the electrode from absorbing moisture as the effect of low content of hydrogen will be reduced to one-half. This will be as a matter of course when considering the fact that moisture contained in the coating material will become one of sources of hydrogen generation if an electrode absorbs moisture.

Effects of moisture absorption by electrodes are as follows:

: Blow holes and/or cracks are readily produced.

: Mechanical properties of deposited metal deteriorate (crack resistance may drop).

: External appearance becomes worse.

: Coating becomes readily separatable and arc becomes unstable.

As the above-mentioned troubles can be readily generated if moisture absorbed electrodes are used, electrodes should be re-dried in order to retain their quality. Conditions for re-drying are shown in Table 2.8.2-3.

Table 2.8.2-1 Actual Annual Consumption of Steel Plates (1985)

Material Size (mm)	Unit Weight (T)	No. of Sheets (Sht)	Total Weight (T)
6 x 1.850 x 10.800	0.985	46	45.254
8 x 1.850 x 10.800	1.295	99	128.192
10 x 1.850 x 10.800	1.639	30	49.161
12 x 1.850 x 10.800	1.798	188	337.944
16 x 1.850 x 7.600	1.843	13	23.962
16 x 2.430 x 7.509	2.335	29	67.704
20 x 1.850 x 6.000	1.754	20	35.085
22 x 1.219 x 5.000	1.137	7	7.962
25 x 1.850 x 5.000	1.828	24	43.868
32 x 1.850 x 5.000	2.361	5	11.806
38 x 1.850 x 3.250	1.906	8	15.248
50 x 1.000 x 4.750	1.852	12	22.218
Others (Steel materials in 6 mm or less)	-	-	44.796
Low alloy steel (LC4140)	-	-	46.500
Total		481	879.700

Table 2.8.2-2 Actual Annual Consumption of Electrodes (1985)

Type of Electrode	Consumption	Unit Price	
		US$/kg	¥/kg
Low hydrogen type	21.450	0.80	128
For stainless steel	0.975	5.33	853
For surface hardening/overlay	0.300	1.02	163
MIG wire	0.300	1.70	272
Self-shielding wire	11.750	2.65	424
Carbone electrode for arc air gauging	0.410	4.10	656
Total	35.190		

Note: 1 US$ = 160

Table 2.8.2-3 Redrying Temperature & Holding Time of Electrodes

Type of Electrode	Redrying Temp. & Holding Time	Absorbed Moisture Requiring Redrying	Storage Temp.
General mild steel coated electrode	120°C x 1 hour	3.0%	-
Low hydrogen type electrode	300 to 350°C x 1 hour	0.5%	100 to 150°C
Very low hydrogen type electrode	380 to 415°C x 1 hour		

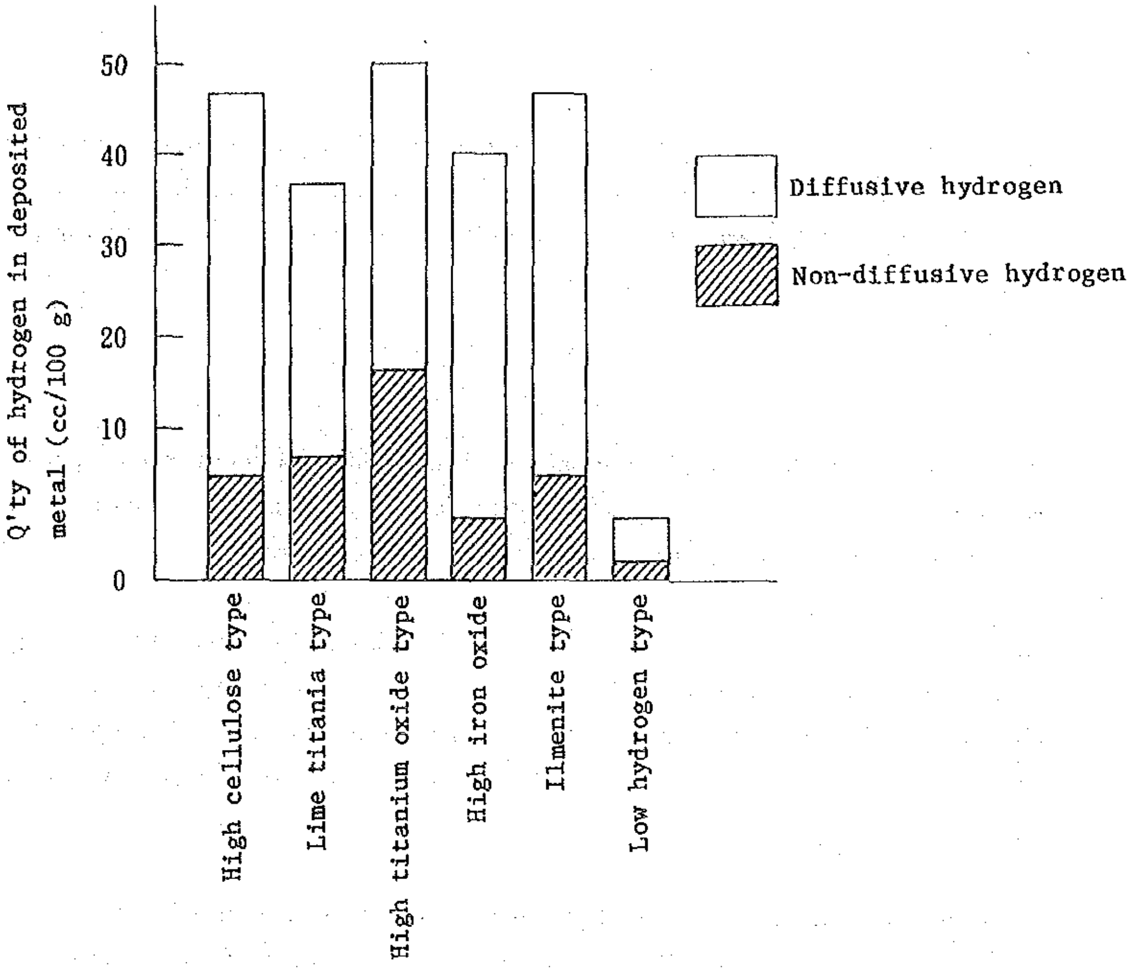


Figure 2.8.2-1 Q'ty of Hydrogen in Deposited Metal

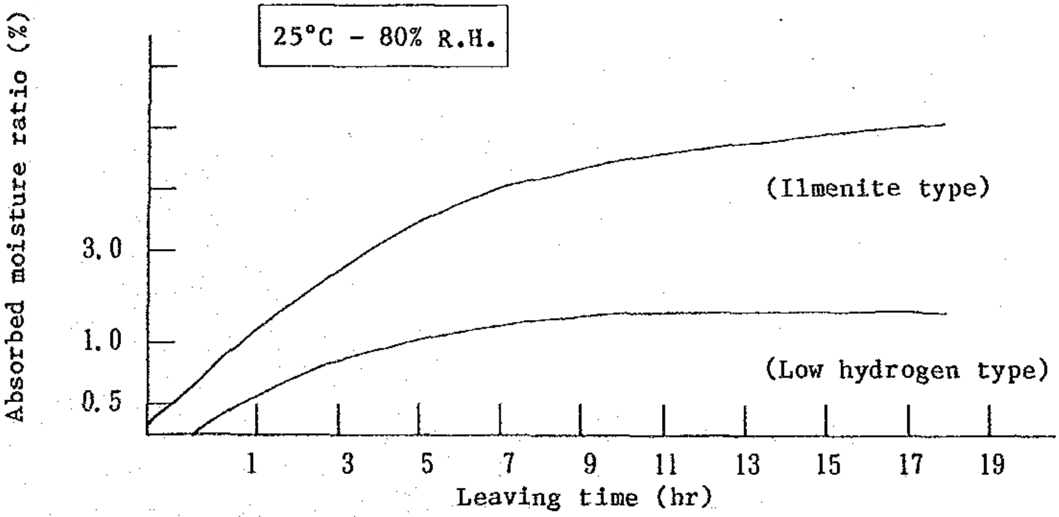


Figure 2.8.2-2 Relationship between Electrode Leaving Time & Moisture Absorption

2.9 Utilities

There are such utilities as electric power, various gases, heavy oil, compressed air and water used for production at the shops and electric power, water, steam and propane gas for living use. Results of the investigation conducted on these utiliteies are described in the following.

1) Electric power

Electric power used at the shops is as shown in Table 2.9-1. Until a recent date, electric power was supplied from the electric power company in Rancagua but currently, it has been changed to be supplied from CODELCO's own power station.

Electric power is transmitted at high-voltage of 34.5 kV and is supplied to all shops after stepped down at the substation of Div. E1 Teniente. Except high-voltage power of 13.8 kV and 6.9 kV supplied to electric furnaces in the foundry shop, 550 V is supplied to the general machinery and 208 V to the lighting system through the switch box at each shop.

Frequency has been changed over from 60 Hz to 50 Hz as a result of change of the source of power supply. As a result, number of revolutions of all machines using motors dropped by 17% in particular, capacity of grinders directly coupled to motors largely dropped and production has been adversely affected. It is planned to gradually replace these motors currently in use with 50 Hz motors.

Table 2.9-1 Electric Power for Shops (1985)

	Item	Specification
1	Receiving capacity	22,000 KVA
2.	Power consumption	
	Peak	10,000 KWH/H
	Monthly, max.	1,622,684 KWH/M
	Annual consumption	
	Foundry Shop	10,985,239 KWH/year
	Plate Shop	1,000,000 KWH/year
	Machine Shop	1,636,287 KWH/year
	(Total)	(13,621,526 KWH)
3.	Voltage	34.9 KV, 13,8 KV, 6.8 KV 550 V, 280 V, 110 V
4.	Frequency	60 Hz
5.	Unit price	0.03 US$/KWH

2) Gases

Specifications of gases used at the shops are as shown in Table 2.9-2. Supply of these gases is collectively controlled by Div. El Teniente, and gases are supplied to respective storage tanks or the cylinder storage yard by external suppliers and the shops use only required quantity.

Out of thse gases, propane, oxygen and CO_2 gas are supplied to the shops through pipes and for other gases, cylinders are brought to near using locations.

The piping system of propane gas is divided into the high pressure piping of 8 kg/cm^2 for cutting and pre-heating and the low pressure piping of 0.03 kg/cm^2 for shop heating, and high and low pressure propane gases are supplied through respective pipings to the foundry plate and machine shops from the collected tanks provided in the open air. For heating, a panel type gas heater is provided at 3500 mm above the floor for every working place.

Oxygen is supplied to the foundry, plate and machine shops through the pipings from the liquefied oxygen tanks and the vaporizers installed at 2 points outside the foundry and plate shops. However, as there are few take-out ports available at the foundry shop, it is necessary to bring oxygen cylinders to the riser cutting yard of the finishing process though the piping system has been provided.

CO_2 gas used for moulding at the foundry shop and is supplied to the core making yard from the CO_2 tank through the piping.

This piping system consists of the main pipe installed 5–7 m above the floor along the pillars of the shop building and the take-out pipe coming down from the main pipe. This take-out pipe has only one take-out port and a header having normally used several take-out ports is not provided.

Table 2.9-2 Specifications of Gases

	Name	Supply Pressure	Supply Capacity	Supply Method	Unit Price	Annual Consumption	Remarks
1	Propane	0.03 kg/cm^2	0.671 m^3/min	Piping		52,359 kg/year	For shop heating
2	Propane	8 "	45 kg/cylinder	Cylinder	0.31 US$/kg	12,909 "	For cutting
3	Acetylene	15 "		"	4.79 "	1,132 "	"
4	Oxygen	9 "	5 m^3/min	Piping	0.36 "	70,140 "	"
5	Oxygen	141 "	9 "	Cylinder		4,230 m^3/year	"
6	Nitrogen	141 "	6 "	"		330 "	
7	Argon	141 "	9 "	"	6.67 US$/m^3	288 "	
8	Hydrogen	140 "	6 "	"		240 "	For plasma
9	CO_2 gas	17.5 "	2.5 "	Piping	0.31 US$/kg	60,910 kg/year	For moulding
10	CO_2 gas	56 "	9.1 m^3/cylinder	Cylinder		273 m^3/year	"

3) Compressed air

Compressed air used at the shops is as shown in Table 2.9-3. Compressed air is supplied to each shop from 3 air compressors provided in the maintenance shop through the piping system. Likewise the gas piping system, the take-out pipe coming down from the main pipe for the compressed air has only one take-out port.

The air compressors have sufficient capacity for consumption at the shops and it seems there are no such problems as shortage of air pressure. However, air leakage was observed at various air hose and tool connections during the investigation. It is said that approx. 1/3 of whole air consumption is leakage at shops which are older than 20 years. It seemed that there was a considerable amount of air leaded at this shop. It is considered necessary to take some measures such as change of pneumatic tools to electric tools in addition to proper maintenance of the piping system from the viewpoint of energy saving.

Table 2.9-3 Compressed Air

Item	Pressure	Supply Capacity	Compressor Capacity	Annual Consumption
Specification	7.1 kg/cm^2	45 m^3/min	112 KW x 3 units	840,000 KWH/year

4) Water

Specification for water used at the shops is as shown in Table 2.9-4. Water is supplied from Rancagua City and pipes in diameter 50 to 100 mm have been laid under ground in the shop yards.

Table 2.9-4 Water

Item	Pressure	Supply Capacity	Compressor Capacity	Annual Consumption
Specification	2 kg/m^2	2.4 m^3/min	0.067 US$/m^3	946,080 m^3/year

5) Heavy oil

Specification of heavy oil used at the shops are as shown in Table 2.9-5. Heavy oil is used as fuel oil for 4 units of the heat treating furnace and boiler for shower bath. Heavy oil tanks are installed in close vicinity to respective furnaces and boilers and except No. 4 Furnance in the scrap yard, the heavy oil tanks in all yards are connected through pipes.

Table 2.9-5 Heavy Oil

Item	Supply Capacity	Storage Tank Capacity	Unit Price	Annual Consumption
Heavy oil	0.23 m^3/min	44 m^3	190 US$/$m^3$	692 m^3/year

2.10 Market survey

The Workshops Department—object of the present study—serves as source of supply of various mining equipment to the El Teniente Division, and as maintenance and repair facility for the same (cf. 90% of the castings produced in the Foundry Shop are intended for the El Teniente Division). This function of the Workshops Department is considered not to change in the foreseeable future.

For this reason, the future demand for products of the Workshops was estimated mainly envisaging the demand expected from the El Teniente Division.

1) Factors influencing the demand for Workshop products

CODELCO's plans for the future are centered around measures for meeting the anticipated lowering of copper content in ore from the mines operated by CODELCO, calling for increased amounts of ore to produce the same amount of metal, and the circumstance also applies to the El Teniente Division. The hardness of ore to be mined further is tending to increase at the mines.

The quantities of copper metal to be produced by the different CODELCO Divisions are planned to progress as indicated in Table 2.10-1, according to which the level of production at El Teniente Division is expected to be raised in the years to come.

From the foregoing overview, all the three factors that can be considered to influence the demand for Workshop products, i.e.—

- Amount of metal to be extracted from ore
- Copper content of the ore from which metal has to be extracted
- Hardness of the ore which has to be excavated, all point toward increased demand for mining equipment supply and maintenance/repair.

Table 2.10-1 Planned progress of copper production by the different divisions of CODELCO

(Unit: 1,000 tons)

DIVISIONS \ YEAR	1985	1986	1987	1988	1989
Chuquicamata	565	573	573	752	852
Salvador	100	100	100	100	100
Andina	105	105	105	105	105
El Teniente	321	383	383	383	337
TOTAL	1,091	1,161	1,161	1,340	1,394

Source: CODELCO

Table 2.10-2 Product demand forecasts given by CODELCO for Foundry Shop

(unit : ton)

group \ year	1986	1987	1988	1989
Liners for ball and bar mills	3,568	4,103	4,638	5,152
Primary and secondary crushing machine parts	723	831	940	1,044
Bearing support, bushing, etc.	162	186	211	234
Gear, axes, etc.	234	269	304	338
Brake shoe, bearing housing, etc.	117	134	152	169
Parts of Pump (impeller, casing, etc.)	210	242	273	303
Parts of water power turbine	87	87	87	110
Ladle, bucket, and miscellaneous	439	518	595	650
TOTAL	5,540	6,370	7,200	8,000

Table 2.10-3 Product demand forecast given by CODELCO for Plate Shop

(unit : ton)

year group	1986	1987	1988	1989
Repair of Crusher & Ladle	460	510	550	600
Plate structure	1,544	1,841	1,989	2,180
Reinforced Bolt	2,300	2,553	2,806	3,080
Forging	150	180	210	240
TOTAL	4,554	5,084	5,555	6,100

2) Estimated demand for workshop products

Demand forecasts to 1989 for the Workshop products were furnished by CODELCO to JICA at the time of the Site Survey.

The figures for the Foundry Shop—reproduced in Table 2.10.2—and for the Plate Shop—in Table 2.10-3-have been derived by CODELCO specialists, solidly based on a thorough understanding of such factors as:—

- Process of copper production—mining, smelting, refining
- Facilities and equipment used for copper production
- Facilities and equipment required for achieving the production program of CODELCO.

It is revealed in this Table that, in 1989, the demand for products of the Foundry Shop will amount to 8,000 tons, and of the Plate Shop 6,100 tons, representing a roughly 40% increase over the corresponding figures for 1986—of 5,540 and 4,554 tons, respectively.

3. PROJECT OF MODERNIZATION

3 PROJECT OF MODERNIZATION

3.1 Basic Plan

3.1.1 Basic principles of modernization project

The basic principles to govern the Project of Modernization centered around the Finishing and Welding Processes respectively of the Foundry and Plate Shops of the Workshops Department—the specified subjects of the present Study—together with associated operations and equipment, are as follows:

A. To envision the ideal aspect that should befit the Workshops Department, in consideration of future prospects foreseen for the El Teniente Division and for CODELCO as a whole, based on which to draw up a Plan of Modernization that should realize an overall layout and equipment that will amply provide also for further enhancement of production in the years following completion of the Modernization Plan in 1989.

B. To let the Workshops present an aspect befitting a facility serving a copper production enterprise second to none in the world, purged of traces of an antiquated installation forced to operate under poor working conditions to keep up with increasing demand.

C. To permit the Workshops to fulfill their mission of serving as model for emulation by other enterprises in Chile in raising their technical capabilities, and thereby to enhance the national level of technological achievement.

D. To contribute to CODELCO's attaining an accomplished level of technology befitting the leading national enterprise of Chile.

In concrete terms:

E. To first thoroughly study all forms of hardware that are technically applicable to the actual situation; thereupon to aim at introducing installations of high practical productivity matched to the production program for the period of Project implementation ending in 1989.

F. To aim at realizing a safe and agreeable working environment, conformable to CODELCO's guiding principle of Regard for the Human Interests of Corporate Employees.

G. To judge the justification of investment on new equipment on the criterion of internal rate of return (IRR) derived by discounted cash flow method of financial analysis. Based on this criterion, to set aside—for consideration as future installation—such equipment as are technically feasible but should incur outlay to the extent of appreciably increasing production cost.

H. Where values of IRR below standard are obtained, concluding judgment to be passed with due account taken of the foregoing principles, in view of the difficulties foreseen in quantitatively judging the efficiency of investment in certain areas.

I. To formulate recommendations covering also the software aspects—including production control, engineering capability management, safety control, in view of the decisive factor constituted by the human element in bringing out the merits of modernized equipment, which will function effectively on when manipulated by operators concerting to work the facilities effectively. Enhancement of work safety has been specifically indicated as a matter calling for urgent attention, and to this end, the occasion of modernizing the equipment is considered to present an excellent opportunity for improvements in personnel management, to instill basic principles conductive to work safety.

Apart from modernization of productive facilities, buildings, material transfer/handling equipment and other aspects calling for urgent remedy under corporate responsibility to eliminate congestion, and violation of the principles of work safety, are set forth in the Appendix, together with suggestions on measures to be adopted in their regard.

3.1.2 Production Program

1) Foundry Shop

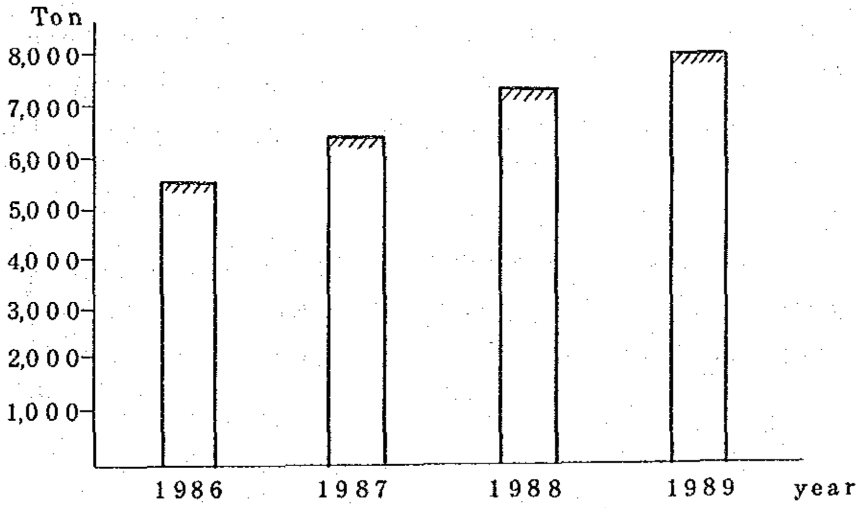
In the present instance, the production program is—by its primary mission—determined, not from trends of the general domestic market, but largely from estimates of the internal demand of the E1 Teniente Division itself. The product mix discussed in what follows is therefore based solely on the estimates given by the E1 Teniente Workshops Department. The period covered ends in 1989, and no indication was obtained on E1 Teniente's forecast for the ensuing years, but the rising trend of demand for the Foundry Shop products can be expected to continue, judging from such factors as the diminishing copper content in the ore to be excavated, and the mine galleries having to be extended toward layers of primary rock presenting increasing hardness for the cutters to bore through, in combination with CODELCO's plans to enhance its copper production.

For drawing up a Modernization Plan for the Foundry Shop, it should be better to have on hand demand estimates covering at least 10 years to come, but since this is difficult to determine at this time, the 4-year forecast officially obtained from CODELCO will be used as basis for deriving the production program.

The forecast for Foundry products is:

Unit: Tons

1986	1987	1988	1989
5,540	6,370	7,200	8,000



The foregoing production figures indicate a production increase in reference to 1986 of about 15% for 1987, abt. 30% for 1988 and abt. 44% for 1989; the yearly rate of increase is 15% for 1987, 13% for 1988, and 11% for 1989.

(1) Product mix by article

The principal product mix is expected not to vary significantly from the current range, covering a wide variety of items produced in small lots, in view of the primary mission of the Foundry to supply mainly replacement components and parts for various mining equipment and machinery.

The production program thus derived is presented in Table 3.1.2-1 for the different product groups of:

A. Ore-crushing bar and ball mill liners
B. Primary and secondary crusher components
C. Bearing supports and bushing (copper alloy castings)
D. Gearing, shafting and power transmission components
E. Brake shoes, bearing housings, etc. for ore car and other rolling stock components
F. Pump impellers and casings
G. Steam turbine components
H. Ladles, converter components, buckets and other miscellaneous articles.

Of the foregoing 8 groups of products, those produced in relatively large lots are the Groups A and B—liners and other components for ore crushing equipment—which represent 77 percent of the total production. This is followed by Groups F—pump components—and D—gearing and shafting. The Groups A, D and F represent in all 85 percent of total production.

The percentages to be contributed by the different product groups are presented graphically in Fig. 3.1.2-1. In the present instance, supply of Foundry products to other CODELCO Divisions or to the general Chilean market, is not envisaged.

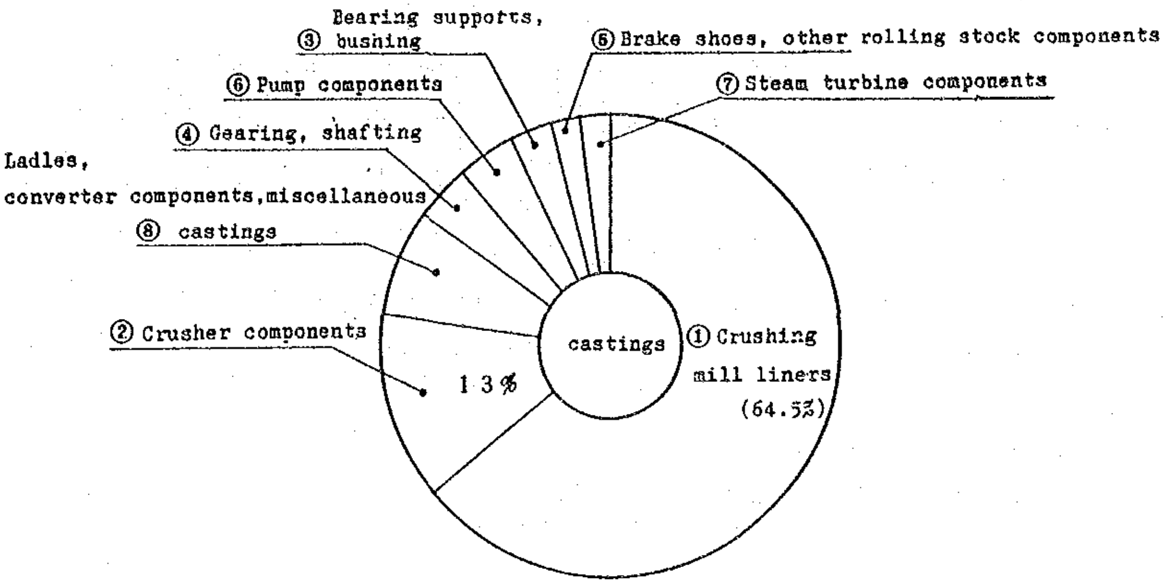


Fig. 3.1.2-1 Envisaged Foundry product mix—by article

(2) Product mix by material

Foundry processes differ with product material, which require not only different raw materials but also different equipment, and call for application of different standard unit manhours.

The production program by material groups is presented in Table 3.1.2-2, and graphically in Figs. 3.1.2-2 and -3. Between the three major categories of materials, the ratios—envisaged to remain without significant change from year to year—are:—

- Steel castings: 57%
- Iron castings: 40%
- Nonferrous—copper alloy castings: 3%.

Table 3.1.2-1 Foundry Shop production program—by product group

YEAR PRODUCT GROUP	1986	1987	1988	1989
A Liners for ball/bar mills	3,568	4,103	4,638	5,152
B Primary/secondary crusher components	723	831	940	1,044
C Bearing supports, bushes	162	186	211	234
D Gearing, shafting	234	269	304	338
E Brake shoes, bearing housings	117	134	152	169
F Pump impellers, casings	210	242	273	303
G Steam turbine components	87	87	87	110
H Ladles, buckets, miscellaneous castings	439	518	595	650
TOTAL	5,540	6,370	7,200	8,000

Table 3.1.2-2 Foundryshop production program—by material group

YEAR MATERIAL GROUP	1986	1987	1988	1989
Steel castings -				
- Ordinary carbon	431	496	560	622
- Low-alloy	234	269	304	338
- High-carbon abrasion-resistant	1,578	1,815	2,051	2,278
- High-manganese	723	831	940	1,044
- Low-carbon martensite stainless	87	100	113	126
- High-carbon ditto	108	124	140	156
- Austenitic stainless	8	9	11	12
TOTAL STEEL CASTINGS	3,169	3,644	4,119	4,576
Iron castings -				
- Ordinary iron	117	135	152	169
- Low-alloy ductile/martensite	93	107	121	134
- Ni-hard (DURTEN)	102	117	133	147
- High-chromium	1,897	2,181	2,465	2,740
TOTAL IRON CASTINGS	2,209	2,540	2,871	3,190
Nonferrous (copper-alloy) castings	162	186	210	234
GRAND TOTAL	5,540	6,370	7,200	8,000

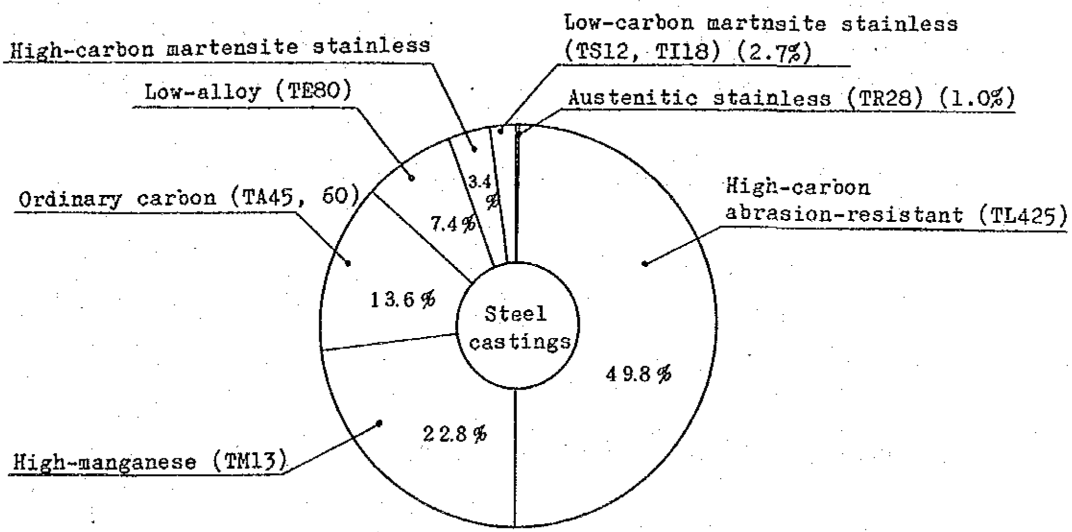


Fig. 3.1.2-2 Envisaged Foundry product mix—by material—steel castings

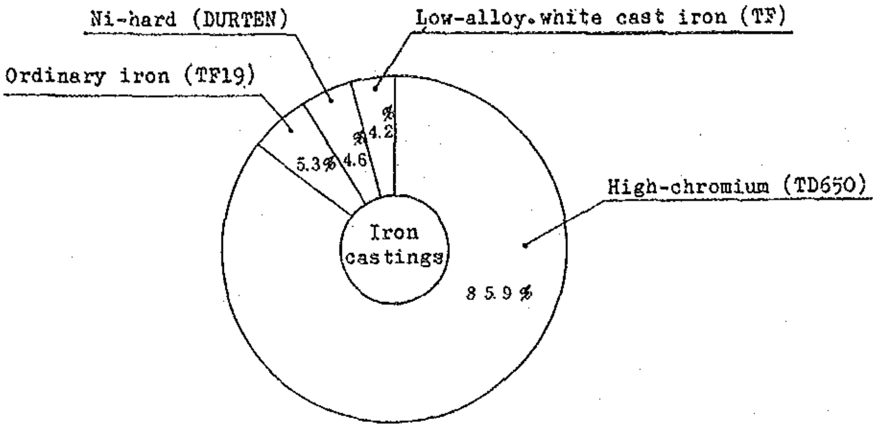


Fig. 3.1.2-3 Envisaged Foundry product mix–by material–iron castings (percentages given weight)

The foregoing Tables and Figures reveal that, of the three groups of material, nonferrous—copper alloy—castings represent only an extremely small portion, the bulk of the products being steel and iron castings. These latter, in turn, are largely of abrasion-resistant material—roughly 50% of the steel castings being high-carbon and roughly 23% high-manganese, and almost 86% of the iron castings being high-chromium alloy.

(3) Product sizes

The sizes of the products to be cast in the Foundry also constitute an essential factor in determining the production program. The product mix being considered not to vary significantly for the period envisaged, the proportions of the different product categories also are considered to remain more or less as currently prevailing.

The three weight categories of products average:

8 kg in Category A
56 kg in Category B
443 kg in Category C,

to be produced in the proportions by weight of:

1% for Category A
7% for Category B
92% for Category C,

i.e. predominantly Category C.

In terms of number of pieces, the proportions would become:

30% for Category A
27% for Category B
43% for Category C.

The sizes range from small pieces weighing less than 1 kg to 23 tons; from small brake shoes, through liners and pump casings to large slag pots and ladles.

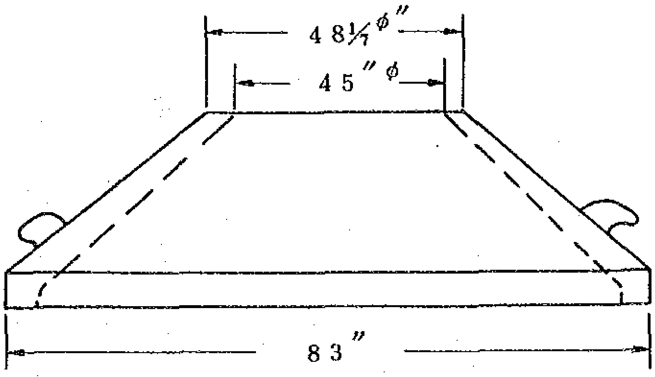
For reference, the quantities produced in 1985 of the principal individual products are summarized in Table 3.1.2-3; the forms presented by the representative castings are illustrated in Fig. 3.1.2-4.

Table 3.1.2-3 Foundry Shop production in 1985 of principal castings

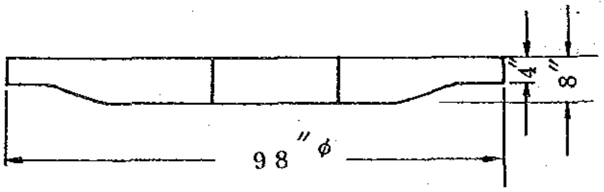
PRODUCT GROUP	MATERIAL*	NUMBER OF PIECES	AVER UNIT WEIGHT (kg/p'ce)	TOTAL PROD WT (kg/year)
Size category 1 t				
1 Ball liners	SC	188	2,500	470,000
2 Exit side liners	SC	60	4,520	291,200
3 Charging mouth covers	SC	60	4,200	252,000
4 Bushing	BC	50	1,160	58,000
5 Coupling shafts	FC	24	2,750	66,000
6 Countershaft boxes	SC	12	1,800	21,600
7 Gearing	SC	12	1,755	21,060
8 Converter mouth pieces	SC	8	5,200	41,600
9 Eccentric sleeves	SC	6	2,700	16,200
Size category 0.5 - 1 t				
10 Pump impellers	FC	60	630	37,800
11 Socket liners	BC	58	640	37,120
12 Feed bushes	SC	20	1,000	20,000
Size category 100 - 500 kg				
13 Mill liners	FC	3,240	398	1,289,520
14 Liners (for Colon)	FC	2,400	312	748,000
15 H liners	FC	200	120	24,000
16 A liners	FC	200	270	54,000
17 Suction liners	SC	60	290	17,400
18 Pump impellers	FC	300	115	34,500
19 Wheels	SC	600	120	72,000
20 Pump casings	FC	60	400	24,000
21 Shafting	SC	160	215	34,400
Size category 100 kg				
22 Buckets	SC	960	43	41,280
23 Follower plates	SC	300	65	19,500
24 Liner mouth pieces	FC	200	96	19,200

*) Casting material: FC: Iron; SC: Steel; BC: Copper alloy

1. Ball liner



2. Exit-side liner



3. Charging mouth cover

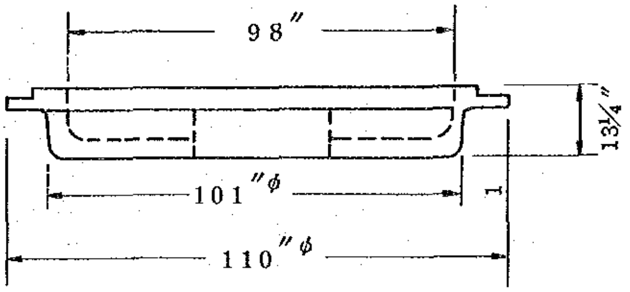
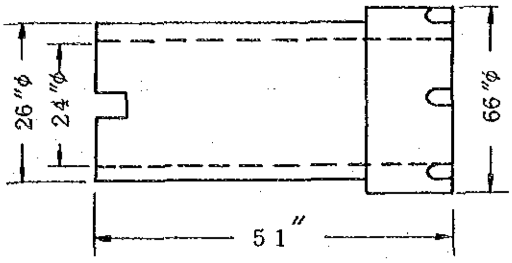
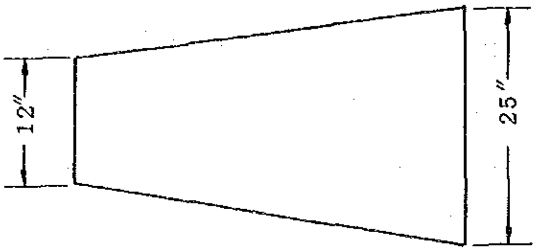


Fig. 3.1.2-4-1/7 Outline drawings of representative Foundry products -1

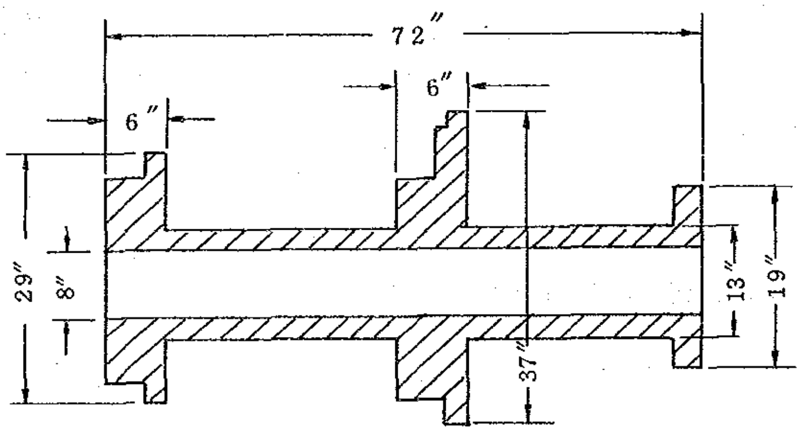
4. Bushing



5. Connecting shaft



6. Countershaft box



7. Gear

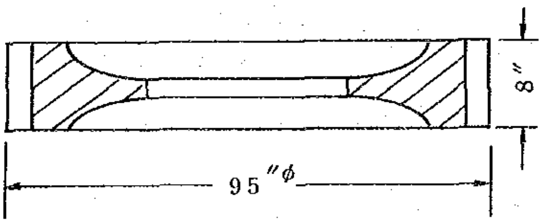


Fig. 3.1.2-4-2/7 Outline drawings of representative Foundry products -2

8. Converter piece

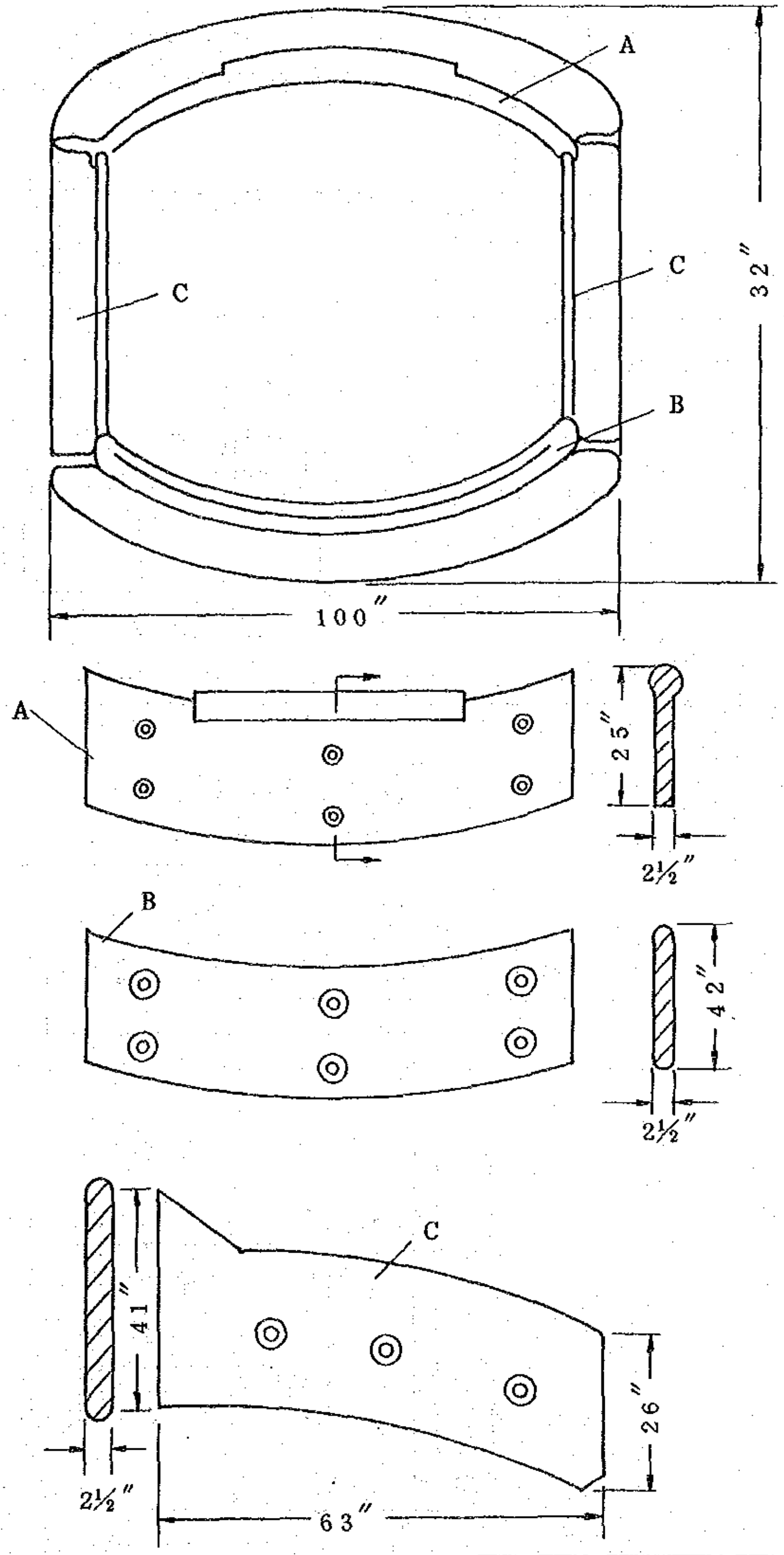
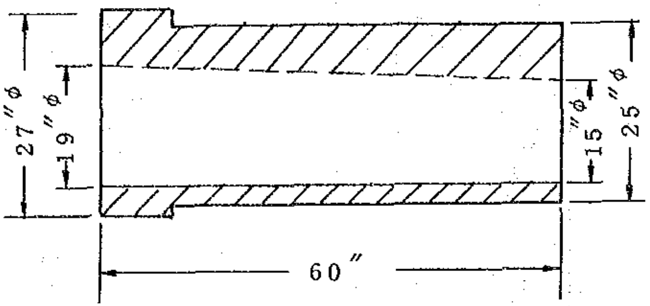
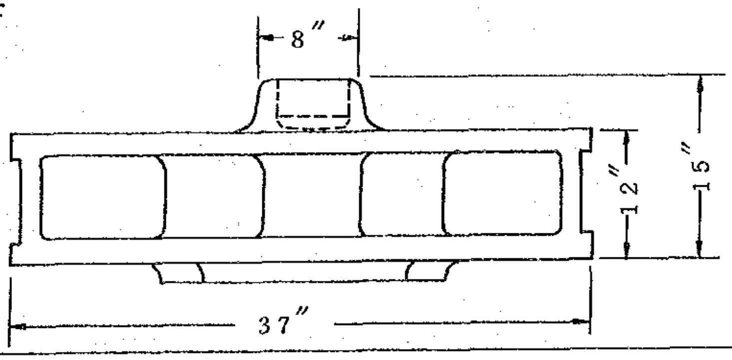


Fig. 3.1.2-4-3/7 Outline drawings of representative Foundry products -3

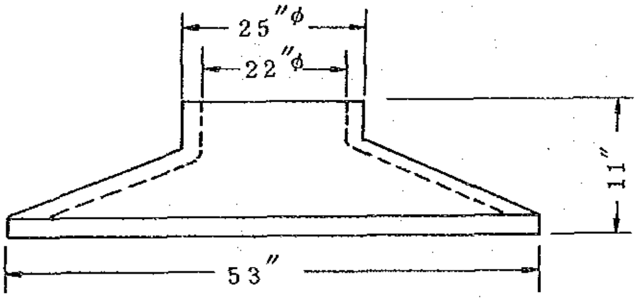
9. Eccentric sleeve



10. Pump impeller



11. Socket liner



12. Feed bush

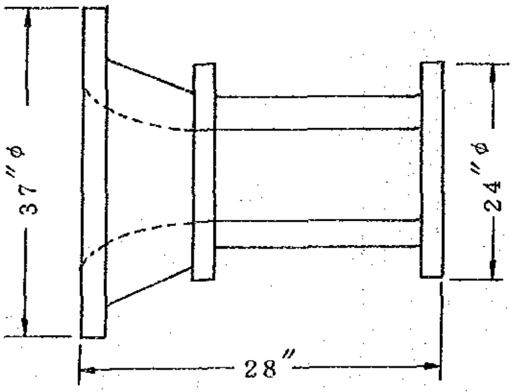
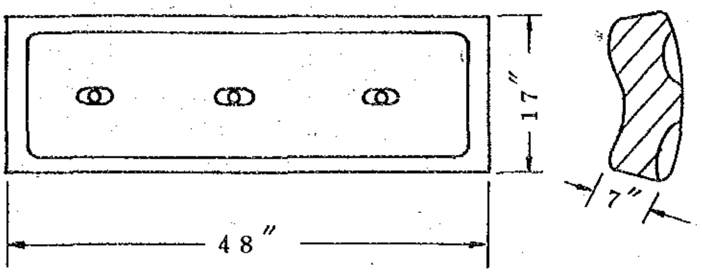
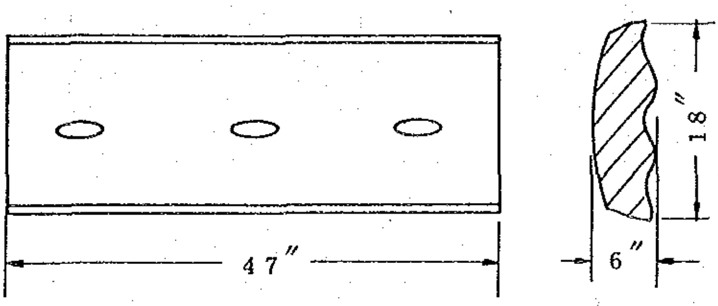


Fig. 3.1.2-4-4/7 Outline drawings of representative Foundry products -4

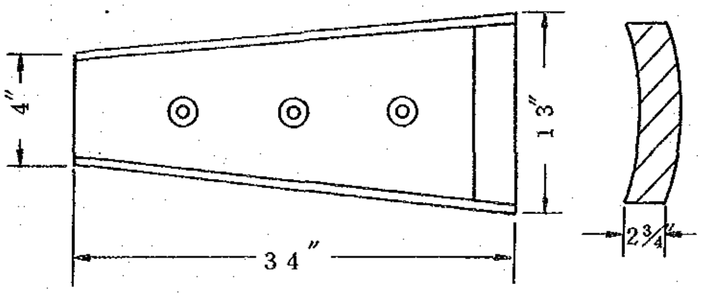
13. Mill liner



14. Liner (for Colon)



15. H liner



16. A liner

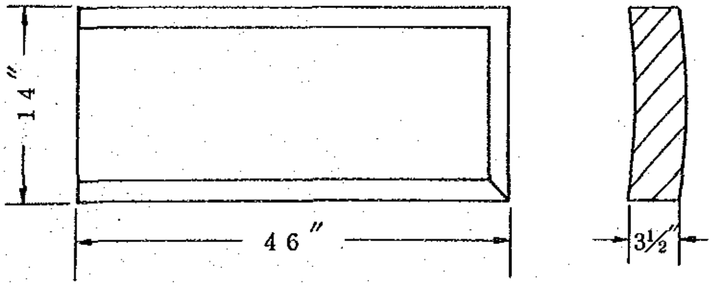
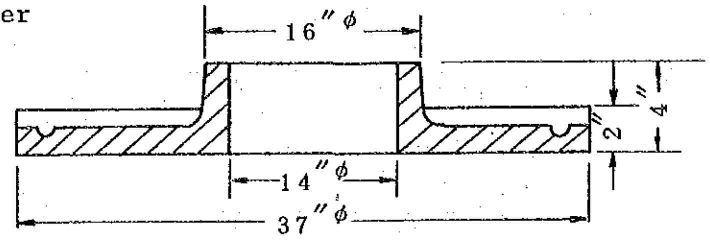
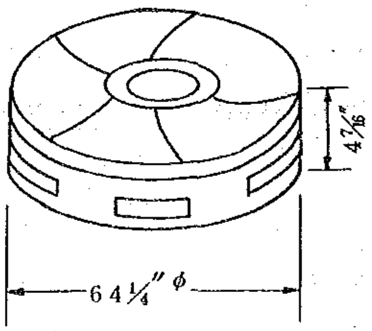


Fig. 3.1.2-4-5/7 Outline drawings of representative Foundry products -5

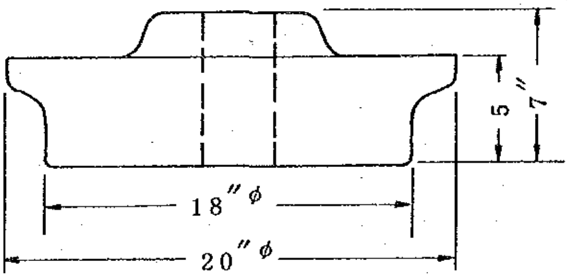
17. Suction liner



18. Pump impeller



19. Wheel



20. Pump casing

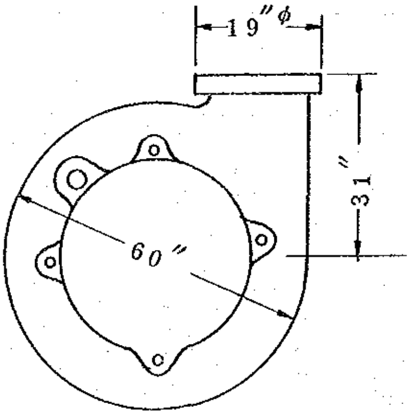
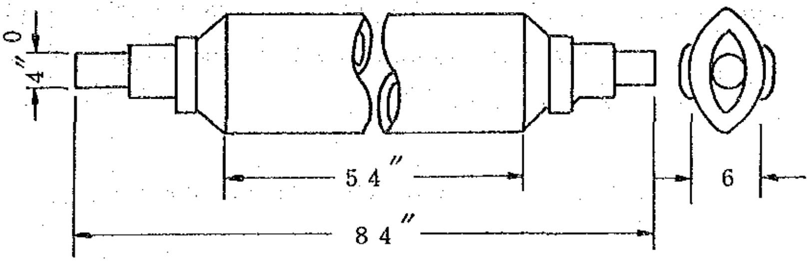
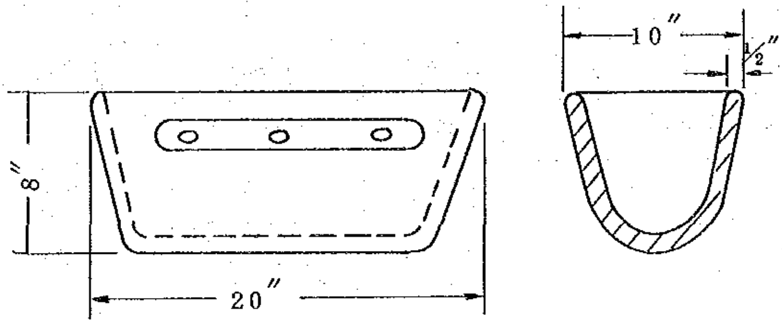


Fig. 3.1.2-4-6/7 Outline drawings of representative Foundry products -6

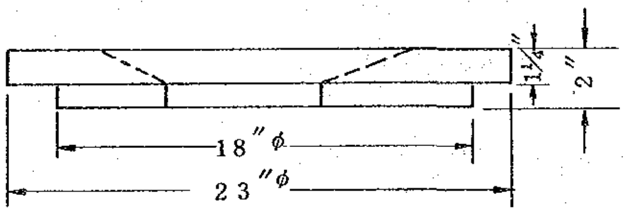
21. Shaft



22. Bucket



23. Follower plate



24. D liner

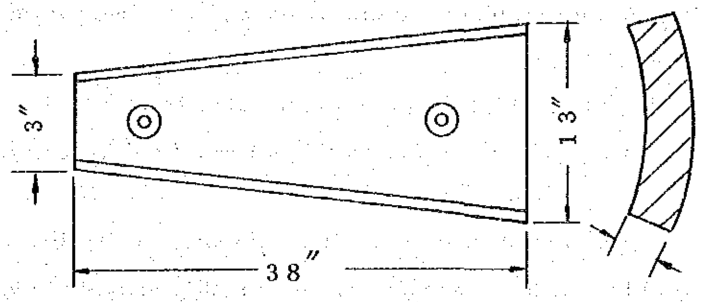


Fig. 3.1.2-4-7/7 Outline drawings of representative Foundry products -7

2) Plate Shop

The premises on which to base the production program to 1989, to provide the envisaged production volume, have been determined from the production plan furnished by CODELCO—reproduced in Table 3.1.2-4.

Table 3.1.2-4 Production Program (Plate Shop)

Ton／Year

	1986	1987	1988	1989
Repair of Crusher & Ladle	460	510	550	600
Plate Structure	1,544	1,841	1,989	2,180
Reinforced Bolt	2,300	2,553	2,806	3,080
Forging	150	180	210	240
Total	4,554	5,084	5,555	6,100

Of the articles listed in the above table, reinforcing bolts and forged products do not involve welding, and have been omitted from consideration in the present Study.

(1) Envisaged production volume

a) Repairs by overlay welding

The articles repaired by overlay welding include ore crusher components (head, bowl, adjustment ring, main frame), ladles, and occasionally, brake drums.

Of these articles, clear indication of the current volume of repair work, together with estimated future increases, have been furnished for:—

- Crusher adjustment rings: Increase from 5 to 10 pieces/year
- Crusher frames: Increase from 5–6 to 10 pieces/year.

These two articles were first tabulated, to realize the specified increases, then, the remaining articles were assumed to increase in volume roughly in keeping with the above two articles. Other articles calling for sporadic repair were assumed to contribute around 10 percent of the overall production volume.

The resulting production program is presented in Table 3.1.2-5.

Representative forms of articles calling for repair are illustrated in Figs. 3.1.2-5 (1/5–5/5).

Table 3.1.2-5 Annual Recuperation Program, weight & amount

	unit weight	1986		1987		1988		1989	
Head	12Ton	12	144Ton	12	144Ton	12	144Ton	13	156Ton
Bowl	6	3～4	18～24	4	24	4	24	5	30
Adjustment of Ring	5	6	30	7	35	9	45	10	50
Main Frame of Crusher	15	5 ～ 6	75～ 90	8	120	10	150	10	150
Ladle	15	9	135	9	135	9	135	10	150
Others			46		52		52		64
Total Weight			460		510		550		600

b) Welded structures

Unlike repairs by welding, welded structures are manufactured largely on spot orders received from the El Teniente Division. The only article regularly produced is support arches for mine gallery, for which 2,400 pieces/year are constantly on oder.

The production program for welded structures is as presented in Table 3.1.2-6.

Table 3.1.2-6 Annual Production Program, welded structure

unit: Ton

	1986	1987	1988	1989
Arch	432	432	432	432
Other Structures	1, 112	1, 409	1, 555	1, 748
Total	1, 544	1, 841	1, 987	2, 180

NOTE: The materials and plate thicknesses of articles requiring welding are assumed to remain without significant change from the current product mix described in 2.2.1.

CHANCADOR CABEZA CORTA SYMONS 7'
CABEZA PRIMITIVA

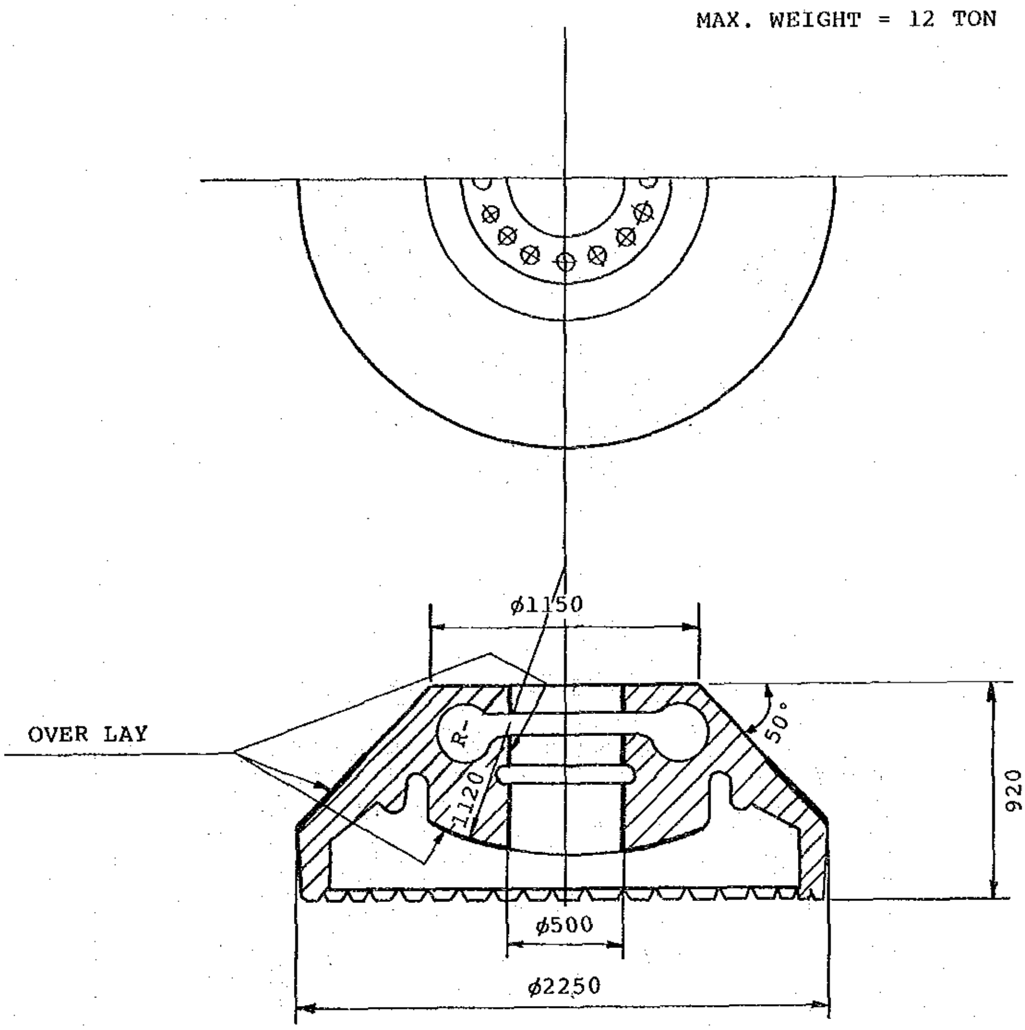


Fig. 3.1.2-5 (1/5) Representative part requiring overlay welding—Head

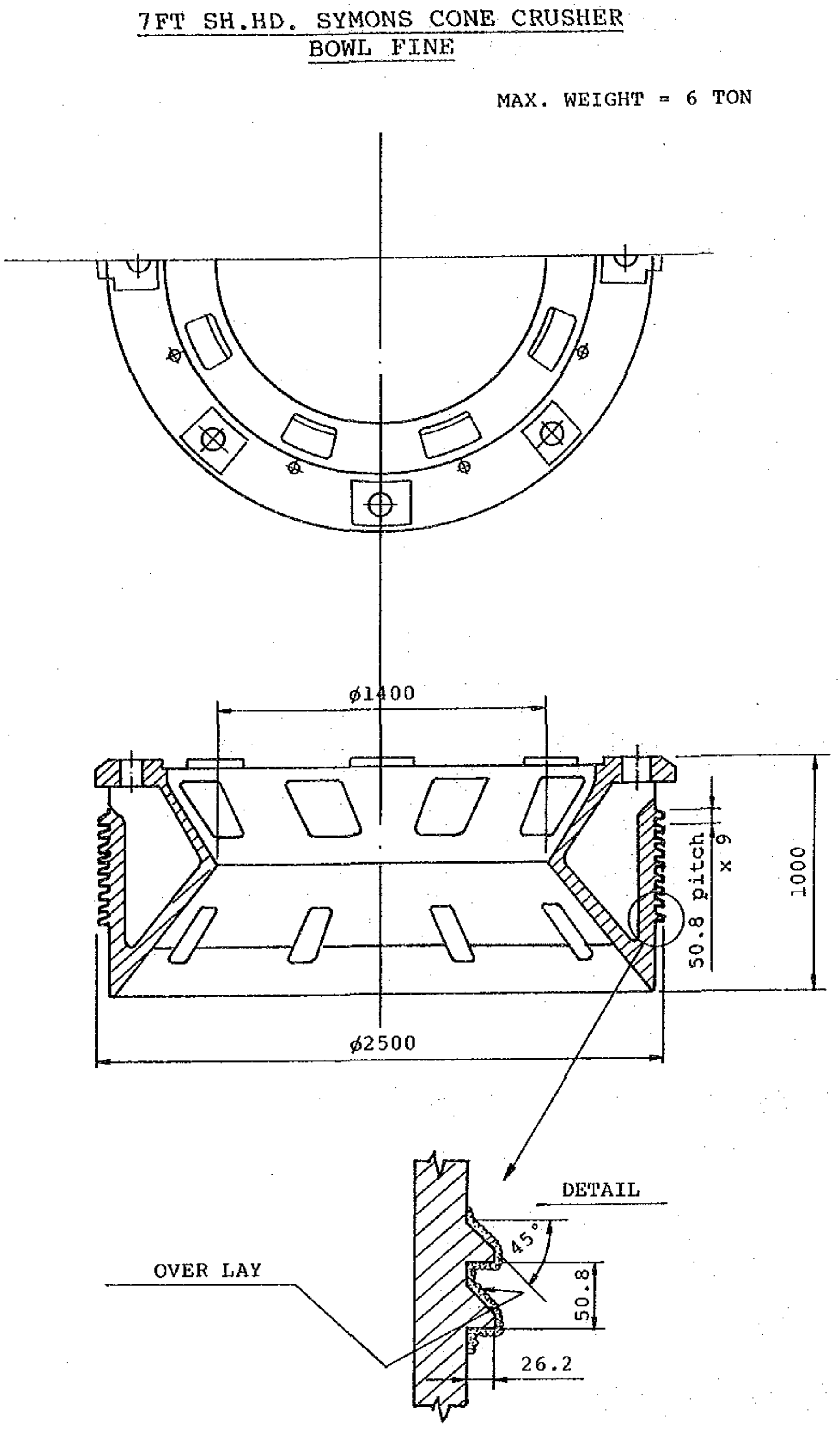


Fig. 3.1.2-5 (2/5) Representative part requiring overlay welding—Bowl

CHANCADOR SYMONS 7' PRIMARIO Y SECUNDARIO

ANILLO DE AJUSTE

MAX WEIGHT = 5 TON

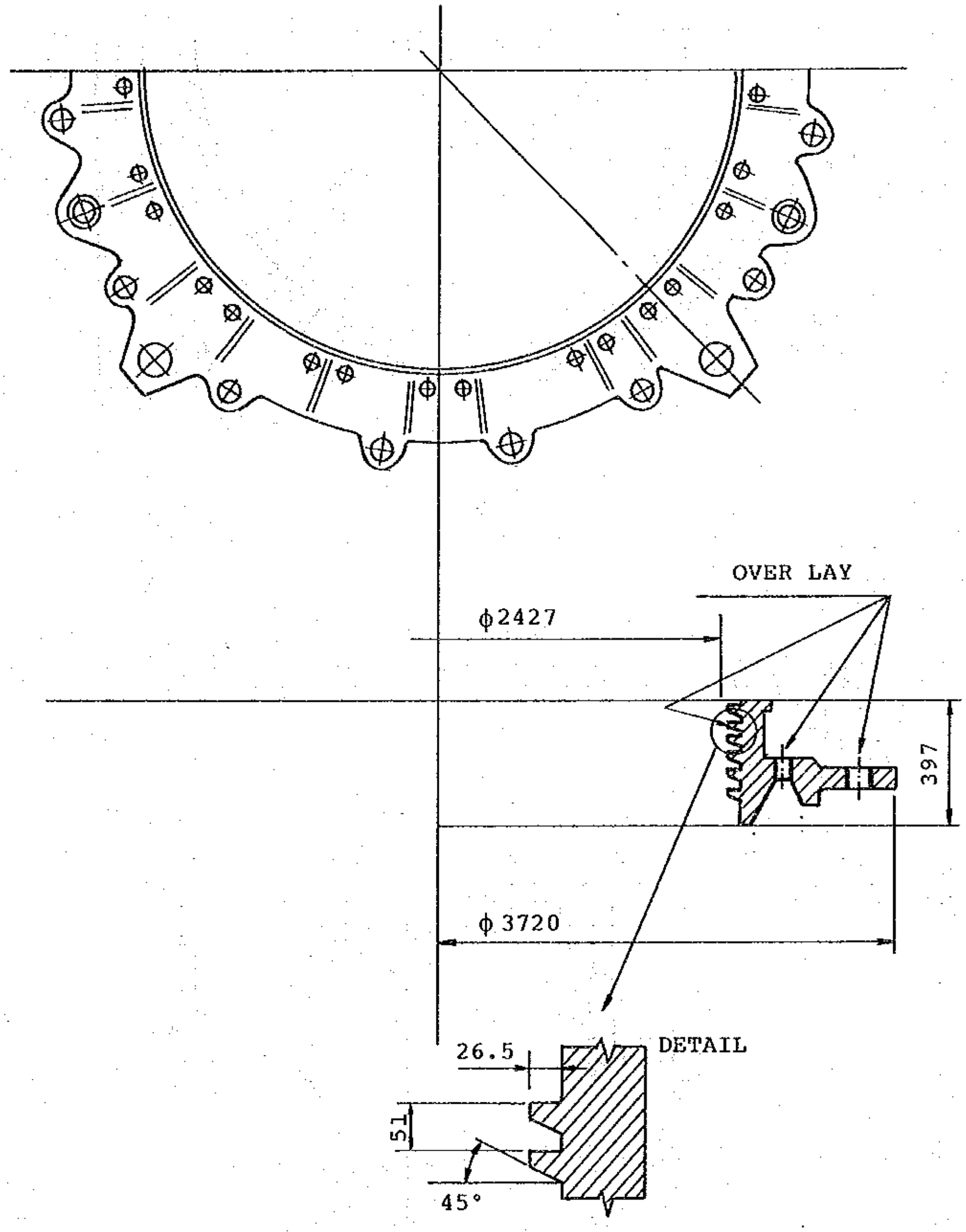


Fig. 3.1.2-5 (3/5) Representative part requiring overlay welding –Crusher adjustment ring

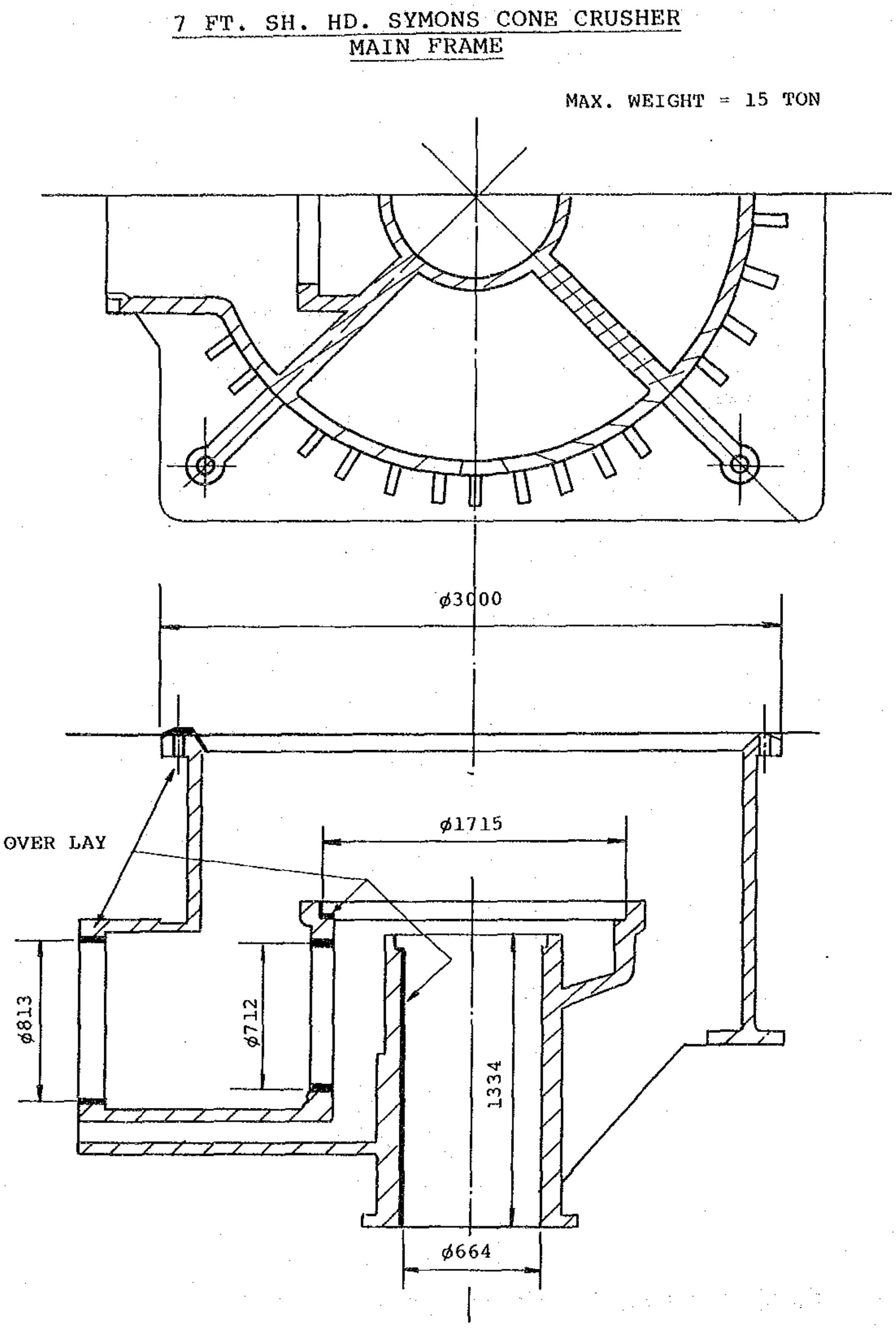


Fig. 3.1.2-5 (4/5) Representative part requiring overlay welding
–Crusher main frame

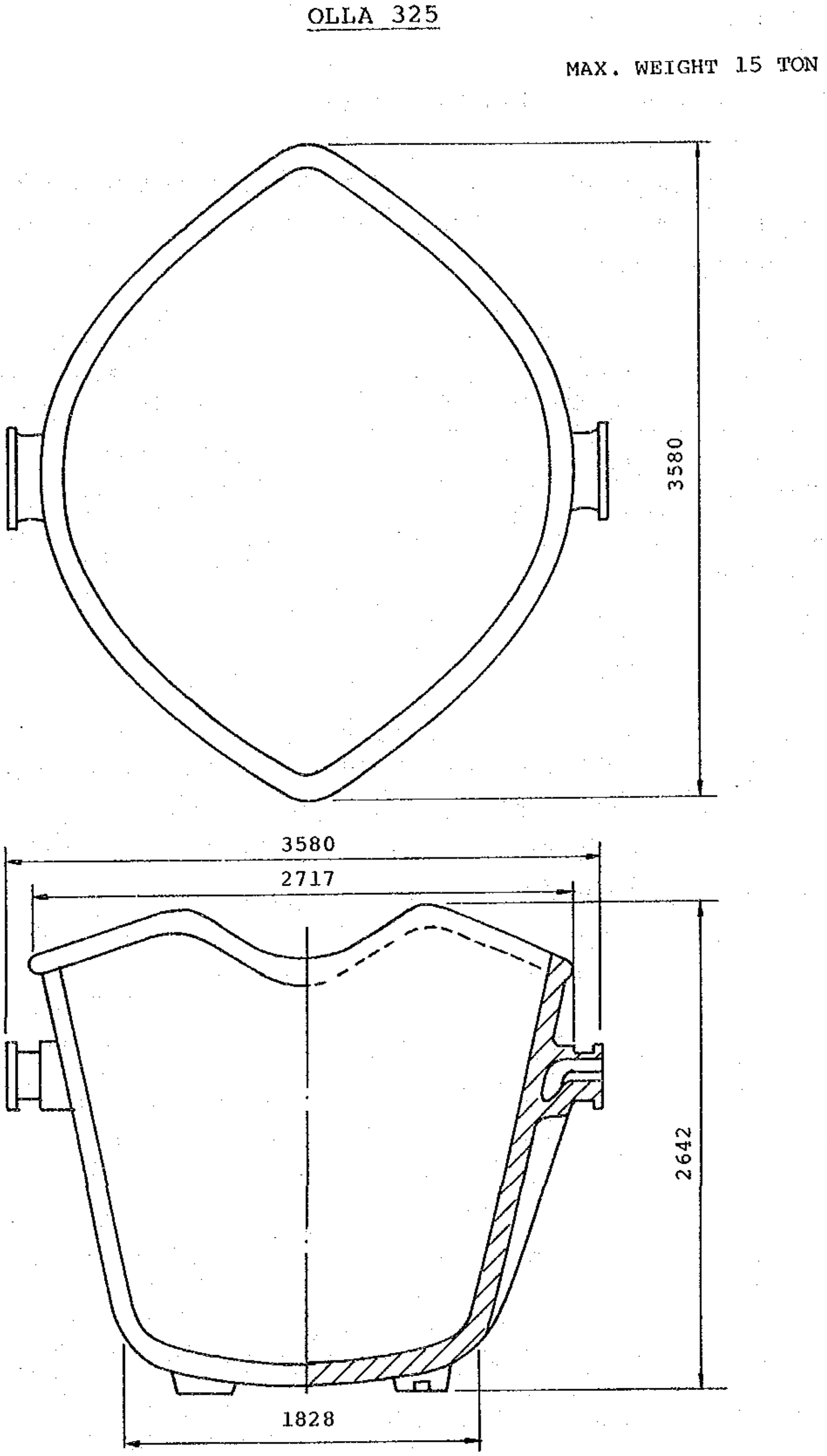


Fig. 3.1.2-5 (5/5) Representative part requiring overlay welding—Ladle

(2) Current productivity

a) Unit consumption of welding materials

From the records for 1985 giving the volume of welding work and materials consumed, the productivity figures have been derived as reproduced in the accompanying Table.

	1985 Prod. Record(T)	Percentage weld MH (%)	1985 MH Record (H)	Weld MH/Weight (H/T)
Weld Overlay	379	30	17,567 (estimate)	46
Weld Structure	1,049	70	40,989 (estimate)	39
Total	1,428	100	58,556	41

*) Proportion of welding manhours: The proportion of manhours spent in welding to the total manhours consumed is based on what was given to the Survey Team by the person in charge at Plate Shop.

**) Welding productivity: (Welding manhours/product weight)

***) Estimated figures.

b) Unit consumption of welding material

(a) Repair by overlay welding

	Weld Method	Weld Material Consump. (Kg/P)	Weld Hour (H/P)	Material/MH (Kg/H)
Head	manual	350~500	200~650	0.77~1.75 (mean 1.26)
Bowl	manual	280~350	350~450	0.78~0.80 (mean 0.79)
Adjustment of Ring	manual	250~600	350~700	0.71~0.86 (mean 0.78)
Main Frame of Crusher	manual	250~550	350~700	0.71~0.79 (mean 0.75)
Ladle	manual & Semi-Auto	629	360	1.75

Note: Figures given between parentheses are average values for the range indicated.

From the values given above, the productivity of repair work by overlay welding becomes:

0.78 kg/h for manual welding
1.75 kg/h for semi-automatic welding.

(b) Welded structures

		DERIVATION
Material for manual overlay welding (kg)	11,180	(17,567h - 3,240h) x 0.78 kg/h
Ditto for semi-automatic overlay welding (kg)	+ 5,670	3,240h x 1,75 kg/h
Total material for overlay welding (kg)	16,850	
Material for structure welding (kg)	18,340	35,190 kg - 16,850 kg
Productivity of welded structure work (kg/h)	0.45	18,340 kg / 40,989 h

NOTE: Taking the example of ore car, the rate of electrode consumption is 568 kg/ 1,192 h = 0.47 kg/h, which agrees approximately with the 0.45 kg/h obtained in the above derivation.

calculation.

(c) Unit electrode consumption

From records for 1985, the quantity of electrode consumed per ton of workpiece welded is:—

–For overlay welding repair: 16,900 kg/379 t = 45 kg/t
–For welded structures : 18,340 kg/1,049 t = 17 kg/t.

3.2 Production Techniques

3.2.1 Foundry Shop

For the Modernization Project, rationalization measures will be planned holding in view:—

- Enhancement of productivity through introduction of modern equipment
- Rearranging the Workshop layout to ensure smoother flow of work
- Enhancement of finished product quality
- Labor saving and improvement of working environment.

At the same time, it will be endeavored to:—

- Enhance the quality of castings emerging from the earlier stages of processing
- Raise the level of techniques applied in the operations associated with the Finishing Process.

In what follows, the subjects treated are:—

- Techniques associated with grinding equipment
- Layout of finishing shop, with consideration given to convenience of work piece transfer and handling
- Considerations affecting molding process in view of rationalizing the Finishing Process
- Establishing effective techniques for rationalizing the Finishing Process, with particular reference to grinding operations.

1) Techniques associated with grinding equipment

The grinding of casting surfaces is basically a process using grindstone, and this basic premise is not foreseen to change in the years to come. For this reason, the different techniques discussed in what follows will envisage the use of grinding wheel, and different equipment used for the different techniques will be judged on their merits for adoption at El Teniente.

The current equipment at the Foundry Shop includes swing, stationary and hand grinders. In modern foundries producing in mass large quantities of castings similar in shape, automated/robotized grinding machines are coming to be adopted, but such machines are yet to be developed for foundries required to furnish castings of wide variety in small lots, as in the case of El Teniente.

Even in this instance, however, certain products such as liners are constantly produced in sizable batches, and the introduction of automatic machines possessing a certain amount of flexibility should be worth considering. As for the other castings, while they should continue to require grinding with conventional swing, stationary and hand grinders, the currently installed equipment of this kind is—as repeatedly mentioned—outdated and inconvenient, having already served up to 30–40 years, and calling for renewal.

(1) Automatic grinding machines

The products of the Foundry Shop being intrisically of wide variety manufactured in small lots, no fully automatic grinding machines yet exist that would suit the present circumstances, but very significant enhancement of working efficiency could be expected of automatic grinding machines retaining a certain amount of operating flexibility.

Products of the Foundry Shop occupying a large share are liners for ball and bar mills. These products manufactured at the Foundry Shop in relatively large lots could be envisaged as a subject around which to consider plans for enhancing process efficiency. The plans, further, should postulate sales efforts for securing orders on products of similar form, in order to justify the introduction of such automatic machines by their utilization to full, since the expected demand for liners even in 1989—approx. 10,000 pieces/year–is still too small to let the automatic equipment be fully worked.

a) Functions required of an automatic grinding machaine

The automatic grinding machine should contribute very effectively to facilitating the grinding operations on the principal products of the Foundry Shop, and to alleviating the heavy labor demanded of the workers in performing this operation.

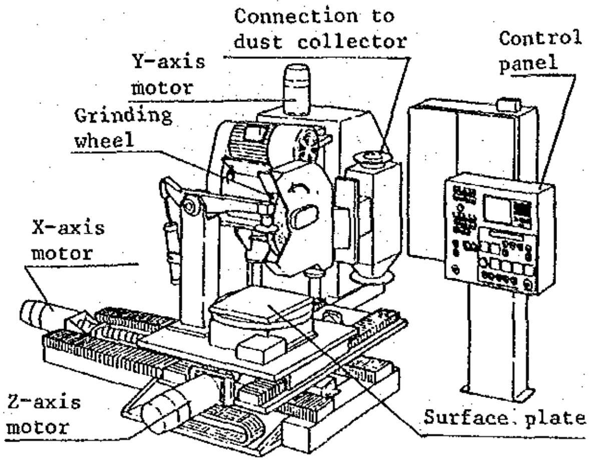


Fig. 3.2.1-1 Automatic grinding machine

The automatic grinding machine illustrated in Fig. 3.2.1-1 serves to remove fins, riser and gate stumps, and other projections left on casting surface.

What needs to be particularly heeded in selecting the type of automatic grinding machine to be acquired is the particular property of high-chromium cast iron, which is highly susceptible to cracking, and this forbids heavy grinding at rapid rate.

The type of automatic grinding machine to be introduced must possess the faculty of taking this circumstance into account.

The operational characteristics required of the automatic grinding machine should therefore possess the following faculties:

(a) "Feed-retract" load-adjusting function

The "feed-retract" load-adjusting function prevents excessive load being applied on workpiece by the grinder, through retraction of the grinding wheel upon sensor signaling excessive load (see Fig. 3.2.1-2).

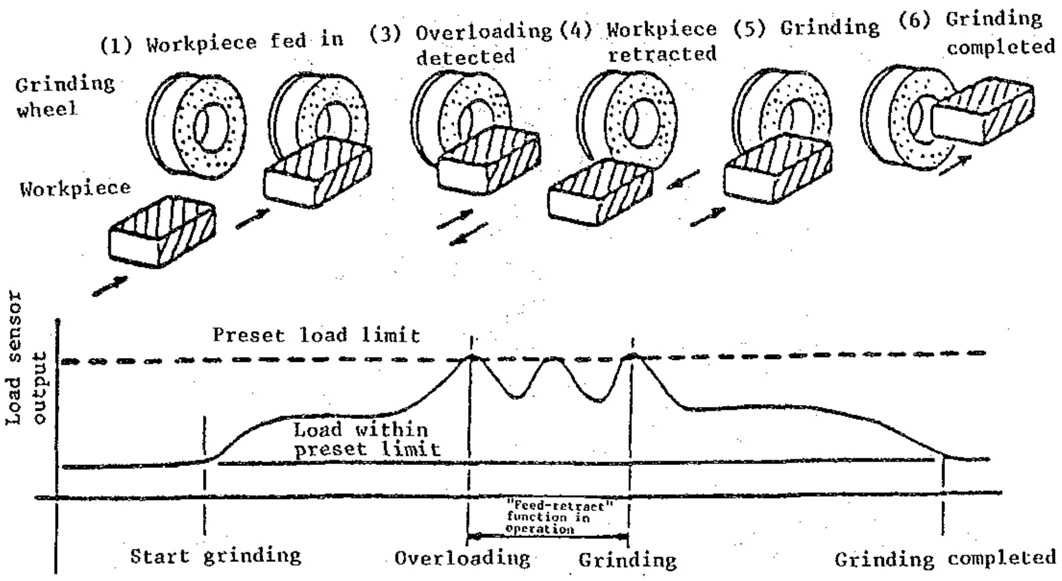


Fig. 3.2.1-2 Functioning of "feed-retract" load-adjusting grinding machine

(b) Contour grinding function

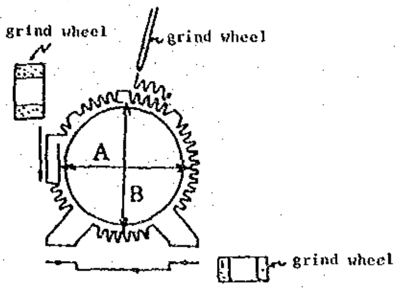
The contour grinding function lets the grinder follow the general contour of the casting skin, to approach the mode of grinding to manual operation, and this accommodates deviations of as-cast dimensions.

With this function, large projections like fins on parting line, gate stumps, core print fins, flow-offs of disparate heights, gates and risers calling for heavy grinding etc., are accommodated through learning faculty to follow the contour of the as-cast surface.

Examples of contour-following faculty are illustrated in Fig. 3.2.1-3.

Examples of application Function

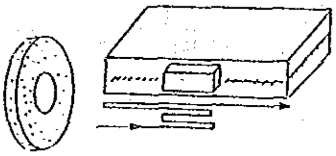
(1) Electric motor frame



a) Accommodate large deviations in as-cast dimensions, such as between the diameters A and B in the accompanying sketch.

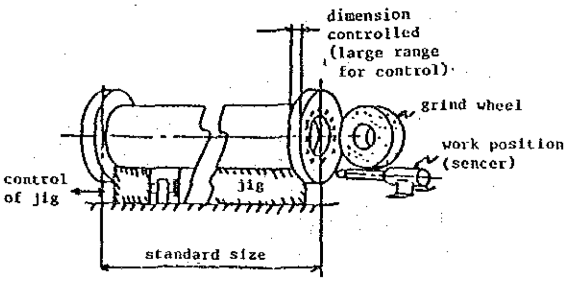
b) Deviations in as-cast dimensions due to jig setting.

(2) Special alloy casting



Grinding castings of special steels susceptible to cracking

(3) Workpiece of indeterminate dimension



Unspecified dimensions that vary widely from one product to another: A sensor detects the workpiece surface, to position the grinding wheel by learning.

Fig. 3.2.1-3 Contour-following grinding

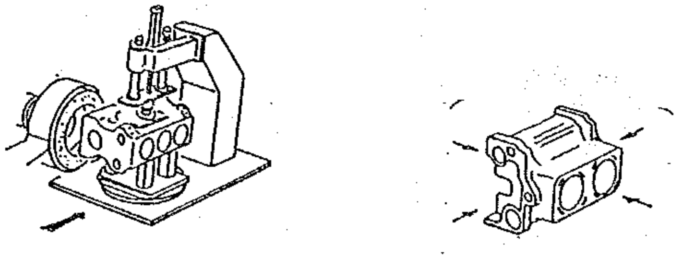
(c) Grinding wheel wear-compensating function

The peripheral speed of grinding wheel will lower with diminishing diameter of grinding wheel due to wear. To compensate this effect of wear, the feed rate of workpiece pressing against grinding wheel is automatically increased to ensure almost constant grinding rate, i.e. constant amount of material ground off from workpiece per unit time, irrespective of grinding wheel wear.

This function serves to enhance appreciably the grinding work efficiency, with corresponding reduction of unit grinding wheel consumption.

(d) Number of faces automatically ground

The grinding machine is capable of automatically changing the workpiece orientation to grind successively up to 4 faces; grinding of the top and bottom faces calls for manual intervention, to remount the workpiece on the work table. (See Figs. 3.2.1-4 and -5).



4-face grinding

Fig. 3.2.1-4 Successive 4-face grinding

Example of grinding sequence

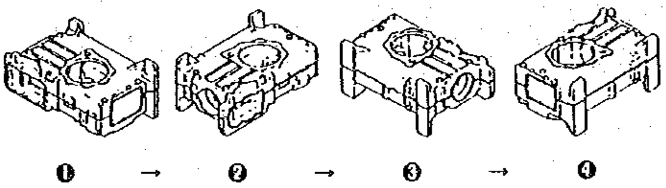


Fig. 3.2.1-5 Sequence of 4-face automatic grinding

b) Ancillary facilities

In introducing an automatic grinding machine, its capability will not be brought out to full unless the ancillary facilities are, in keeping, properly modernized. For instance, jigs and tools to facilitate mounting and dismounting the workpiece on machine—in an integrated grinding system for castings—will be indispensable for ensuring smooth flow of work. The workpiece will often be quite cumbersome and difficult to handle manually, and a mechanized shuttle system making full use of jigs to guide correct positioning of the workpiece on machine table should be introduced along with the machine installation. The operations will then proceed, as illustrated in Fig. 3.2.1-6, in the sequence: Preparing the workpiece (attaching jigs)—transfer onto machine table—grinding—transfer of workpiece out of machine—remove jigs from workpiece.

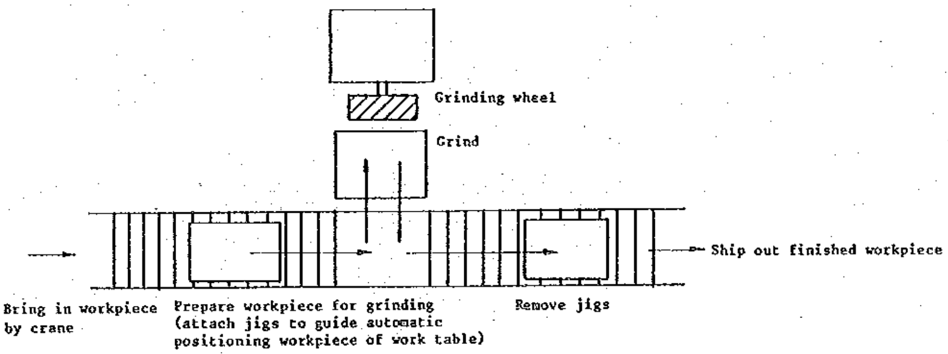


Fig. 3.2.1-6 Example of ancillary arrangement for automatic grinding

c) Points calling for attention in drawing up casting plan, to facilitate finishing

To enhance efficiency in automatic grinding, the projections to be ground off should be, in so far as possible, located at similar positions, even if the casting dimensions may differ from workpiece to workpiece. Moreover, the envisaged automatic grinding machine works successively on 4 faces only of the workpiece, and not on the top and bottom faces—machines automatically working on all 6 faces being too complex to justify introduction in this instance. Postulating an automatic grinding machine working only on 4 faces, the projections to be removed by grinding should, wherever practicable, all be on the 4 faces worked automatically by the machine. Thus, top risers should, in so far as possible, be replaced by side risers projecting out from the side face.

Taking liners as example, Fig. 3.2.1-7 illustrates how the currently practised top risers might effectively be modified to include side risers alone, to facilitate automatic grinding. Another example of effective modification—a valve body casting—is shown in Fig. 3.2.1-8.

An essential consideration in introducing automatic grinding is not to attempt automating all and every grinding operation, but to let the machine cover only the principal operations that are more susceptible to automation. In doing this, the point is to plan the grinding operations in such manner as to permit the maximum variety of work to be done without having to change the position of workpiece on the machine table.

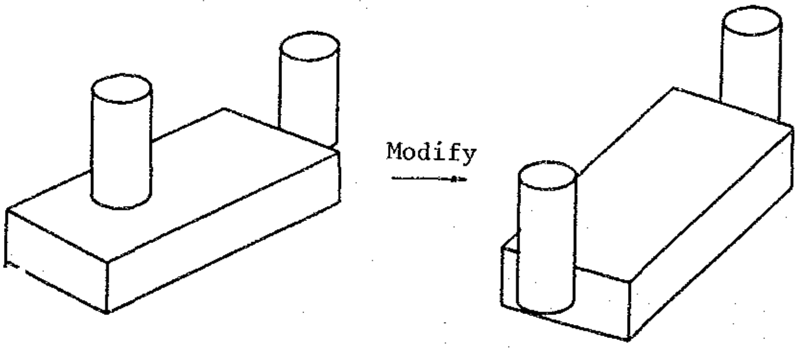


Fig. 3.2.1-7 Modifying the casting plan to facilitate automatic grind—liner casting

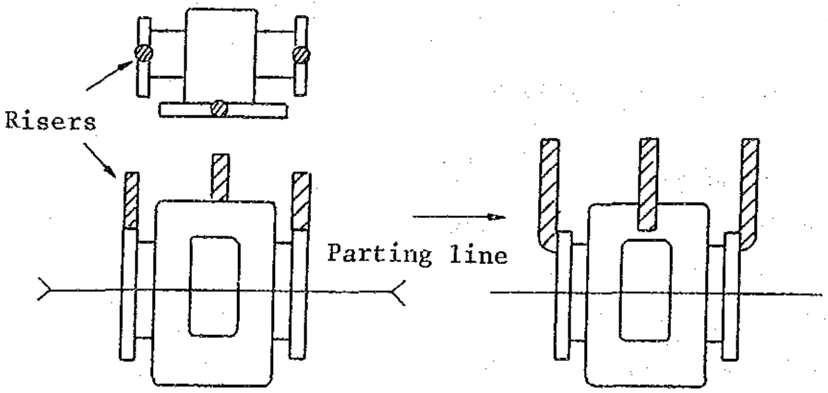


Fig. 3.2.1-8 Modifying the casting plan to facilitate automatic grinding—valve body

For this, the points to be considered are:

A. To mount the workpiece with bottom side of casting facing downward: This side of the casting normally carries little or no fins or other projections.

B. To relocate projections on top side of the casting, wherever possible, to the side faces—as already stated.

C. To review the casting design or plan for surfaces located at positions difficult of access to the grinding wheel, to seek means of facilitating grinding wheel access.

d) Considerations for enhancing machine capacity

Upon acquisition of automatic grinding machines, consideration should be given to maximizing their utilization. Points to be heeded in this connection are:

A. To seek producing articles in batches of similar configuration. Consideration might be given in this connection to production of stock articles in relatively large batches, rather than in small batches on order.

B. While the automatic grinding machine mainly envisages liners as object, the machine should be utilized whenever practicable, for finishing other forms of castings as well. For this, mounting jigs should be devised to accommodate workpieces of various shapes. Castings that cannot have top risers eliminated might also be accommodated, by utilizing specially-devised jigs that permit mounting the casting with the top risers projecting horizontally.

(2) Swing grinders

Swing grinders currently available comprise 5 of large and 4 of medium size, and constitute the principal equipment for finish grinding. The large swing grinders, however, have already seen dozens of years of service, with make shift modifications to permit their continued use to this day. Moreover, a recent change of electric power supply from 60 to 50 Hz has lowered the grinding wheel peripheral speed down to around 35 m/s, with consequent appreciable impairment of grinding performance.

A variety of new type grinding machines have been developed in recent years, and swing grinders are coming to be replaced by modern machines providing higher performance. The swing grinding machine, however, still today, serves usefully for certain uses, particularly for finishing a wide variety of castings in small lots and of large size. Although some improvement of operating efficiency might be brought by simply replacing their driving motors to match the present power supply frequency, the units currently installed could be renewed to benefit, in view of their outdated performance.

Renewal of the swing grinders should, the units currently installed, however, could effectively be renewed, in view of their present low performance, without having to alter the current operating procedure, bring very appreciable enhancement of grinding efficiency, on account of the significant improvements incorporated in the new models of swing grinder.

a) Grinder design

A description is given in what follows of a representative modern swing grinder model (Fig. 3.2.1-9).

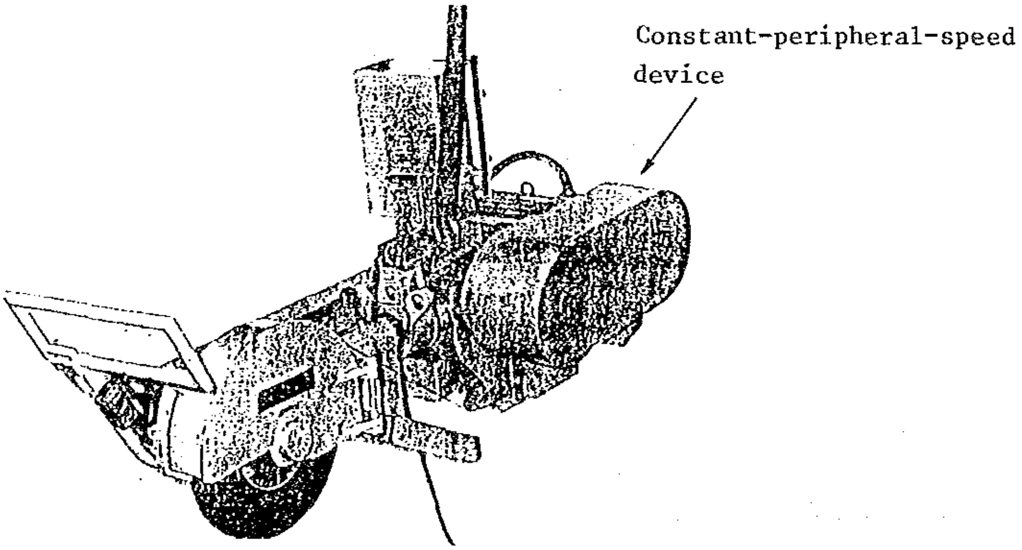


Fig. 3.2.1-9 Modern type of swing grinder

(a) Grinder body

The general arrangement has been appreciably modified from past models, and incorporates a device for maintaining constant peripheral speed of the grinding wheel, through a system for compensating the reduction by wear,. through regulation of driven pulley speed.

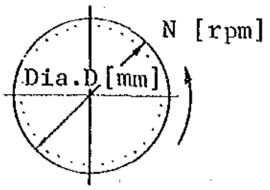


Fig. 3.2.1-10 Peripheral speed of wheel diameter

(b) Constant peripheral speed device

A grinding wheel rotates with a peripheral speed

$V = \pi DN/1,000$ m/min

where D: Grinding wheel diameter [mm]

N : Grinding wheel rotating speed [rpm].

When the grinding wheel wears down, with accompanying reduction of wheel diameter, the peripheral speed V will lower accordingly to the value V_2 in Fig. 3.2.1-11. To restore V to the original level V_1, the wheel rotating speed N will have to be increased in inverse proportion to the reduced diameter D.

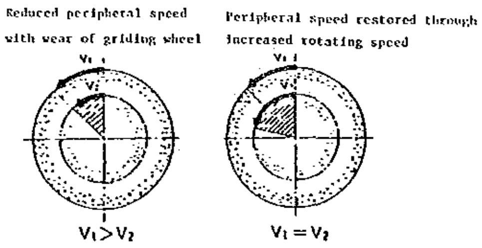


Fig. 3.2.1-11 Peripheral speed compensation

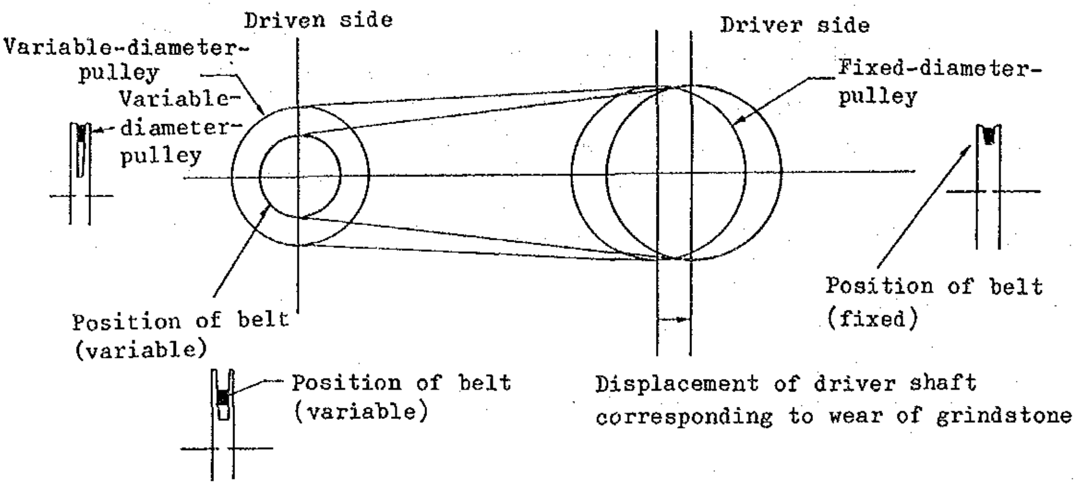


Fig. 3.2.1-12 Speed compensating pulley device

To ensure this increase of rotating speed, a constant peripheral speed device (Fig. 3.2.1-12) is provided.

Upon wear of grinding wheel, the driving shaft is displaced by a corresponding amount away from driven shaft, and the driving belt is thereby forced to act on the driven pulley at a position of correspondingly reduced diameter. This automatically increases the rotating speed of driven shaft in reference to the driver.

(c) Other features

This swing grinder also features an arrangement whereby the angle of grinding wheel can be changed while slung, and a device for changing the position of center of gravity, to permit minimizing the manual load requiring to be applied by the operator.

Also, the handle for holding the grinding wheel in position can be slidden laterally at will, to facilitate monitoring the grinding action on workpiece.

b) Ancillary equipment and shop arrangement

Granted that a new type of grinder such as described above is introduced, its enhanced performance can be effectively brought out only if the ancillary equipment and shop arrangement is modernized in keeping. With the current shop arrangement, the handling and transfer of workpiece should constitute an impediment to improving the overall grinding efficiency. The handling transfer operations follow the sequence:

A. Bringing in the workpiece by crane
B. Setting the workpiece on work table
C. Setting the grinder to correct position and height for grinding
D. Grinding
E. Transferring the grinder to a new grinding position
F. Setting the grinder to the new position/height for grinding
G. Grinding
H. Repeating the steps D to G.

It will be seen from the above sequence that, apart from the operation of grinding proper, considerable time will be spent in the ancillary transfer and adjustment steps. To facilitate these ancillary operations and to minimize the time required therefore, the measures to be adopted include:

A. Installation of work tables incorporating positioner, rotating table and/or other devices to facilitate and expedite rotating/tilting of the workpiece.
B. Replacement of the current chain blocks by motor-driven hoists for slinging the grinder, equipped with control switch located conveniently within reach of the operator, to facilitate and expedite grinder positioning and movement.
C. Adoption of quick-release clamps for slinging the workpiece. The current practice of slinging rectangular workpieces like liners by means of a single round of chain is not only laborious and time-consuming, but also unsafe. The introduction of clamps suitably devised to grip the workpiece should contribute significantly to enhancing the working efficiency and safety.

The foregoing ancillary equipment and shop arrangements for the swing grinder shop can be considered to rationalize the grinding operations including the preparatory steps, and to save much of the heavy labor involved in the operations.

(3) Stationary grinders

The current equipment comprises 4 stationary grinders, used for finishing small castings. All these grinders are more than 10 years old. While still serviceable, the equipment does not provide rotating speed adjustment to compensate grinding wheel wear, with consequent appreciable lowering of grinding wheel peripheral speed with wear.

New types of stationary grinder are provided not only with constant peripheral speed device but also with mechanism for maintaining correct clearance between grinding wheel and work table. (This clearance is stipulated by low in Japan to be held within 3 mm.) Another innovation incorporated in modern stationary grinders is a means whereby the feed of workpiece onto grinding wheel is assisted by leverage.

Introduction of stationary grinders incorporating such faculties should contribute to enhancing productivity and to improving the working conditions on shop floor.

The functioning and arrangement of a typical modern stationary grinder are described in what follows.

a) Constant-peripheral-speed stationary grinder

An example of modern constant-peripheral-speed stationary grinder is illustrated in Fig. 3.2.1-13.

It incorporates rotating speed compensating device, and leveraged workpiece feeding by pedal.

b) Constant-peripheral-speed constant-work-table-clearance device

The constant-peripheral-speed device functions on the same principle as described for the swing grinder under § (2).

In this instance, the principle is combined with constant-work-table-clearance mechanism. Upon wear of grinding wheel, the clearance between grinding wheel and work table increases from the original A mm to B mm (Fig. 3.2.1-14). Compensation of this clearance is realized by approaching the grinding wheel shaft toward work table by a distance (B−A) mm. This displacement increases at the same time the distance between driving and driven shafts, which brings about a reduction of the effective diameter of driven pulley, to increase the grinding wheel rotating speed and thereby ensure compensation of peripheral speed.

The leveraged workpiece feeding device is illustrated in Fig. 3.2.1-15. Pressing the pedal actuates a lever system that tilts the work table toward grinding wheel, to press the workpiece against grinding wheel.

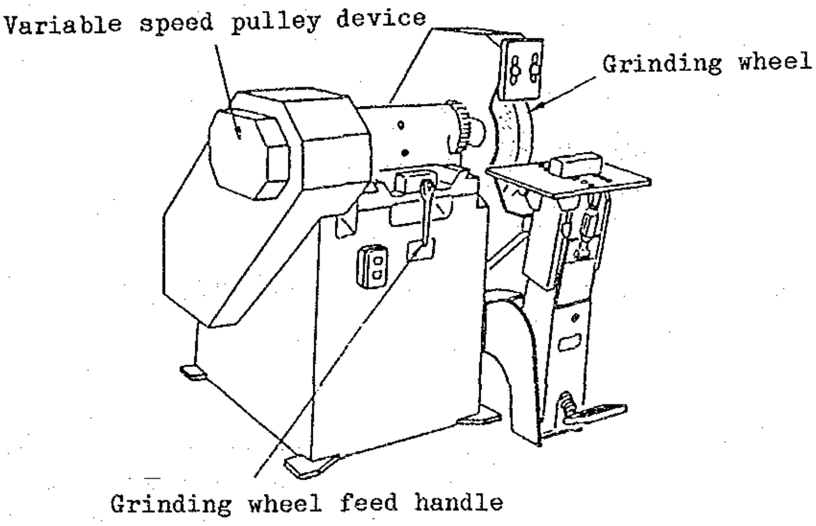


Fig. 3.2.1-13 Example of modern stationary grinder

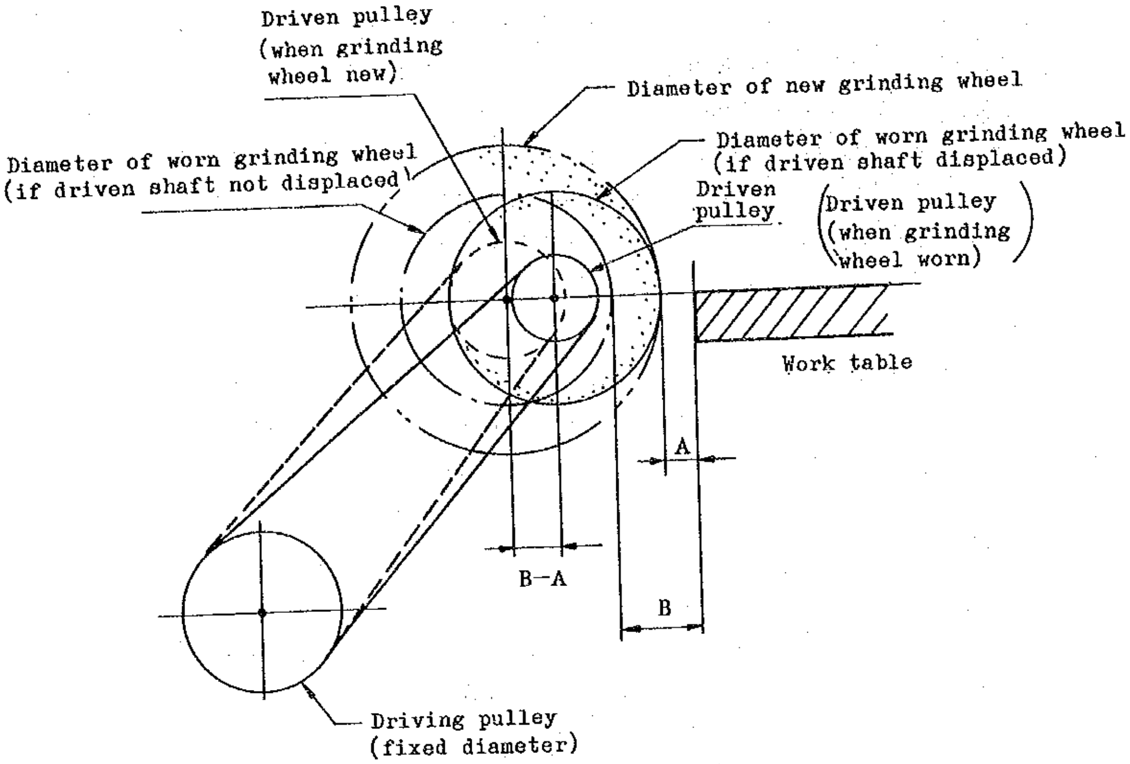


Fig. 3.2.1-14 Constant-peripheral-speed constant-work-table-clearance mechanism

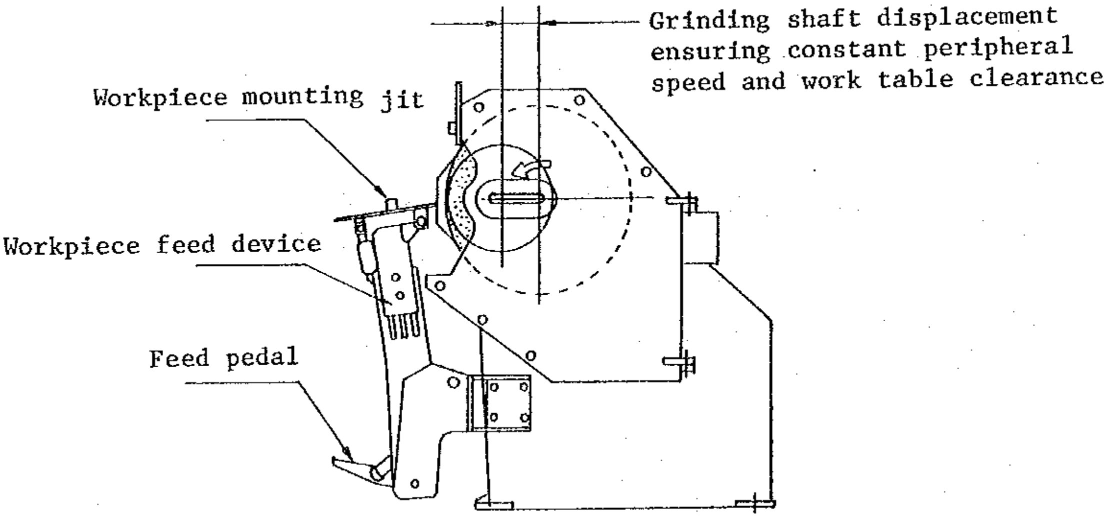


Fig. 3.2.1-15 Leveraged workpiece feed device

(4) High-frequency grinders

Hand grinders are marketed with electric and pneumatic drives. The latter type is superior in repect of operatng ease, but calls for the installation of elaborate compressed air supply network, and further consumes considerable electric power for generating the compressed air, while it also leaves room to be desired in terms of operating efficiency, vibration, noise, and service life.

High-frequency motor-driven grinders are already in use at El Teniente, but the models currently installed are cumbersome and heavy to manipulate. New models recently developed in Japan are almost as compact and light as pneumatic grinders, and easy to manipulate. Their introduction should contribute to enhancing productivity and labor saving.

a) General form

The new high-frequency motor-driven hand grinder is presented in outline in Fig. 3.2.1-16, in comparison with a corresponding pneumatic model.

b) Grinder weight

The new high-frequency motor-driven grinder weights only 2.7 kg, compared with the 4.1 kg of a conventional model, and it lighter even than the corresponding pneumatic machine, of 2.95 kg (see Table 3.2.1-1).

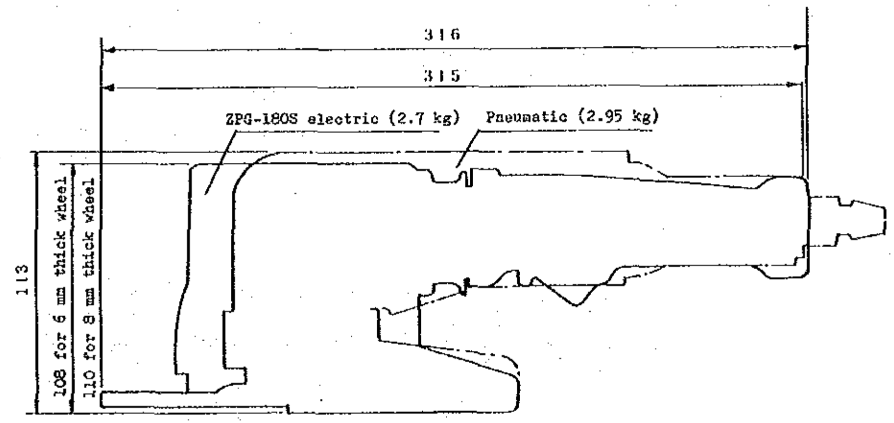


Fig. 3.2.1-16 New type high-frequency motor-driven hand grinder, compared with pneumatic model

c) Acceleration/deceleration at start/stop of grinding

The newly developed high-frequency motor-driven grinder utilizes a current inverter for power source instead of the conventional motor-generator, which latter had the inconvenience of not providing controlled acceleration at start and deceleration at stop of grinding operation. With the current inverter power source, controlled acceleration and deceleration of driving motor speed provides optimum operating conditions, eliminating shock with excessively rapid startup, and prolonged costing down upon switching off.

The foregoing operating characteristics are graphically illustrated in Fig. 3.2.1-17.

d) Torque characteristics

The new high-frequency motor-driven grinder is rated at approximately 100 g-m torque, but when performing heavy grinding, a torque above 200% of this rating is demanded, and provision to meet such demands is incorporated in the system (see diagram in Fig. 3.2.1-18).

Table 3.2.1-1

	WEIGHT (Kg)	WEIGHT RATIO	
New model ZPG-180S	2.7	0.66	0.92
Old model T-180GDPZ-5	4.1	1	-
Pneumatic grinder	2.95	-	1

NOTES:

1. Values of weight not including griding wheel and connecting cables.
2. Weight of pneumatic grinder represents what is considered an average value.

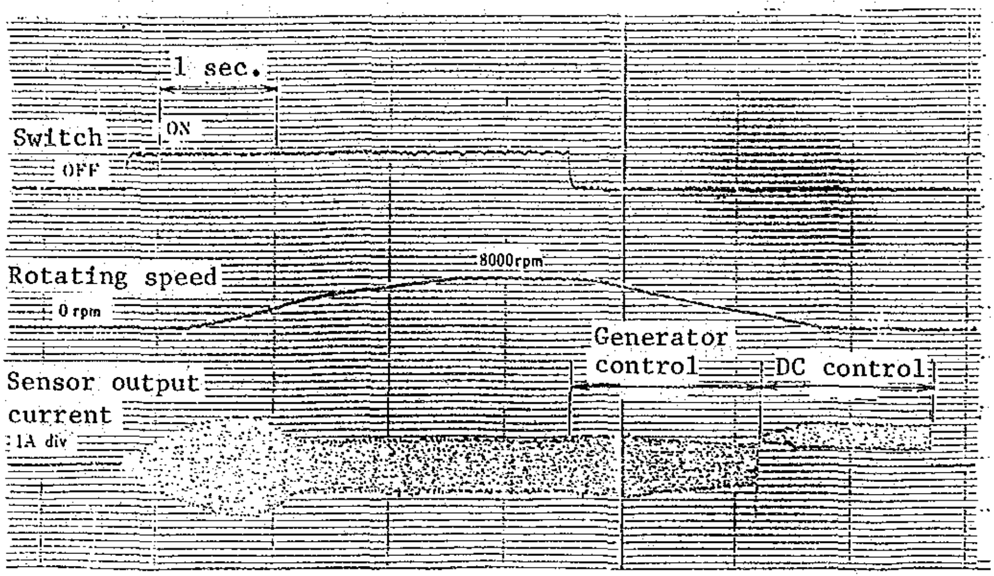


Fig. 3.2.1-17 Operating record of inverter-controlled high-frequency motor-driven grinder

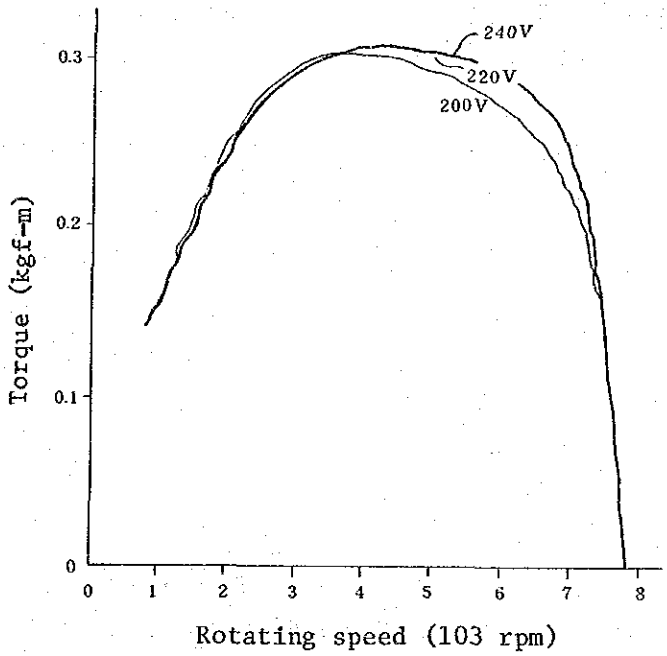


Fig. 3.2.1-18 Torque characteristics of high-frequency motor-driven grinder

c) Grinding performance

The induction motor powered by high-frequency current and driving the grinder at a maximum grinding wheel peripheral speed of 4,800 m/min, when combined with a grinding wheel specifically intended for this grinder, permits high-speed heavy grinding to be performed with a small pressing force of workpiece on grinding wheel.

The rate of grinding obtainable is markedly higher than obtainable with a corresponding pneumatically driven grinder. With pneumatic grinder, increasing the force of workpiece pressing against grinding wheel results in marked lowering of grinding wheel speed; in the case of induction-motor driven grinder, the rotating speed hardly changes with load, and this is what permits this grinder to operate at a high grinding rate.

Data on grinding performance are given in Table 3.2.1-2.

(5) Equipment to be introduced

The equipment to be introduced for the grinding process is as given below. For further details of specifications, see under 3.3.2.

Table 3.2.1-2 *Grinding performance obtained with high-frequency motor-driven grinder*

GRINDING WHEEL CONSUMPTION (g)	Q'TY OF WORK-PIECE GROUND (g)	GRINDING RATIO	ELECTR. POWER CONSUMPTION (W)
60	640.5	10.68	1,400

NOTES: Material ground : SS41
Pressing force : 4 kgf
Grinding angle : 15–30°
Manhours required: 5 min×2×2 men = 20 man-min
Grindstone : A/WA24P of 180 mm dia.×6 mm edgeless
RESIPON

Table 3.2.1-3 Summary list of equipment for grinding process

EQUIPMENT/FACILITIES	
1	Automatic grinding machine, with ancillary facilities for transfer of workpiece
2	Stationary grinder
3	Swing grinders, with electric hoist, positioner, and other ancillary equipment
4	High-frequency motor-driven grinders, with high-frequency power source (1 for each grinder), and grinding wheels (2 grades per grinder)

2) Shop layout for workpiece handling/transfer

After pouring, the casting is passed successively through the steps of shaking out, sand stripping, fettling, heat treatment, descaling, chipping, grinding, remedial welding, touching up and inspection. If nonconformities are detected anywhere in this sequence, some of the steps will be repeated. This sequence of operations is presented graphically in Fig. 3.2.1-19.

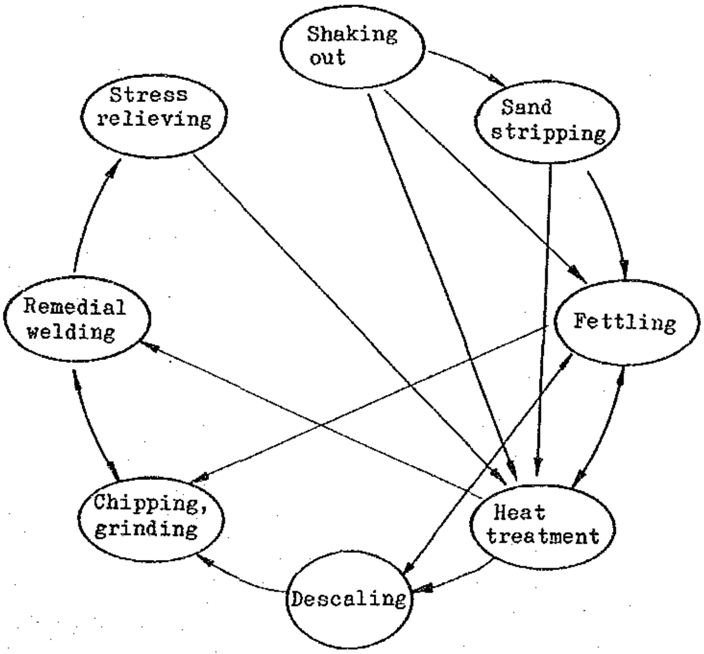


Fig. 3.2.1-19 Sequence of work in Finishing Process

It is seen from Fig. 3.2.1-19 that heat treatment represents a repeatedly passed step in the Finishing Process, and the facilities for performing this step require to be frequently visited by the workpiece. Yet, at the El Teniente Foundry Shop—as shown in Fig. 3.2.1-20—the furnaces for heat treatment are scattered in 3 locations far and wide from the Finishing Shop. Such an incommodious layout is the very probable result of gradual build-up through long years of history, but it cannot be denied that it causes intolerable inconvenience in the daily operations of finishing.

Another inconvenience of the current layout is that the overhead traveling crane does not run through the entire length of building, but is interrupted midway, with shotblasting shop located in the midst, to force the work to flow along a most incommodious path.

The furnaces, moreover, are built-up brick structures not susceptible to easy relocation, and modifying the shop layout should call for renewal of the furnaces.

In the Modernization Plan, the finishing shop should be rearranged in the following manner.

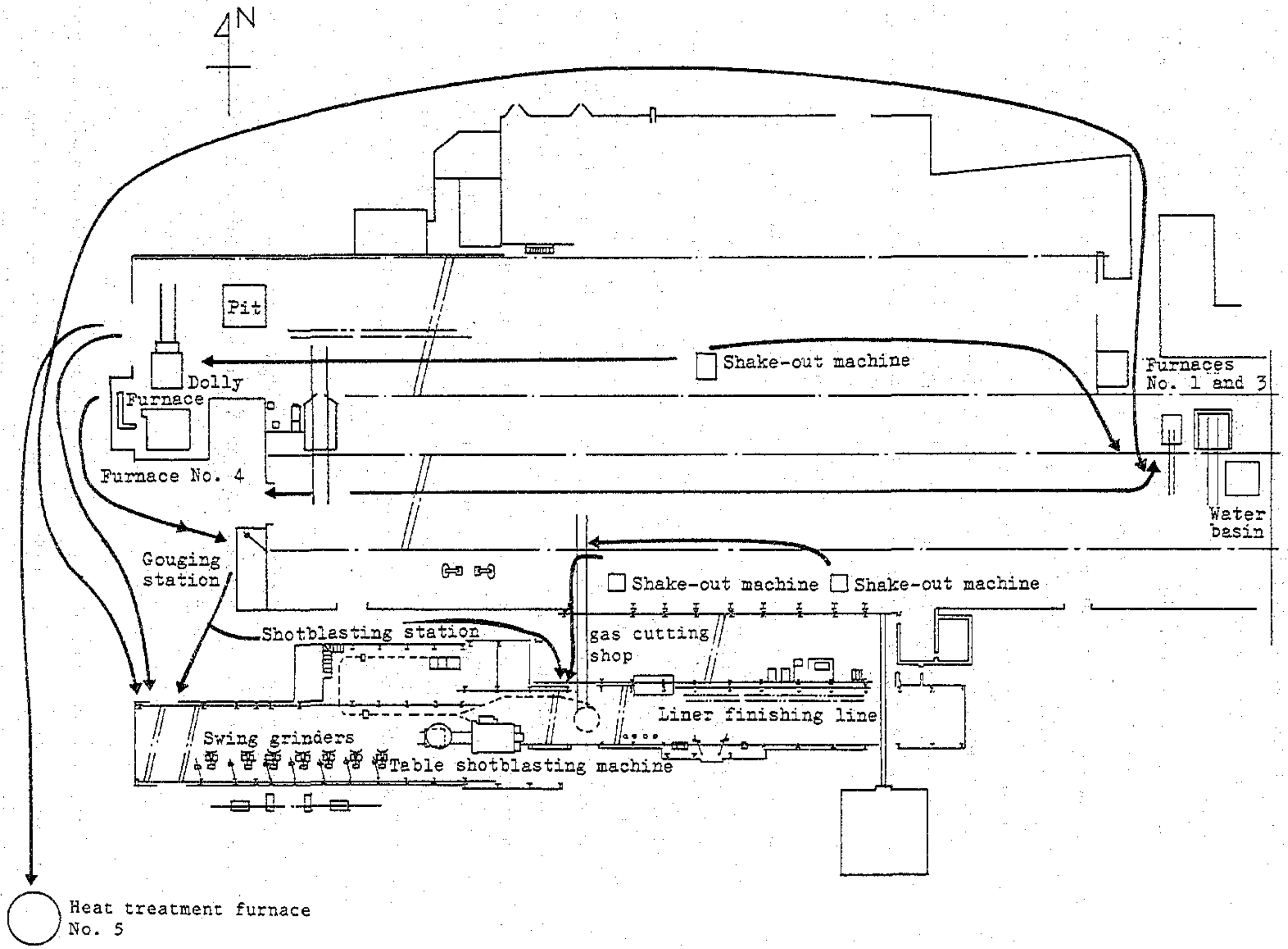


Fig. 3.2.1-20 Current layout of finishing shop

A. Furnace Nos. 1 and 3 might be retained for the time being in their present locations, but in future they should be relocated (replaced) in more convenient locations close to the Furnace No. 4.

B. The finishing shop should be rearranged in an extension to the present swing grinder bay, by reconstructing part of the building, with overhead traveling crane made to serve the entire length of the modified building.

C. The table shotblasting shop currently located at mid-length of the building should be relocated close to the building entrance.

D. The spaces bordering on the molding shop currently occupied by drum shopblasting and gas-cutting installations should be reserved for future installation of machine molding line, to be acquired in the future: No other permanent installations should in the meantime be located in this space.

E. Ultimately, the finishing shop, should be all relocated in new premises, in a rational layout including the heat treatment furnaces arranged free of restrictions from surrounding installations.

3) Considerations on molding shop in view of its effect on the finish grinding process

The time required for finishing castings is largely determined by the quality of product to be finished, leaving little freedom for independent rationalization of the finishing operations and facilities. For this reason, the operatins upstream—in particular, the molding and pouring processes that determine the casting quality—exert a determining influence on the finishing process. For instance, if lost patterns could be introduced, dispensing with risers requiring subsequent removal, this would leave almost no finishing work requiring to be subsequently applied. The current situation is quite far from such an ideal situation. But a step closer to this ideal situation requires to be strived for, by having the operations upstream of finishing reviewed from the standpoint of simplifying and facilitating the finishing operations.

Based on the foregoing considerations, the molding process should first be reviewed in consideration of facilitating the finishing step, holding in view the following points.

(1) Castings with minimum projection of fins

Fins tend to generate at the parting line, when the cope and drag are not properly in contact, or when effective measures have not been provided for holding down the buoyant force acting on cope. Observation of as-cast products at the Foundry Shop have revealed fins found almost continuously present between runner and casting body: For eliminating such incongruities, basic factors governing molding require to be restudied.

a) Smoothing the parting surface

For smoothing the parting surface, the patterns should be designed wherever possible with molding boards; where this is not possible, accurately flat independent molding boards should be used, to ensure correct parting line.

b) Open molding

In the case of open molding, the parting surface should not be retouched by spoon after ramming and parting the mold, and to obviate this necessity, molding sand should be uniformly rammed.

c) Reducing core print clearance

In the finishing process, removing the fins generated along core print clearances represent a considerable amount of work. A larger clearance for core print facilitates molding work, but this results in much additional finishing work: Patterns should be reviewed for eliminating unduly wide core print clearance.

Also, core print clearances tend to increase with age of pattern, and proper control of patterns is required in this regard.

(2) Mis-match of mold

Mis-matches between cope and drag result in deformed casting, which requires an inordinate amount of finishing work, and even rejection of casting. Very strict control of matching between cope and drag should be enforced, to avoid undue workload on finishing, particularly finish grinding.

The Survey Team observed mis-matches reaching 7 mm on a casting from mold on board—though it was indicated to be a trial casting. Even considering this case to be an exception, matching accuracy would appear to require improvement. This observation applies particularly to machine molding.

The key points to be heeded are as indicated below:

a) Pattern/flask adjustment

The pattern, flask and other elements ensuring correct matching of cope and drag should be thoroughly adjusted at the time of trial casting: "Well begun is half done", and proper checking at outset is essential for obtaining castings free of mis-match.

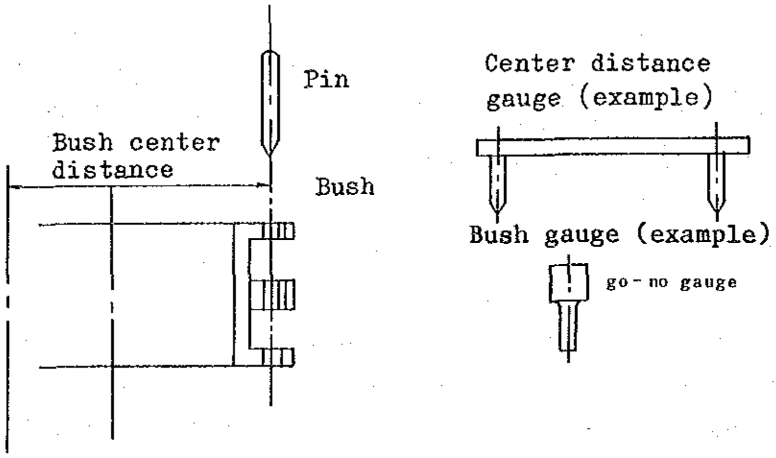


Fig. 3.2.1-21 Example of pin, bush, and gauge for checking pin/bush accuracy

b) Control of pins/bushes

The accuracy ensured by the pins and bushes to guide matching of cope with drag requires to be properly controlled. This is hardly enforced in current practice at the Foundry Shop, and calls for improvement, with periodical checks. Such checks can be conveniently performed using gauges such as shown in Fig. 3.2.1-21.

Such gauges should be prepared for checking:—

- Pin accuracy (diameter, straightness)
- Bush hole diameter
- Distance between bush hole centers across flask.

c) Dowels

When pins are not used for matching, Dowels should be prepared in several standard sizes, for matching cope with drag.

(3) *Elimination of burning-in*

Removal of burned-in sand and sinters calls for considerable grinding work, consuming much grindstone, and their generation should be avoided in so far as possible. Particularly, burned-in sand along risers and upstream of gates makes it difficult to cut by gas. Current practice appears to permit generation of burning in and sintering to appreciable amount.

To remedy this situation, the following basic principles should be respected.

A. Silica sand used for molding

The currently used grade of silica sand contains silica to only aroung 86%, which provides insufficient refractoriness.

B. Remming

The mold should be carefully and uniformly rammed hard, to prevent facing sand from metal penetration.

C. Use of chromite sand

Positions where metal penetration and burn-in are particularly liable to occur should be molded with chromite sand.

D. Cores susceptible to metal penetration

Cores particularly susceptible to metal penetration, such as for bolt holes on liners, being to be surrounded by melt and by material of high heat capacity, shold be entirely of chromite sand, and carefully molded. Strict control should be applied to these cores to eliminate chipped edges and insufficient ramming. Elimination of burning in and sintering should not be considered possible by applying coat.

(4) Position of riser

Certain steel castings require, by necessity of directional solidification, to be cast with molding allowance, but their removal requires considerable work in finishing. To eliminate this additional work, risers should wherever possible be located on flat surfaces; another consideration is to design risers so as to form an extension of the finished casting contour (Fig. 3.2.1-22).

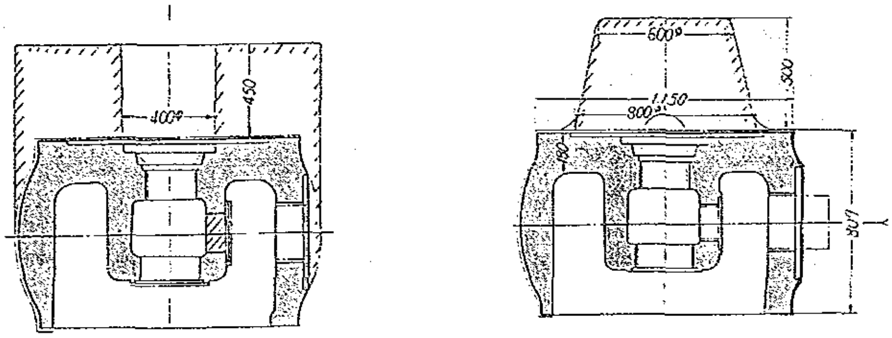


Fig. 3.2.1-22 Example of modification to riser location

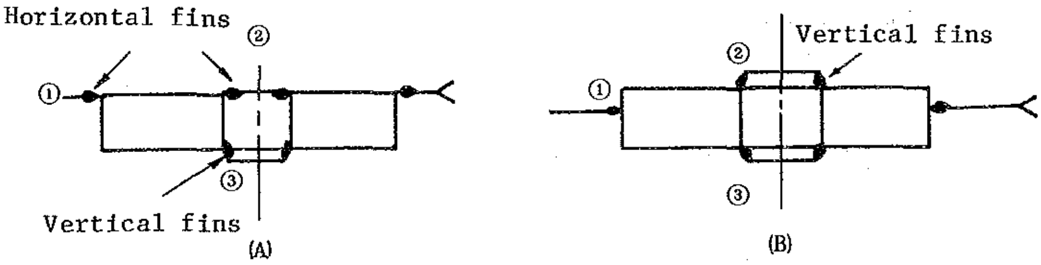


Fig. 3.2.1-23 Example of modification to parting surface position

(5) Position of parting surface

Removal of parting surface fins is easier on flat than on curved surface. For instance, cores of cylindrical castings should be inserted in core prints in such manner as to produce radial, and not axial, fins. In the example of Fig. 3.2.1-23, a ring casting is produced in the Sketch (A) with radial fins at the locations marked 1 and 2. By shifting the parting line to mid-width of ring (Sketch (B)), both fins 2 and 3 come to be in axial direction, which is easier to grind off. The radial fins on circumference, moreover, are quite easily removed by grinding machine.

As illustrated in the foregoing examples, planning the upstream processes with consideration to facilitating the operations downstream will contribute very effectively to rationalizing the overall foundry process. The principle is elementary, but it requires close coordination between those in charge of the upstream and downstream operations to concert with each other in reviewing and replanning their operations with a common objective of realizing a rational overall shop practice, and in devising the best means of maintaining control of the stipulated procedures. The target whould be to ensure workpieces emerging from each stage of processing to be within specified limits of quality, for passing on to the next stage. For this, standards governing operating procedures and techniques, as well as inspection criteria, should be established, to ensure workpieces that are always within stipulated range of quality to be furnished to the subsequent stage, whoever undertakes the work at each stage.

Those in charge of molding should not consider their mission completed upon pouring; they should be provided occasions of observing the shaking out and finishing processes to obtain a clear picture of how their castings require processing in the downstream stages. It should be beneficial to let workers in the molding shop serve for a time in the finishing shop, to let them see how small fins and deformations call for heavy finishing work.

Those in charge of finishing, in turn, should notify those in charge of upstream opeations about castings that require inordinate finishing work, to have the casting design or plan reviewed to improve the situation.

4) Finishing operations upstream and downstream of grinding

Apart from the grinding operations discussed above, the ancillary finishing operations also should be the subject of standards governing applicable techniques and operating procedures, to replace the current practice of relying on experience, in order to ensure a stable and enhanced level of shop practice.

(1) Shaking out

The shaking out operaton of removing the casting from flask calls for establishment of work procedure standards, covering such elements as temperature at shake-out, cooling time (days) after pouring, and other relevent items.

With repsect to cooling, steel castings in particular are liable to generate internal stresses through solidification shrinkage, sometimes to the extent of deformation or even fracture. This applies particularly to high-carbon steel castings containing more than 0.45% C, which require to be slowly cooled at a rate not exceeding 30–60°C per hour: This controlled cooling is said to remove internal stresses to the extent of 60%.

Cooling time between pouring and shaking out will differ with casting shape, wall thickness, material and ambient temperature: With material containing less than 0.45% C, shaking out can be carried out upon casting temperature lowering to 400°C; with castings containing more than 0.45% C, the casting requires to be cooler than 300°C. In particular cases of castings presenting complex shape liable to generate high internal stresses, and others susceptible to cracking such as high-carbon and high-chromium materials, measures should be introduced for controlling the actual casting temperature.

During shake-out, the facing sand can partially or wholly fall off from casting, to result in excessively rapid local cooling, and generate harmful internal stresses. This applies particularly to operation with shake-out machine. To avoid this, particularly with castings of high carbon content or of complex shape, and when large temperature differences prevail between casting and ambient air, the casting after shake-out should be covered with sand or other suitable heat insulating material. Steel Steel castings particularly liable to cracking should further be transferred after shake-out to a cooling furnace previously heated above 200°C, to be slowly cooled at a rate not exceeding 50°C/h. Another precaustion in cooling a shaken-out casting is to lay them in such position as to prevent their own weight from generating deformation while still hot.

For information, examples are given in Figs. 3.2.1-24 to -26 of standards stipulating the number of days to be allowed for cooling after pouring. These data should be regarded as typical examples: The actual standards to be applied in individual cases should be determined independently by each foundry, based on internal data.

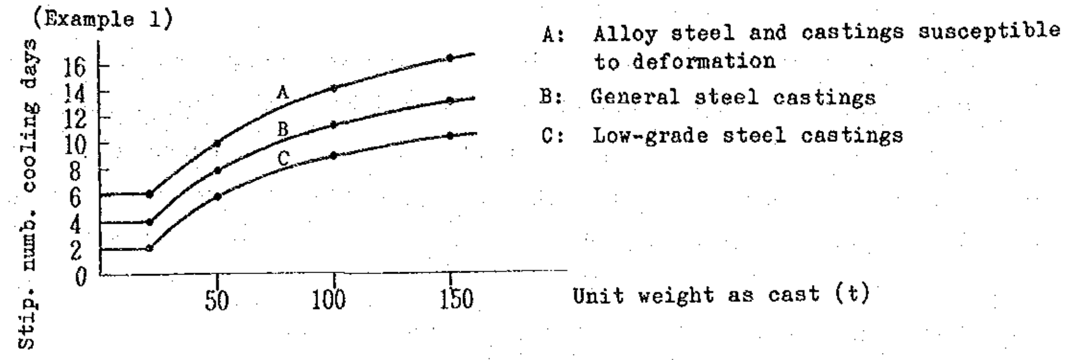


Fig. 3.2.1-24 Cooling time as fucntion of as-cast unit weight

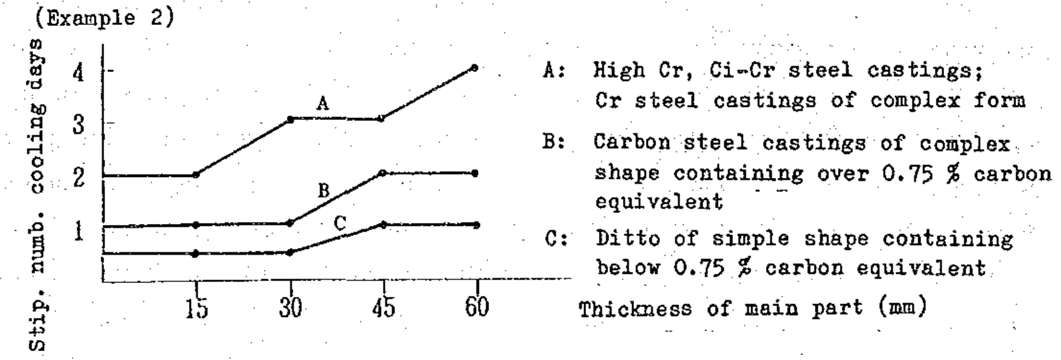


Fig. 3.2.1-25 Cooling time as function of as-cast wall thickness—thin wall castings

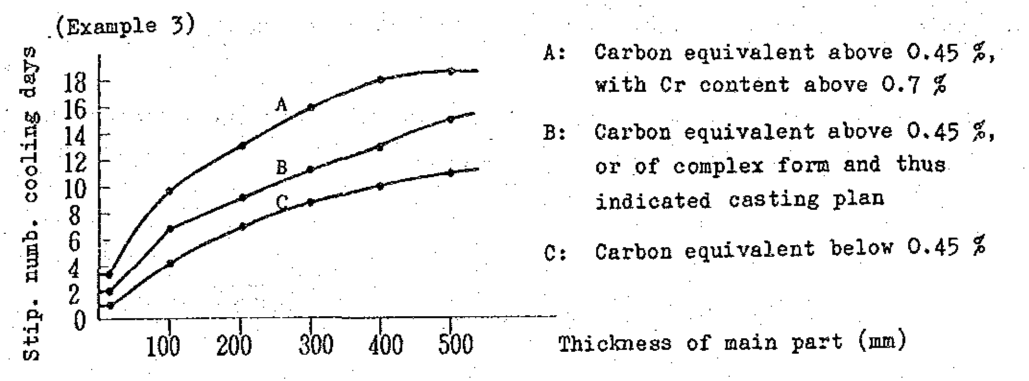


Fig. 3.2.1-26 Cooling time as function of wall thickness—thick wall castings

(2) Sand stripping

Upon shaking out, the casting is stripped of sand. As in the case of shaking out, operation at excessively high casting temperature will risk causing large temperature differences between the casting inner and outer surfaces, such as to generate residual stress, deformation, or even cracking. This calls for strict control of curing time between shaking out and sand stripping.

Work standards should be established governing sand stripping.

The principal purpose of sand stripping is to facilitate the subsequent operation of fettling, and to remove cores remaining in the casting to disturb the temperature distribution in heat treatment.

With respect to curing time, it should be noted that castings with thick walls or that contain cores of complex shape will generate temperature differences exceeding 300°C between inner and outer surfaces, with consequently large disparities in shrinkage; the presence of cores and core grids will further obstruct casting shrinkage to accentuate the internal stresses, to the extent of causing cracks. Casting temperatures above which sand stripping should be forbidden will differ with casting shape, wall thickness and ambient temperature, but as a rule of thumb, 300°C is a normal upper limit for materials containing less than 0.45% C, and 200°C for those above 0.45% C. Exceptions are small castings which can be stripped of sand immediately after shaking out, and in certain cases, sand stripping is performed at casting temperatures as high as 500 or 600°C. On the other hand, castings of particularly complex shape or steel castings containing above 0.70% carbon equivalent, when required for unavoidable reason to be sand-stripped at tempertaures above 300°C, should thereupon be placed in a preheated furnace for proceeding immediately with heat treatment.

For information, an example of maximum casting temperatures permissible for sand stripping is presented in Figs. 3.2.1-27 and -28.

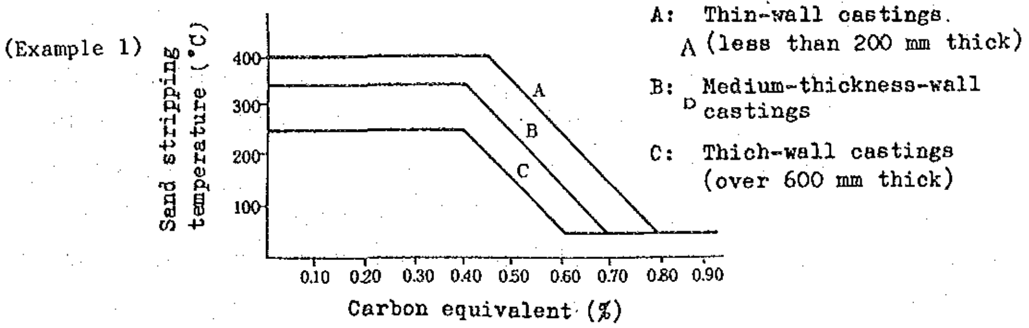


Fig. 3.2.1-27 Maximum casting temperatures for sand stripping as function of carbon equivalent content in steel castings

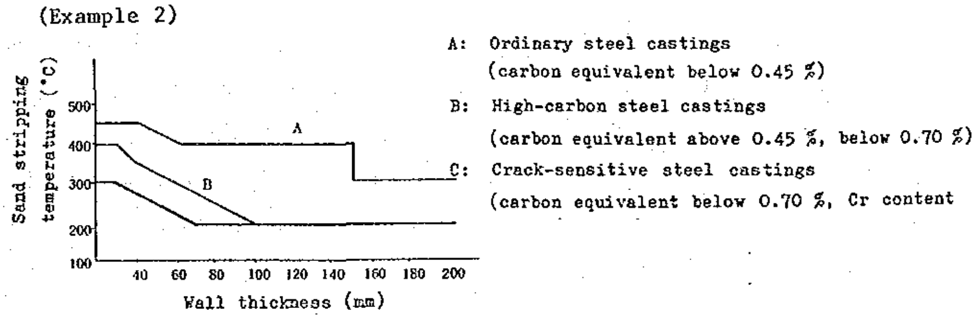


Fig. 3.2.1-28 Maximum casting temperatures for sand stripping as function of casting wall thickness

At the El Teniente Foundry Shop, castings, upon shaking out by machine, have their cores removed by hand, followed by shotblasting. The castings produced are of relatively simple form, so that this manual method has sufficed in the pass, but for further rationalizing the sand stripping operations, the introduction should be considered of such mechanized equipment as:—

- Hanger sandblasting machine
- Turntable core knockout machine
- Crane-suspended sandblasting machine.

a) Hanger sandblasting machine

The current equipment comprises 1 table shotblasting and 1 drum shotblasting machine. The latter unit is of 1,062 mm diameter×1,220 mm, used for small castings. Currently, the machine is utilized also for castings of relatively large size exceeding nominal capacity of the unit: The introduction of an adequately sized machine should contribute to enhancing work efficiency. The table machine is not efficient for working on castings that require cleaning both outside and inside surfaces. For such work, hanger shotblasting machines are most effective: The workpiece is slung fom traveling hanger to pass through shot cabinet, during which they are cleaned both inside and outside (see Fig. 3.2.1-29).

b) Core knockout machine

Mechanical sand stripping is normally performed by core knockout or hydroblast machine. The latter type of machine, however, makes use of water for cleaning, which involves the necessity of installing and maintaining complex ancillary facilities for treating the effluent. The core knockout machine is a kind of shotblasting device equipped with ancillary installation for subsequently separating the shot from sand. Operating efficiency is 8 to 10 times obtainable with manual work.

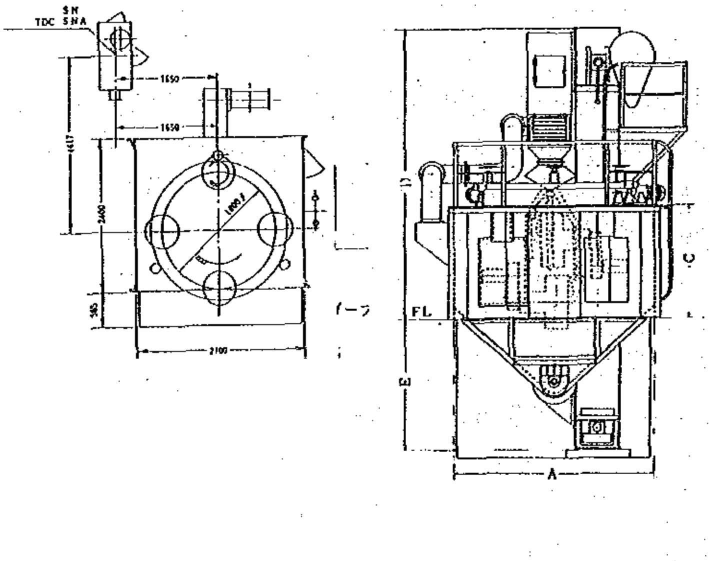


Fig. 3.2.1-29 Example of hanger sandblasting machine

Permissible casting temperture is normally below 300°C, but temperatures up to 500°C can be permitted with the adoption of heat-resistant conveyor.

An example of core knockout machine is illustrated in Fig. 3.2.1-30.

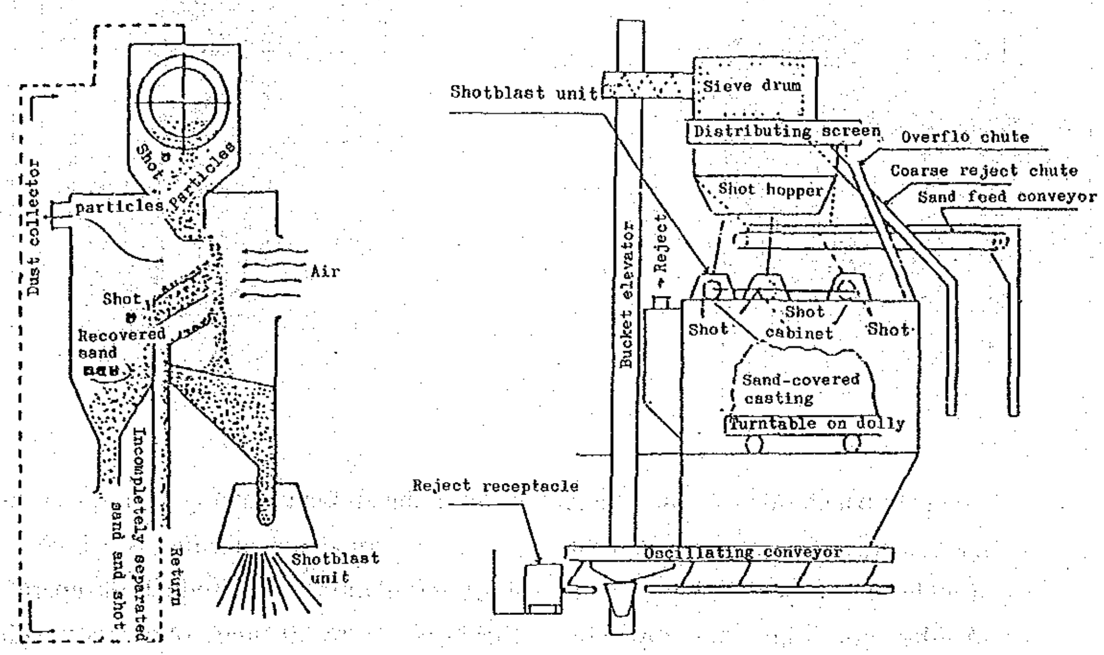


Fig. 3.2.1-30 Example of core knockout machine

c) Crane sandblasting machine

The crane sand shotblasting machine operates with the workpiece suspended from crane inserted in the cabinet, and treated thus suspended, by shotblasting simultaneously from above and from below. Large units are capable of dealing with castings exceeding 30 tons in weight.

The current forecast of products from the Foundry would not justify the introduction of these machines, but it may be considered in future when large ladles and crusher bodies come to be manufactured in large batches.

An example of crane shotblasting machine is illustrated in Fig. 3.2.1-31.

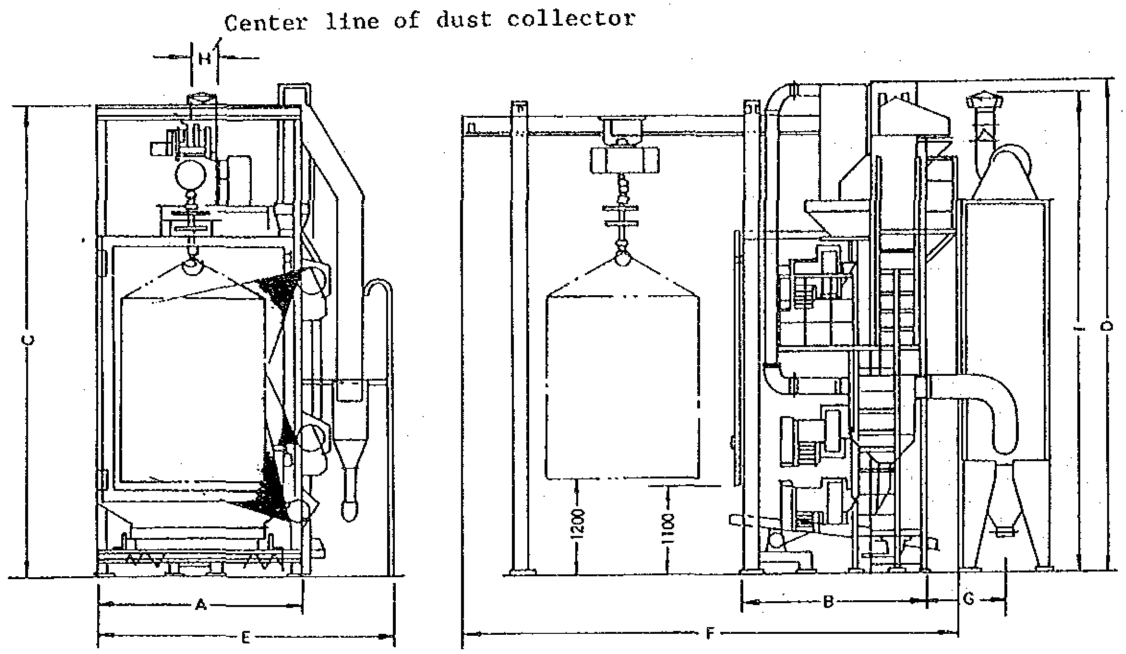


Fig. 3.2.1-31 Example of crane shotblasting machine

The foregoing modern equipment should serve effectively in rationalizing the current sand stripping operations, but none are considered economically justifiable for the rates of production forecast for the period examined. Their introduction should be retained in mind when considering future plans for expansion.

3) Cutting work

The removal of risers, runners, gates and other projections is normally done by gas cutting, with special methods of cutting applied on particular materials. Materials requiring particular consideration occupy a large portion of the Foundry products, and call for attention in the methods applied in their fettling, including preheating and postheating.

Work standards require to be established governing fettling operations.

Gas and arc cutting exposes the affected parts to rapid heating and cooling, to result in microstructure similar to quenching; this phenomenon added to the existing residual stresses, can cause cracking. This calls for preheating or annealing before fettling. Exceptionally, gas cutting without preheating is permitted with castings containing less than 0.45% carbon equivalent for removing projections of cross section below 500 mm diameter; in all other cases, preheating to at least 150°C is desirable.

Moreover, in the case of low-alloy steel castings containing above 0.60% carbon equivalent, particularly when they are alloyed with chromium, vanadium, molybdenum or other ingredients causing high quench hardening, diffusion annealing requires to be applied, in order to diffuse the carbides deposited at grain boundaries, and thereby preventing embrittlement at the time of cutting; the cutting furthermore should be performed upon preheating above 200°C.

After cutting, rapid cooling will increase internal stresses, to risk cracking, particularly with castings of high carbon equivalent and with projections of large diameter: Such castings should have the affected parts coovered with thermal insulation sheet or straw ash, to ensure a cooling rate below 100°C/h. Further, material containing above 0.6% carbon equivalent and with wall thicknesses above 300 mm, as well as alloy steel castings of high thermal cracking sensitivity, call for immediate placement in preheated furnace for stress removal annealing.

a) Fettling high-manganese steel castings

High-manganese steel castings are normally cut by gas, but only after water toughening to obtain a completely austenitic structure before proceeding with the fettling. Also, cooling in water is applied immediately after fettling, to prevent affection by heat of the cut surface.

In avoidable cases where fettling requires to be performed without heat treatment, the projections are cut leaving a stump at least 50 mm high, to prevent cracks from generating on the casting body.

b) Fettling stainless steel castings

Stainless steel is difficult to cut with ordinary gas torch. This is due to the extremely high melting point possessed by chromium oxide contained in this material, and which generates slag that covers the cut surface to prevent reaction between oxygen and base matal.

Special methods available for cutting stainless steel castings are listed in Table 3.2.1-4. Those most commonly used are cutting by powder and by grinder.

Table 3.2.1-4 Special methods available for fettling stainless steel castings

METHOD	SUBSTANCE
Powder cutting	Particles of iron and oxygen are ignited to melt the base metal. The cutting gap produced is 3 - 4 mm, much the same as with gas cutting.
Arc cutting	With carbon or steel wire used as electrode, a relatively high electric arc serves to melt and cut the base metal. The cut surface is rough, and the cutting gap relatively wide.
Plasma jet	A non-consumable electrode is surrounded by water-cooled copper-alloy nozzle, and an arc is generated between the two; a suitable gas is fed through the arc, and which is thereby heated and then projected from a nozzle at high speed in the form of plasma jet, to cut the metal. Cutting speed is high, and the cut surface very smooth.
Flux cutting	This method has been developed mainly envisaging stainless steel. The flux, of sodium carbonate and bicarbonate, of high acid resistance, serves to dissolve the chromium oxide and transform it into highly fluid alkali salt. Plates up to 25 mm thick can be cut at a rate of 230 mm/min and 100 mm thick at 130 mm/min.
Cutting grinder	The material is cut by a grindstone of resinous material 3 - 5 mm thick rotating at high speed. The cut surface is smooth. Materials of any property can be cut, and is moreover little affected by heat. The diameter of projection to be cut is limited by the grinding wheel size: Cutting through 250 mm is about the limit of present-day grinding wheels.

For information, examples are given in Fig. 3.2.1-32 and Table 3.2.1-5 of minimum, casting temperatures prescribed for fettling.

(Example 1)

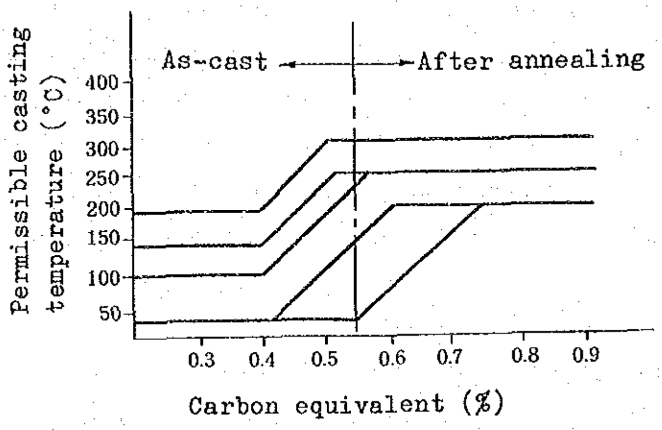


Fig. 3.2.1-32 Minimum casting temperatures permitted for fettling risers, as function of carbon equivalent content

Table 3.2.1-5 Minimum permissible temperatures permitted for cutting risers on castings of different steels

MATERIAL	CARBON EQUIVALENT CONTENT (%)	RISER DIAMETER (mm)			
		800	800-1,000	1,000-1,300	1,300
SC42 SC46 SC49 SCW SCMn1	Below 0.50	Can be cut at room temperature		Hot cutting required	
SCC3 SCMn2	0.50 - 0.55				
SCC5 SCMn3 SCCrM2 Others	Above 0.55		Cut only after heat treatment		

NOTES:

SC42, 46, 49 : Carbon steel

SCMn1, 2, 3 : Low manganese steel

SCCrM2 : Mn-Cr-Mo steel

SCW : Steel castings for welded structures

SCC3, 5 : High-tensile carbon steel casting

c) Cutting off iron casting risers

Risers on iron casting can be removed by knocking off, but those of large diameter call for hammering with large sledges, requiring heavy labor. Instruments that have been tried for this operation include pendulum strikers, drop weights, grinder, saw, as well as hydraulic and pneumatic machines. In attempting to mechanize this work, the problem is relatively simple when products of similar shapes are produced in large batches, which can be treated by machinery devised for that particular form of casting. Such is castings of castings for automobiles. For the case of wide variety manufactured in small batches, partable models have been developed for removing risers up to 70 mm diameter, but none are yet available for dealing with risers as thick as 100–120 mm diameters, such as carried by many castings of the Foundry Shop. Consequently, fettling by hand sledge will have to be continued for the time being, but this operation can be rationalized to some extend by:—

- Incorporation contractions at riser root to facilitate knocking off (adoption of exothermic sleeve)
- Adopting a riser cross section close to rectangle, to facilitate breakage.

Examples of potable riser breaker are shown in Figs. 3.2.1-33 and -34. These machines exert an impact of 24 tons by pneumatic force. Risers up to 250 mm diameter with contracted neck cross section of 4,000 mm^2 can be broken.

4) Fettling

After cutting off risers, castings require to be finished, in order to make the products conformable to drawing. The operations requiring to be performed are chipping and grinding. These operations are performed using tools, machinery, and/or grindstone, whichever is suited to the particular product. For this, work standards require to be established, with particular consideration given to work safety. Considerations are required to be given to minimize finishing operations, for which clear standards require to be established specifying the quality of product, in terms of skin roughness, as-cast dimension and other relevant factors. Chipping of steel castings is performed by arc air gouging or by scarfing. Both these operations affect the material by heating, so that attention is required in the case of high carbon equivalent material (above 0.6%), which risk generation of minute cracks and hardening of chipped surface. In principle, these materials are left with chipping and grinding

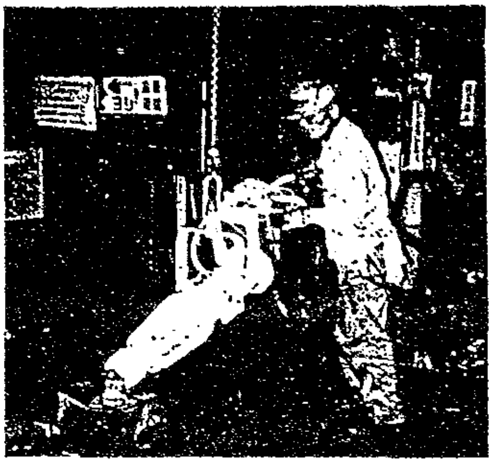


Fig. 3.2.1-33 Portable riser breaker at work

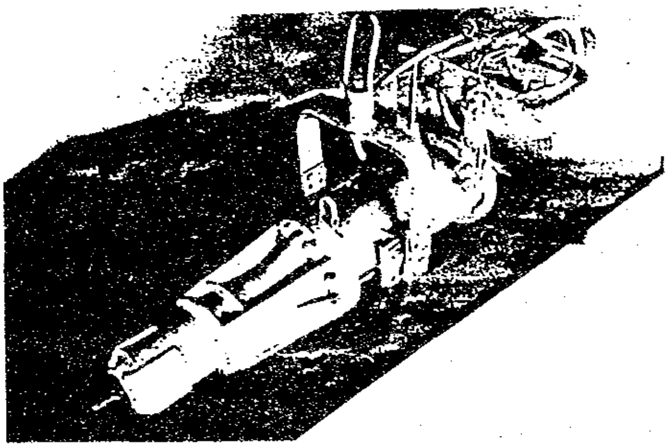


Fig. 3.2.1-34 Portable riser breaker

Table 3.2.1-6 Example of standard arc air gouging conditions

ELECTRODE (mm)		CURRENT (A)	GOUGING SPEED (m/min)	GOUGE DIMENS. (mm)	
DIA.	LENGTH			DEPTH	WIDTH
5.0	305	100 - 200	900 - 1,200	3 - 4	7 - 9
6.5	305	200 - 350	900 - 1,200	4 - 5	9 - 11
8.0	305	250 - 400	700 - 1,000	5 - 6	10 - 12
9.0	305	300 - 450	400 - 700	6 - 7	11 - 13
11.0	305	400 - 550	300-400	8 - 9	13 - 15
13.0	305	450 - 600	200 - 300	9 - 10	15 - 17-

allowance at least 2 mm thick in the case of scarfing and 1 mm in the case of gouging, in order to permit removal of heat-affected layer by subsequent chipping or grinding.

Arc air gouging is performed by DC power source applying an arc between the work-piece and a carbon electrode sheathed in copper or aluminum; the metal melted by the arc is blown off by means of a high-speed jet projected parallel to the electrode. Very small thermal effect is applied to the base metal, so that subsequent removal of heat-affected layer is only required to a depth of 0.5–1.0 mm in the case of remedial welding.

Steel castings of carbon equivalent content above 0.6% require subsequent grinding of gouged surface to a depth of around 1 mm, or else thermal treatment for stress removal. With materials of carbon content above 0.8%, or containing Cr, Mo or other crack-sensitive alloying elements, the gouging requires to be preceded by preheating above 150°C.

For information an example of standard conditions applicable to arc air gouging is presented in Table 3.2.1-6.

Scarfing, similarly to gas cutting, is performed by letting a high pressure oxygen jet issue parallel to the sufrace of base metal, to blow off the metal upon melting by oxygen-LPG torch. The drawback of this system is the high heat input that is imparted, to generate a quench-hardened layer attaining 2–4 mm in depth. The heat-affected layer is removed by grinder or by heat treatment. For steels containing above 0.6% carbon equivalent, the base metal has to be preheated, and followed by heat treatment to remove stress.

For information, work standards for manual scarfing are presented in Table 3.2.1-7.

Of the different finishing operations, grinding has already been discussed under §3.2.1-2), and will not be repeated here.

Table 3.2.1-7 Example of work standard for manual scarfing

SCARF. WIDTH (mm)	TORCH DIA. (mm)	T'CH ANGLE (°)	GOUG. SP'D (m/min)	G. PRESS.(kg/cm2) OXYGEN	G. PRESS.(kg/cm2) ACELYLENE	G. CONS (m3/h) OXYGEN	G. CONS (m3/h) ACETYLENE
8 - 10	3.3	25 - 30	300 - 450	1.75	0.49	5.7-6.1	2.1-2.2
11 - 13	4.3	25 - 30	400 - 610	1.75	0.49	2.3-2.4	
14 - 1.6	5.6	25 - 30	500 - 810	1.75	1.00	2.5-2.9	

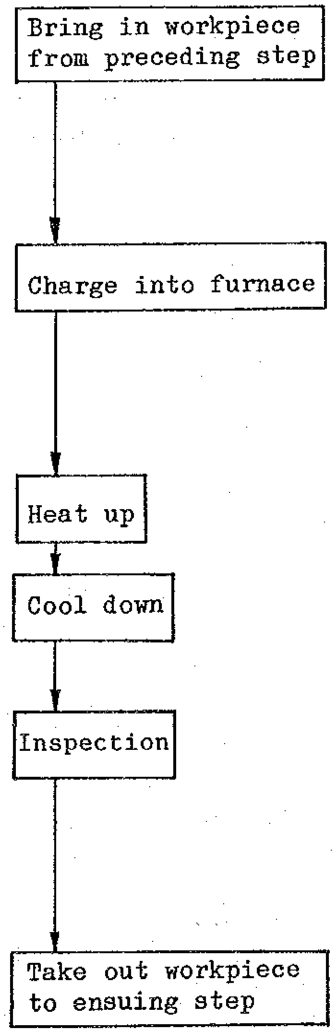
5) Heat treatment

Compared with othe finishing techniques, heat treatment is more theoretical in nature, and has been analyzed metallurgically to permit determination of the operating conditions in a systematic manner. Nevertheless, actual operations are susceptible to considerable scattering of results, which can be inputed either to non-observance of the prescribed basic conditions, or to inadequate control limits being established.

In what follows, a description will be given on this aspect of controlling the conditions of heat treatment.

(1) Sequence of operations

The heat treatment of steel castings follows, in principle, the sequence shown below.



A. Identify workpiece
B. Check heat treatment work instructions
C. Inspect workpiece visually

D. Record condition of charging in furnace
5) Record positions of thermocouples mounted on workpiece

F. Inspect workpiece visually
G. Measure surface hardness

H. Identify workpiece
I. Record completion of heat treatment
J. Compile heat treatment record

(2) Points to be heeded in controlling heat treatment

A. Identification of workpiece

The person in charge of process marks the workpece with heat or product No., client name and other indications necessary for identifying the workpiece. The person in charge of heat treatment verifies the indications to identify the workpieces.

B. Work instruction sheets governing heat treatment

Heat treatment working instruction sheets should be issued to specify the procedures to be followed on shop floor. An example of such instruction sheet is presented in Table 3.2.1-8.

C. Visual inspection

Visual inspection is performed to verify absence of casting defects harmful for heat treatment, such as shrinkage cavity, cracks, slag inclusion, burning in.

D. Recording furnace charge

A record is made of the manner in which the workpieces are charged in furnace, with measurements of distances from furnace floor, wall, to serve as data for analysis in the event of heat treatment nonconformities.

E. Recording thermocouple position on workpiece

In the case of important workpieces, thermocouples are mounted also on workpiece, and the mounting position of the thermocouple are also recorded.

F. Visual inspection after heat treatment

Visual inspection is repeated on the workpieces after heat treatment, to verify absence of cracks or deformation.

G. Surface hardness measurement

The surface hardness of workpieces after heat treatment is measured by Shore or other instrument, to ascertain conformity with specification. Even in the absence of hardness specification, the hardness should be recorded to serve in monitoring the heat treatment, by reference to tensile strength, which can be converted to equivalent surface hardness.

H. Workpiece identification

The heat-treated workpieces are identified, and if identification marks have been obliterated by the tratment, the marking is remade to prevent confusion.

I. Indication of heat treatment completion

Upon completion of heat treatment, and verification of conformity with specification, the workpieces are marked to indicate completion of heat treatment.

J. Recording heat treatment conditions

The records of conditions applied in the heat treatment should be preserved, to serve as evidence for presentation to client as necessary and as internal record for controlling heat treatment operations.

Table 3.2.1-8 Example of heat treatment work instruction sheet

Heat treatment work instruction sheet (No.)

Client	Designation	Drawing No.	Heat No.	Product No.	Material

Weight etc.	Chemical composition (%)											
	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	Ti	Al	Others

Mechanical properties							
Yield pt. kg/mm^2	Tens. streng. kg/mm^2	Elongation %	Red. of area %	Hardness H_B	Impact Streng.	Bending streng.	Other properties

Procedure; temperature curve; work instructions

Drafted by:

Date:

For information, an example of such heat treatment record is presented in Table 3.2.1-9.

What is essential is to manage the heat treatment equipment so as to be constantly maintained in good operating condition. In particular, thermocouples and other instruments should be periodically inspected and calibrated to ensure their accuracy. Thermocouples used should carry certificates issued by official institutions; standards should be established for controlling accuracy thresholds below which the instruments should be maintenanced.

At the E1 Teniente Workshops, the heat treatment furnaces are inadequately equipped with temperature monitoring instrumentation, with the exception of Furnace No. 4. Inadequately accurate control of the actual workpece temperatures during heat treatment will render meaningless all standards established for heat tratment. The situation calls for urgent correction.

Measures require adoption to have all furnaces equipped with automatic temperature recorders monitoring at least 6 points.

The Furnaces Nos. 1 and 3 are currently provided with temperture sensor measuring only 1 point, and not equipped for temperature recording. Consequently, no evidence is retained of the actual conditions of heat treatment applied in these furnaces. Temperature control is the essence of heat treatment, and means of adequate control and recording is an indispensable equipment for all heat treatment furnaces.

Table 3.2.1-9 Example of heat treatment record

Heat treatment record	
1. Customer	
2. Item	
3. Procedure, standard Nos.	
4. Heat No.	
5. Material specification/grade	
6. Date	
7. Furnace No.	
8. Location of workpieces in furnace	
9. Temperature record	
10. Quenching/cooling rate after heating	
11. Workpiece hardness	
12. Approved by:	
13. Customer approval	

Upon introducing automatic recording temperature sensors measuring at least 6 points, records should be retained of the temperature curves, in which the date of treatment, workpiece designation, material, heat No., and other pertinent data should be inscribed, to be preserved together with the heat treatment operating records.

6) Repair welding

Steel castings are liable to carry defects generated by a number of factors coming to play in the course of their casting process. Such defects—within certain limits—are permitted to be repaired by welding. However, if incorrectly applied, remedial welding can cause dangerous consequences in service, so that extreme care requires to be taken in controlling the conditions of application.

For this reason, standards should be established governing remedial repair of steel castings. Such standards may differ according to customer, but the foundry should have its own standards based on which to have agreement accorded by the customer in advance.

Standards governing remedial repair should include the following items:

A. Method of detecting defect: Dye penetrant, magnetic particle, ultrasonic, radiographic, ...
B. Grade of defect permitted remedial repair: e.g. reference to ASTM standard
C. Method of removing defect
D. Welding method: Welder qualification, welding method, electrode, ...
E. Method of inspection after remedy
F. Heat treatment after remedy.

Electrodes require to be selected to suit the base metal—ordinary steel, low-alloy steel, high-alloy steel, ... It should be ideal to use electrodes of the same material as the base metal, but in consideration of easier welding, it is normal practice to select an electrode matched in mechanical property to the base metal. Examples of electrodes adapted for welding different grades of steel casting are given in Table 3.2.1-10.

Table 3.2.1-10 Electrodes suited for welding different steel casting materials

BASE METAL	ELECTRODES (JIS DESIGNATIONS)
SC37	D4301, 4303, 4311, 4313
SC42	D4316, 4324, 4326, 4327, 4340
SC46	D5000, 5001, 5003, 5016
SC49	D5026, 5300, 5316, 5326
SCMn1A	D5300, 5316, 5816, 5826
SCMn2A	DK5616, 5618
SCMn3A, 5A	DK6316, 6318
SCPL21	DL5016-2, 5018-2, DK5026-2
SCPL22	DL5016-3, 5018-3
SCPL11, SCPH11	DT1216
SCPL21, 22	DT2313, 2315, 2316, 2318
SCPH23, 32	D2415, DT2316, 2318, 2416
SCPH61	DT2516
SCMnH1 - SCMnH21	DFMA-B, DFMB-B, DFMC-B, DFMD-B, DFME-B
SCS1, 2	D410, 309Mo
SCS11 - 19	D308, 308L, 316, 316L, 309, 309Mo, 316CuL
SCS20 - 23	D316CuL, 347, 309Mo
SCS24	D430

NOTES:

JIS symbols for uses of electrodes Ditto for base metal (steel castings)

D: Mild steel, high-tensile steel
DT: Heat-resistant steel
DL: Low-temperature steel
DF: Abrasion-resistant steel
D followed by 3 digits:
Stainless steel

SC: Ordinary carbon
SCMn: Low-alloy
SCMnH: High manganese
SCPH: For high-temperature/high-press. service
SCPL: For low-temperature/high-press. service
SCS: Stainless

Even with correct grade of electrode, their management in terms of humidity control in particular decisively governs the quality of weldment that can be obtained: In the case of coated electrodes, the coating is liable to absorb moisture, to cause bead cracking, pinhole and other defects, so that adequate drying before use is essential for obtaining weldments of conformable quality. This applies particularly to low-hydrogen electrodes, which absorb moisture proportionally to the duration of exposure to atmosphere. Proper control of electrodes is necessary even after drying in oven.

Current conditions at Foundry Shop are far from satisfactory in respect of electrode management: It is urgently advised to install a drying chamber for electrodes, and establish strict standards governing electrode management.

For information, the drying temperatures applicable to different electrodes are presented in Table 3.2.1-20; Fig. 3.2.1-36 shows the relation between duration of exposure to atmosphere and moisture absorption by electrodes.

Table 3.2.1-11 Drying temperatures prescribed for electrodes

(Unit: °C)

Electrodes for mild steel	
D4316	250 - 300
D4316 (High-tensile base metal)	385 - 415
D4301	80 - 120
Electrodes for high-tensile steel	
D5016	300 - 350
D5816	350 - 400
Other electrodes	385 - 445
D5003	80 - 120
Electrodes for low-alloy steel	
D2315	300 - 350
D2316	300 - 350
Electrodes for stainless steel	200 - 250

NOTE: Symbols in JIS for indicating electrode grade: D: For mild steel; first 2 digits: Tensile strength in kgf/mm^2 last 2 digits: Coating, welding position etc.

Before repair welding, complete removal of the defect must be ascertained. Welding should be preceded by preheating of the base metal. Electrodes should be selected to match the base metal, and should be strictly controlled for moisture content. Finally, the welded part should be properly treated to remove residual stresses.

The heat-affected zone of the base metal is liable to be affected by hardening, residual stress, cracking. As countermeasure, the base metal requires to be preheated above prescribed temperature, to prevent rapid cooling after welding. Preheating tempertures normally require to be above 150°C for steel castings containing more than 0.40% carbon equivelent, and above 200°C for alloy castings containing chromium and/or mloybdenum. A zone in base metal extending to a depth of at least 4 times the weldment is normally required preheating; castings of particular shape or materials that contain elements conducive to crack sensitivity should be preheated—in furnace or by other suitale means—to temperatures above 200°C by suitable method.

For removing residual stress, the workpiece requires normally to be heated above A_1 transformation point (550–650°C). In certain cases the workpiece may be heated locally by oxygen-LPG burner or other suitable means. In such cases, the welded part should be heated to the prescribed temperature and held for 30 min for every 25 mm of weldment depth, then cooled at a rate below 100°C/h. The range of base metal to be heated in normally a distance of 250 mm from edge of weld, and 4 times the length of deposited metal. The relation between holding temperture and residual strength remaining after heat treatment is indicated in Fig. 3.2.1-35.

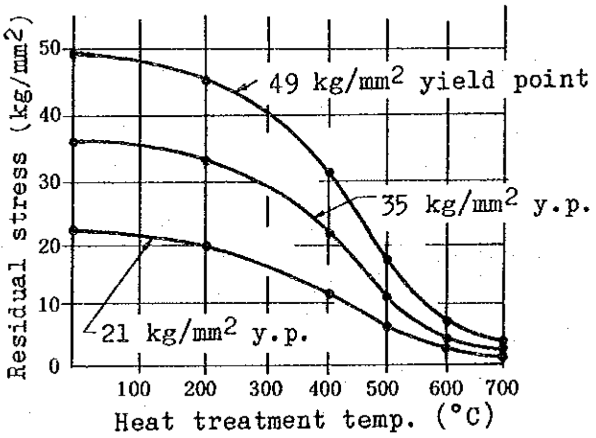


Fig. 3.2.1-35 Relation between heat tratment temperature and residual stress remaining after treatment

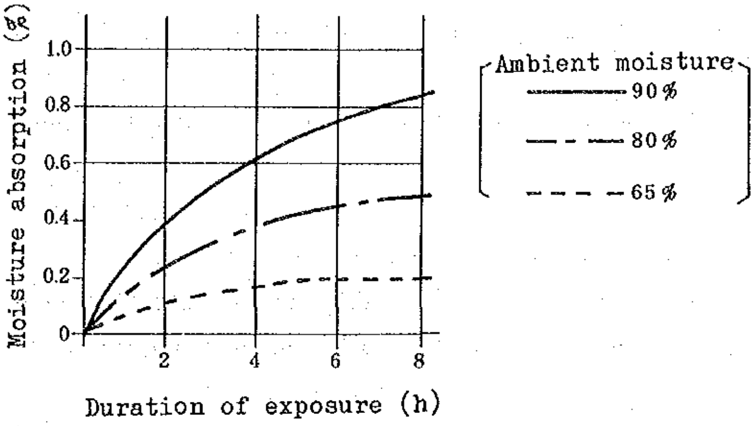


Fig. 3.2.1-36 Relation between duration of exposure to atmosphere and moisture absorption by electrodes