THE FEASIBILITY STUDY
ON
THE MODERNIZATION OF WORKSHOPS
OF
CORPORACION NACIONAL DEL COBRE DE CHILE
IN
THE REPUBLIC OF CHILE
FINAL REPORT

MARCH, 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to the request of the Government of the Republic of Chile, the Government of Japan has decided to conduct a feasibility study on the Project for Modernization of Workshops of Corporacion Nacional del Cobre de Chile (CODELCO) and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Chile a survey team headed by Mr. Koji Chikaraishi (Ishikawajima-Harima Heavy Industries Co., Ltd.) from June 28 to July 27, 1986.

The team had discussions with the officials concerned of the Government of Chile and conducted a field survey in the Project-related areas, including Santiago and Rancagua. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Chile for their close cooperation extended to the team.

December, 1986

Keisuke Arita
President
JAPAN INTERNATIONAL COOPERATION AGENCY

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Abbreviation

ASTM	American Society of Testing Materials
AWS	American Welding Society
ASME	American Society of Mechanical Engineers
ANSI	American National Standards Institute
API	American Petroleum Institute
BS	British Standard
NS	Norsk Standard
JIS	Japanese Industrial Standard
ISO	International Organization for Standardization
POS	Purchase Order Specification
WPS	Welding Procedure Specification
NDE	Nondestructive Examination
PT	Dye-penetrant Test
RT	Radiographic Test
UT	Ultrasonic Test
FMEA	Failure Mode Effects Analysis
FTA	Fault Tree Analysis

Collation Table for Terms in English & Spanish

The Republic of Chile	República de Chile
CODELCO	CODELCO
Div. El Teniente	Div. El Teniente
Rancagua	Rancagua
Workshop Department	Departamento Talleres
Workshop	Maestranza
Foundry Shop	Fundición
Plate Shop	Maestranza Calderería
Machine Shop	Maestranza Fabricación
Repair Shop	Maestranza Reparaciones
Maintenance Shop	Mantención y Servicios
Production Dept.	Producción
Finishing Process	Terminación
Welding Process	Soldadura
Quality Assurance	Garantía de Calidad
Quality Control	Control de Calidad
Inspection	Inspección
Review	Repaso
Evaluation	Evaluación
Approval	Aprobación
Audit	Revición de Cuentas
Verification	Verificación
Reliability	Exactitud
Design Review	Repaso de Diseño
Dispersion	Disperción
Deviation	Desviación
Bias	Propensión
Tolerance	Tolerancia
Productivity	Productividad
Recuperation	Recuperación
Safety	Seguridad
Frequency Ratio	Razón de Frecuencia
Severity Ratio	Razón de Severidad, Gravedad
Training	Capacitación
Investment	Inversión
Depreciation	Depreciación

Environmental Pollution	Incomodidad Público
Pollution	Polución
Diffusion	Difusión
Environment	Ambiente
Cast Iron	Fundición de Acero
Cast Steel	
Iron & Steel	Siderúrgica
Carbon Steel	Acero Carbono
Special Steel	Acero Especial
High Tensile Steel	Acero de Alto Tensor
Copper	Cobre
Brass	Latón
Bronze	Bronce
Stainless Steel	Inoxidable Acero
Welding Material	Materia de Soldadura
Corrosion	Corrosión
Qualification	Calificación

CONCLUSIONS & RECOMMENDATION

Conclusion & Recommendation

1. Philosophy

1) Future vision

The Republic of Chile is one of the foremost copper producers of the world, amongst nations of U.S.A., U.S.S.R., Canada and Zambia, in which, U.S.A. and Canada are in the retarding trend of the primary industries with excessive wage demands of the workers and Zambia suffers political confusion and is unreliable of the output. The Copper production of the Republic of Chile, on the contrary, despite the difficulties in politics and in economy of past several years, still has stable production and cost competing capability. The CODELCO, as a national corporation, is a huge conglomerate, having an output share of 80%, about a million tons annually. Its management context, despite the decline of the copper price in world market, is sufficiently sound and its competing power is in the excellent position among domestic as well as competing foreign countries and stands as an important part sustaining Chilean economy.

In 1980s, when the signs of stabilization and growth seem to appear in the economy of Chile, the CODELCO aspires agressively to establish an expansive strategy, already implementing large investments in the mining divisions, thus deftly intends to dominate in the world copper market.

Div. El Teniente is the largest underground copper mine in the world, and also has the oldest traditions in the CODELCO. The mining department has the foremost cost competing capability, resulted from accumulated past tremendous investment and the prevailed well-organized management and technology; annual output of about 300,000 tons, about 30% of the CODELCO production, indicates its importance in the enterprise. The confirmed deposits of El Teniente guarantees more than 100 years of production, keeping present output; doubtless to keep dominant role as a leader of the copper producer in the country for coming long future.

The proposed target production goal in the Feasibility Study indicates projection up to 1989 but it should be necessary to take a consideration for the future expansion even beyond 1989 and the concrete policy in the future vision shall be soundly developed for the production increase maintaining the cost competing capability.

2) Future stance of the workshops department

Workshops Department (Departamento Talleres) is responsible to execute an engineering service including the supply of the mining machines and equipment in Div. El Teniente. As indicated in the basic principles, the CODELCO has a responsibility, as a leading national corporation, to raise technical level of the mining industries in the country and the Workshop Dept., as a part of the responsibility, to demonstrate high technical levels in the products and also in the production processes. The Department, though the replacement and renovations had been carried out in its long history of the activity, while the range of the production activity varies from Foundry, Machining, Welding to Maintenance and Repair, including manufacturing, recuperation, repairing, the entire facilities can not be said as the most advanced.

Especially, the proposed field of the Finishing Process in the Foundry and the Welding Process in the Plate Shop and just in the time of replacement and also the industrial safety records are indicating rather unsatisfactory among the worst in the Dept.

The earliest breakthrough from present situation to establish safe, job-enriched shop, shall be envisaged, definitely avoiding an impression of the old-fashioned inferior environment and the strained production.

3) Facilities in the finishing process of the foundry and in the welding process of the plate shop.

In the trend of industrial technology, the innovations are doubtlessly directed to the energy-saving, automatic control. The heavy manual work depending on human labour, shall be replaced by the mechanical instruments and in above-mentioned 2 processes, the automation shall definitely be employed in not so far away future. Therefore, the proposed investment shall be determined in the future vision of automation/robot context.

2. Technical Feasibility

1) Automation

The grinding process which has long been considered difficult for the automation/robotization, now becomes possible for the application of CNC (Computerized Numerical Control). Tremendous variety of the products in the Foundry Shop would easily anticipate enormous cost for the computer programming and the preparation works for entire coverage of the automation. However, fortunately over about 60% of the products are of the Liners, which can be categorized in some range of the sizes and dimensions. For those items of the works, a multipurpose CNC automatic grinding apparatus shall be introduced as a breakthrough in this field. This machine has an automatic memorized/teaching function, and following to the primary movement on the surface of the product to be grinded, the movements are automatically memorized inside the machine, thus subsequent grinding work shall be continuously and automatically carried out.

And the 4-face grinding operation is possible by a sequential control; thus the manual preparation work and idling shall be eliminated and considerable improvement shall be expected by the uninterrupted continuous work.

In the domain of the mass production welding, a complete automatically controlled robot weld had already been in actual use, indicating doubtless transition from an advanced technology to general application. As for the arc welding with large heat input, a complete unattended welding can now be applicable with the combination of the memorized/teaching and automatic position sensing device. The Welding of the Plate Shop, in not so far away future, would come into the domain of unmanned automation, thus, the investment program shall be implemented along with the direction of future automation trends.

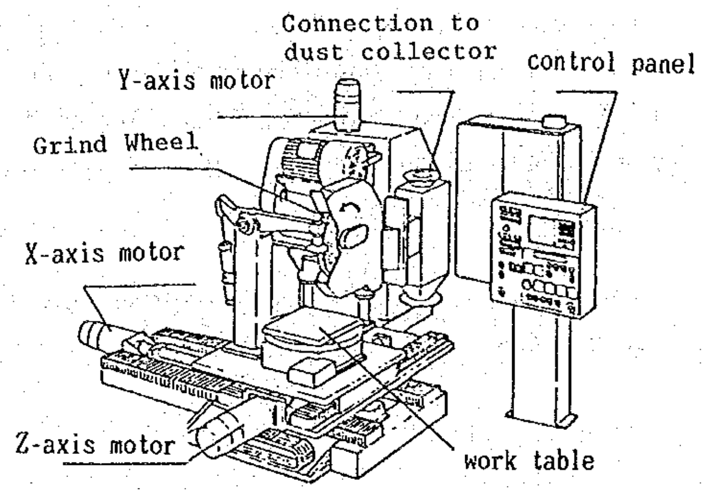
Considering verieties of the products in the Plate Shop, a multipurpose arc welding process can be found in the gas-shielded type MIG welding, so the flux-cored wire welding shall be selected as the main process, having better bead appearance and superb weldability. Gas-shielded flux-cored wire welding shall be applied mainly in the welded structure and in hard-facing recuperation work and in addition, for the work requiring especially high deposition of the weld, an automatic submerged arc welding shall be employed.

And to facilitate the maximum welding efficiency, the down-hand weld shall definitely be employed, for which a Positioner and a Manipulator shall be introduced to acquire efficient continuous work.

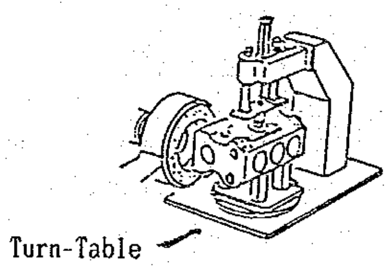
2) Efficiency increase

In addition to the CNC automatic grinding apparatus, the productivity improvement in the Finishing Process can be attained: the one is the attachment of the Constant Surface Speed Device, *the other being an adoption of the High Frequency Grinder.* The constant surface speed device is applicable to the conventional Swing Grinder and to the Fixed-type Double Head Grinder, which is capable to develop constant grinding efficiency, by revolution increase device corresponding the decrease of the diameter of the grindstone. The high frequency grinder is excessively lighter compared with the conventional type, with good maneuverability and high revolution, thus contributing to the efficiency.

In the welding process, the transition from manual welding to semi-automatic and to automatic welding means considerable productivity increase. Upon the introduction of the new technology, training would generally be required, but in the Plate Shop, fortunately the solid wire gas-shielded type welding have already been in use, an additional training is not necessary. Contrarily, easier the handling and better bead appearance can immediately benefit to reduce welders' labour.



Sequentially controlled 4-face CNC (Computerized Numerical Control) Automatic Grinding Machine



4-face Grinding

3. Hardware Investment as of the Economically Feasible

Effects of the new investment shall surely include the improvement of Industrial Safety, Environmental Improve, the Interface Improvement between Shops in the Workshop Dept. as a whole, especially in the area of Material Distribution and Transportation and also, resulted Motivation Incentives of the Employees, which are difficult to evaluate quantitatively.

Therefore, the Financial Analysis shall be conducted from more directly calculable Man power, Fixed & Indirect Costs, rather avoiding various qualitative considerations.

As agreed in the Progress Report, dated July 22, 1986, the criteria of the acceptance of the new investment is determined as IRR (Internal Rate of Return) of 15% in the Discounted Cash Flow Method.

The acceptable investment is as follows.

* The Finishing Process in the Foundry (Terminacion de Fundicion)		
Swing Grinder with Constant peripheral Speed Device		4 sets
High Frequency Grinder		6 sets
Turn Table		4 sets
Amount of Investment	US$156,000	
* The Welding Process in the Plate Shop (Soldadura de Caldereria)		
Flux-cored Wire Gas-shielded MIG Welding Machine		18 sets
Submerged Arc Automatic Welding Machine		1 set
Positioner & Manipulator		2 sets
CO2-Gas Distribution Piping System		
Amount of Investmen	US$467,000	

4. Other Hardwares as Advanced Commitment

According to the financial analysis on the Finishing Process of the Foundry, the direct and visible productivity increase from the hardware investment is not significant compared with that of the Welding Process in the Plate Shop. This is because that the given proposition is limited to rather secondary, service work of the grinding stage in the Foundry and also because there are no unique innovation factors in the stage of the grinding.

The Foundry Process is a field of industrial technology, where enhances precious history and tradition and accumulated experience and know-how sustain present casting technology. Despite importance in the area of technology, as the work process accompanies dust, excessive heat, smoke and fumes, it is difficult to get out from the image of the heavy, dirty work of previous century primary industry. While other shops of the Workshop Dept. are steadily transferred from manual work to semi-automatic, automatic process and even to the automation/unmanned control, the Foundry has some critical feeling to be left discarded behind. Therefore, the Foundry Shop has to remove the dark impression of unpleasant situation and is in the immediate demand from another aspect of establishing safe, pleasant and job-enriched environment.

Notwithstanding quantitative financial evaluations, the Foundry Shop shall put the flow of the materials in order and shall fully employ mechanical power in the movement and transportation of the products and as a milestone of the future development of the mechanization and automation, an introduction of automatic machine-grinding shall be accepted.

For these purposes, the Turn-Tables and Electric-driven Hoists may be employed for the immediate installations.

The "Sequentially controlled Tetra-Surface CNC Automatic Grinding Apparatus", is exceptionally expensive at present stage (US$ 375,000/set); "OK Sign" for the new investment could not be given from the financial analysis in a narrow area of the Finishing Process. And as an immediate substitute proposal of the "Vertical 4-Face Grinding Apparatus with Hydraulic Power", excluding the automatic control but still employing the mechanical power, is also expensive (US$195,000/2 sets, CIF-Price plus removal/re-installatin cost of existing Shot Blast), while insignificant in productivity gain due to the exclusion of the automation.

Therefore, finally arriving, the decision to employ the automation/mechanization in the Finishing Process in the Foundry, shall be given in a global context of the philosophy in the Workshops Dept. as a whole. The items to be analyzed shall include a CNC Automatic Grinding Apparatus, removal/re-installment of the Shot Blast and the Re-arrangement of Shop Immovables & Equipments.

The extent of the global renovation plan will include following order in a rough estimations.

Renovation of the Shop Immovables			US$625,000
Overhead Crane	10 tons	2 sets	312,500
Overhead Crane	5 tons	1 set	137,500
Traverser		2 sets	62,500
Removal/Re-Installment of Shot Blast		2 sets	62,500
CNC Automatic Grinding Apparatus		1 set	375,000
Double-Head Grinder with Constant			
Constant Peripheral Speed Device		2 sets	25,000
Dust Collecting Apparatus		2 sets	187,500
Total			about US$1,787,500

Above feasibility shall be analyzed on the aspect of a global vision beyond 1989 on the Republic of Chile, the CODELCO, Div. El Teniente, in which the philosophy of Human respect, Safety Environment, the Trend of Technical Innovation of the world, Economical Growth and Expansion and also resulted Labour Cost Increases and then, a Policy of the Introduction of Unmanned Automation shall be discussed.

5. Software

Upon implementing the modernization projects, the most important item which should not be disregarded, is the creation of human resources inside the enterprise. Because, even while how excellent the machines were, it is a human being who would operate them. Each individual has an independent sensitivity, emotional undulation; therefore, to accomplish a specific target with large group of personnel in the continuous activities, it would be difficult to attain expected results without intended concentration of the total motivation.

The given schedule of the modernization program involves a period of 3 years to 1989, and the 1st year, 1987 is considered to be a purchasing stage of the new investments, thus, the hardware of equipment is not expected to be installed. So, the year 1987 can fortunately be used for the analysis and for the improvement of the management of the Workshop Dept., designated as the year of Software Renovation.

There is an example of the campaign of the enterprise that would give the organization a strong tension, extracting motivations of the employees, thus activating the company as a whole.

Title of Quality is hoisted as a slogan of the campaign, in view point of easy understanding for the general public; it is called a Company-wide QC Activity.

The Productivity Circle, now currently adopted in the CODELCO can be designated in the category.

The term "Quality" shall not be limited only in that of the hardware products, but shall be enlarged to cover the quality of the enterprise, the quality of human assets to widen the field of the campaign.

The Glossary of Terms.

Quality Assurance, QA.

All systematic measures which are necessary to ensure that the conformance with specified requirements is planned and obtained.

Quality Control, QC.

The operational techniques and activities that sustain the product or service quality to specified requirements, it is also use of such techniques and activities.

Inspection.

The part of the quality assurance which, by measurements, tests or investigation, determines whether the product or service in accordance with the prescribed quality requirements.

The purport of the campaign is that the entire activities to contribute to the society through the provision of better products as the aim of the enterprise, are to be designated as the quality activities, encompassing from Engineering Pre-Study to Safety Managements and to the Training of the Employees.

The philosophy is as natural as that through the supply of better products in conformance with the customers' requirements, the company can be benefitted with the increase of the demand, expanding the company operations and thus, acquired profits can contribute for the progress of the society as well as for the improvement of the life of the personnel in the whole enterprise.

As for a slogan, QA represents exact conformance to the customers' requirements and QC to be the persistent endeavour to realize the designated quality through logical, scientific processes. There is a tendency to have severer inspection for the sake of attainment of the good quality, but it is unsatisfactory and inadequate. One cannot declare assurance of the quality even when everything is in accordance with predetermined procedure of inspection. There might be a chance that the analysis of the specification and drawing insufficient or the functions of the products or production processes might induce trouble.

Or the process of the inspection might be inadequate. The QC Dept., only, therefore, can not be responsible to manage the quality and also, a passive attitude cannot sustain the quality.

Active attitude from the starting of the planning is necessary, Problems and weak points shall be visualized to entire members concerned and the improvements shall be pursued under full understanding and humble attitude. As aforementioned, the origin of the quality campaign is in "What is the real requirements of the customer for the product?", which shall be always kept in mind through entire stages of the production developments.

Engineering Pre-Study and the Design Review are among the effective ways and the creation of the Construction Standards and Work Instructions contribute to minimize personal differences and also to homogenize the quality of the productions. And despite whatever the obstacles are, the persistent endeavour to keep once-decided procedures will determine success of the campaign. When the organization and systems of the control once have been deployed, one, sometimes, tends to feel relieved as the mission completed. There should be many obstacles such as the restrictions due to facilities, inadequate environment or abrupt change of the weather, during the implementation. When the difficulties arise, easy compromise at the down-stream of the organization shall not be permitted; the corrective actions shall be carried out under controlled status, analyze the nonconformance to prepare the next step, which directly benefit to maintain the tension in the enterprise. The past record of the failures are precious assets of the enterprise. Open-minded, humble recognition of the failure, the immediate actions of improvement and their quick feedback cycle are important. The largest effect to vitalize the organization shall rest in the consents of participation.

Voluntary incentives; the pleasure of seeing own proposals to be realized actually; these activities require accumulations of patient daily efforts of the management.

The improvement of the industrial safety is totally in the same philosophy. To raise the safety record, one tends to direct to conform the regulations more strictly, but a consensus of the entire organization is the most necessary more than anything, so that the safety improvement shall not be accomplished without mutual cooperation between the management side and the labour side, and that the compulsion and the passive attitude would not contribute to major advancement. No one would intend to have injury in his work and everyone would like to accomplish better work if he has to. To do the work safely is to think how to work easily to attain good job, which means exactly to have the pre-study before actually start the job.

Through Safety Pre-Study and Design Review, the entire membership concerned can have a chance to issue honest proposals and also to have a chance to understand and listen humbly to different opinions of others; these contribute to raise a sense of participation and to understand the work by his own responsibility, not be compulsory.

In this way, to pursue the safety is completely same as to raise the productivity of the enterprise and it is not unreasonable to take up the safety as a factor to improve the quality of the enterprise.

In Foundry Shop, and in the Plate Shop, the records of the industrial safety are among the worst, in which the most of the accidents have been classified in the category of "Accidents in safe conditions". Improvement would not be difficult, if both the management side and the labour side declare their sincere intentions toward the safety and would carry out their responsibility without any easy compromise and going on maintaining higher tensions.

6. Recommendation

1) Immediate promotion of the modernization up to 1989

The proposed Modernization Programs are expected to acquire their results in rather short period from 1987 to 1989. To make sure the productivity increase by new investment of automations & Semiautomatic Apparatus, an improvement of "Quality" shall be inevitable. Quality of the products, quality of the production process, quality of the human assets along with quality of the safety engineering shall be improved in the following categories.

(1) A concept design of the facilities of Plate Shop which is demonstrated in the Appendix of the Final Report shall immediately be realized for the strict conformance of the Safety Act as mandatory responsibility of the enterprise.
To show a perfect fulfilment of the responsibility for the safety establishment as of the management side, would stimulate the feelings of employees, which would surely contribute to raise the safety record.

(2) It shall be clearly declared in the Workshops that the QC responsibility is in the entire membership of the employees, not in the QC Dept. only. Each individual will carry out a good work at his stage, which means the quality shall be built-in at each production stage. To distinguish clearly what kind of the quality is required in this stage and also to confirm it by himself, the work manuals or the QC Process Chart shall be edited by all members concerned to visualize his work. "Compile the Safety Instructions" is also effective to motivate workers' participation.

(3) Several remarks, as stipulated in the Final Report shall be carried out for the quality improvement.
* SiO_2 contents in the casting sand.
* Roughness control of gas-cutting surface.
* Accuracy control in edge preparation of the weld.
* Welding material storage: Discipline & Order at the storage, Drying, etc.

(4) Upon the introduction of the new investment, a project team shall be composed in the Workshops Dept. to provide smooth technical acceptance and installations. And also, it is desired to invite a specialist engineer from the time of arrival of the equipment until the perfection of the technology transfer.

2) Future vision beyond 1989

The given propositions are limited in rather narrow areas of 2 processes in the Workshop Dept. To evaluate another higher development of the existing excellent enterprise of CODELCO in the perspective future beyond 1989, following recommendations shall be given.

(1) Establish a survey group comprising Sales, Finance and Technology experts to analyze future vision of the Workshops Dept., Div. El Teniente. An overall aspect of the feasibility study might lead to another conclusion to inspire higher productivity, especially in the area of coordination and transportation between shops. The survey includes the future trend, in which the trend of the technical innovation of the world, economical growth and expansion and resulted labour cost increases and then, a policy of introduction of unmanned automation shall be discussed.

(2) A quality management expert shall be invited to develop the Motivation Program (ex. CODELCO Productivity Circle) of QA/QC Activity and QC Circle Activity and to excite decisively company-wide Motivation Activity.

1. INTRODUCTIONS

1 INTRODUCTION

1.1 Background of the Study

As part of an overall project for modernizing the Workshops Department of its Div. El Teniente, the Corporacion Nacional del Cobre de Chile (CODELCO) expressed its desire for a plan of Modernization to be drawn up centered around the Processes of Finishing in the Foundry and of Welding in the Plate Shop, forming part of the Workshops Department.

In response to the request addressed in this connection, Japan International Cooperation Agency (JICA) has entered in the implementation of the technical assistance, the JICA sent a preliminary survey mission to the Republic of Chile from Feb. 22, to Mar. 4, 1986 and between JICA and CODELCO, the Scopes of Works to be performed in carrying out the relevant survey was agreed upon on Mar. 3, 1986.

The Site Survey Mission sent by JICA visited the Republic of Chile from 28 June to 27 July, 1986 and discussed with CODELCO representatives the condition under which the Plan of Foundry/Plate Shop Modernization should be carried out.

The present Final Report on the Feasibility Study has been drawn up on the basis of the Progress Report and also through Japan-side domestic works.

1.2 Objectives of the Study

The envisaged Feasibility Study is to be undertaken with the objectives of studying the Foundry and Plate Shops in Div. El Teniente of CODELCO, to draw up and report on a Plan of Modernization of the two Workshops, based on technical, financial, economic and other considerations, with emphasis placed on the Finishing Processes in the Foundry, and on the Welding Process in the Plate Shop.

The study will be undertaken principally on the processes and departments agreed upon at the time of Preliminary Survey, through overall examination from both the technical and management aspects of:—

- Workshop equipment
- Production control
- Production processes

- Quality control
- work safety measures.

Suggestions and recommendations will be made, together with observations on points requiring to be heeded in implementing the Modernization Plan.

1.3 Scope of the Study

The study will cover the Foundry and Plate Shops of the Workshops Department, El Teniente Division of CODELCO, to examine the Finishing Process in the Foundry Shop and the Welding Process in the Plate Shop, as well as related domains. The items to be surveyed and examined are:—

- Workshop layout and arrangement
- Workshop equipment
- Workshop management and control
- Production techniques
- Safety in work
- Market demand (to serve in establishing production program).

The report covering the Plan of Modernization will include:—

- Required funds
- Program for personnel instruction/training
- Schedule of implementation
- Financial analysis
- Economic evaluation
- Conclusions and recommendations.

1.4 Methodology of the Study

To make sure of ensuring what is essential in planning a modernization project, i.e. of correctly grasping the root of current problems, surveys will be conducted integrally covering all aspects including (a) quality, (b) cost, (c) delivery on schedule, (d) safety in work, and viewed from all angles including (a) management, (b) equipment, (c) technical capability, (d) engineering management, (e) materials, (f) instruction and training. The resulting information and data will be analyzed to pinpoint the basic factors currently impeding smooth production; the items calling for improvement will be enumerated, and their order of priority given, to serve in drawing up the Plan of Modernization.

The financial analysis will be performed by Discounted Cash Flow Method, to derive the Internal Rate of Return (IRR). The economic evaluation will be discussed in the light of the position occupied by the Workshops Department in the Div. El Teniente of CODELCO, i.e. as a service facility with the mission of satisfying the needs of the Division with its manufacturing services. In full awareness of the future possibility of products from the Workshops coming to be supplied to other Divisions of CODELCO or to the general Chilean market, it was agreed that the present Feasibility Study will not be extended to consideration of such extended activities.

The question of safety control was a subject to which particular reference was made in the Scope of Works. The Survey will cover current conditions of work at the Foundry and the Plate Shops, as well as instruction and training programs immediately affecting employee discipline and motivation. Based on the findings, a comprehensive plan for improvement of safety at work will be proposed.

CODELCO is envisaging 1989 as final year of the Modernization plan. Finalization of the Feasibility Report being scheduled for March, 1987, commencement of investment in new equipment should only start in the beginning of 1988 at earliest: in order to accomplish CODELCO's intention by having the renovated Workshops attain full production rate during the immediately following 1989, all the requisite new equipment should require to be procured and installed in a single step as early as possible. To time in with the foregoing equipment installation, it should be well to undertake the concomitant programs for improving the managerial aspects and instruction/training schemes during 1987.

1.5 Constituents of the Survey Mission

JICA has assigned a survey mission headed by K. Chikaraishi and sent to the Republic of Chile from June 28 to July 27, 1986. Members of the mission are listed up in the Appendix.

The lists of the Chilean counterpart and the reference documents are also indicated in the Appendix.

2. CURRENT ASPECT OF EL TENIENTE DIVISION WORKSHOPS

2. CURRENT ASPECT OF EL TENIENTE DIVISION WORKSHOPS

2.1 Outline of Workshops

2.1.1 Historical background, location, environment

1) Historical background

CODELCO derives its origin from a number of U.S. copper concerns, which were nationalized in 1976 and integrated into a single State-owned and -operated enterprise. The El Teniente Division was originally run by Kenecot.

The El Teniente mine was first excavated in 1905. What eventually became the present Workshops were originally established in the early 1930's, as facilities for constructing and repairing equipment and machinery for mining, smelting, transporting and other operations associated with mining, and which were subsequently extended and improved in keeping with the expansion of mining activities.

2) Location

The Workshops are located within the premises of the El Teniente Division Head Office in Rancagua, about 80 km north of Santiago. Rancagua is situated in a basin surrounded by mountains and extending about 30 km north to south and about 15 km east to west. The city is served by the main highway and railroad traversing the length of the country, both lines of transport linking Rancagua directly with the Capital, from where other road and rail connections are available to the trade ports of Valparaiso and San Antonio.

The El Teniente mine and appurtenant facilities for ore concentration at Sewell and Colon, and for smelting at Caletones are located in the mountains about 40 km north-northeast of Rancagua, and linked by an expressway (see map in Fig. 2.1.1-1).

The El Teniente Division premises at Rancagua are situated in mid-city, close to the railroad station, and occupy an area of about 260,000 m^2, to constitute the sole large establishment in the city.

The Division comprises:—

- The Administrative Department exercising control over the entire division, and
- Workshops Department operating the manufacturing/repair shops serving the mining and ancillary operations of the Division.

The Workshops occupy about 60,000 m^2 of ground in the center of the Division's property (see Figs. 2.1.1-2 and -3).

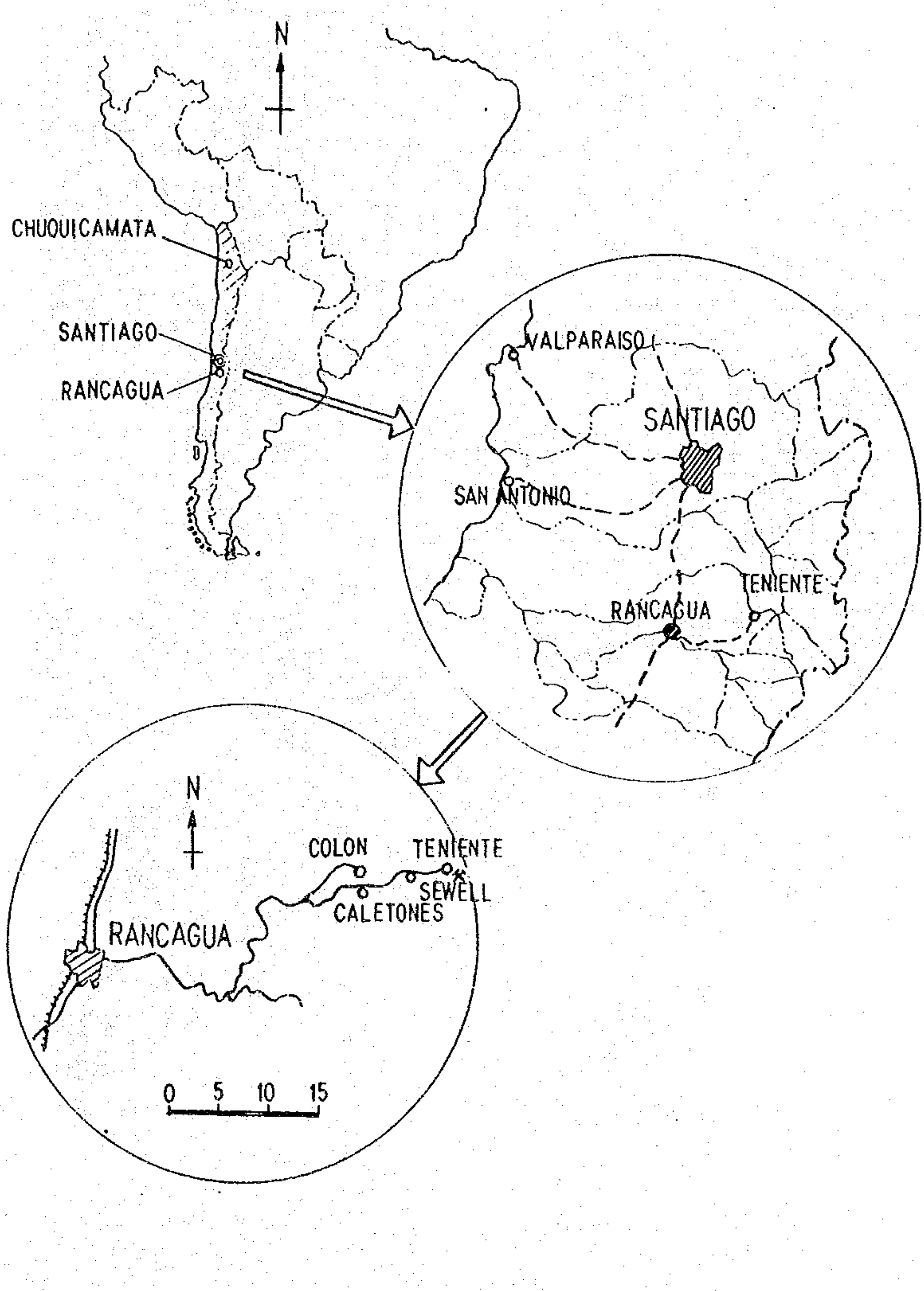


Fig. 2.1.1-1 Geographical location of El Teniente Division facilities.

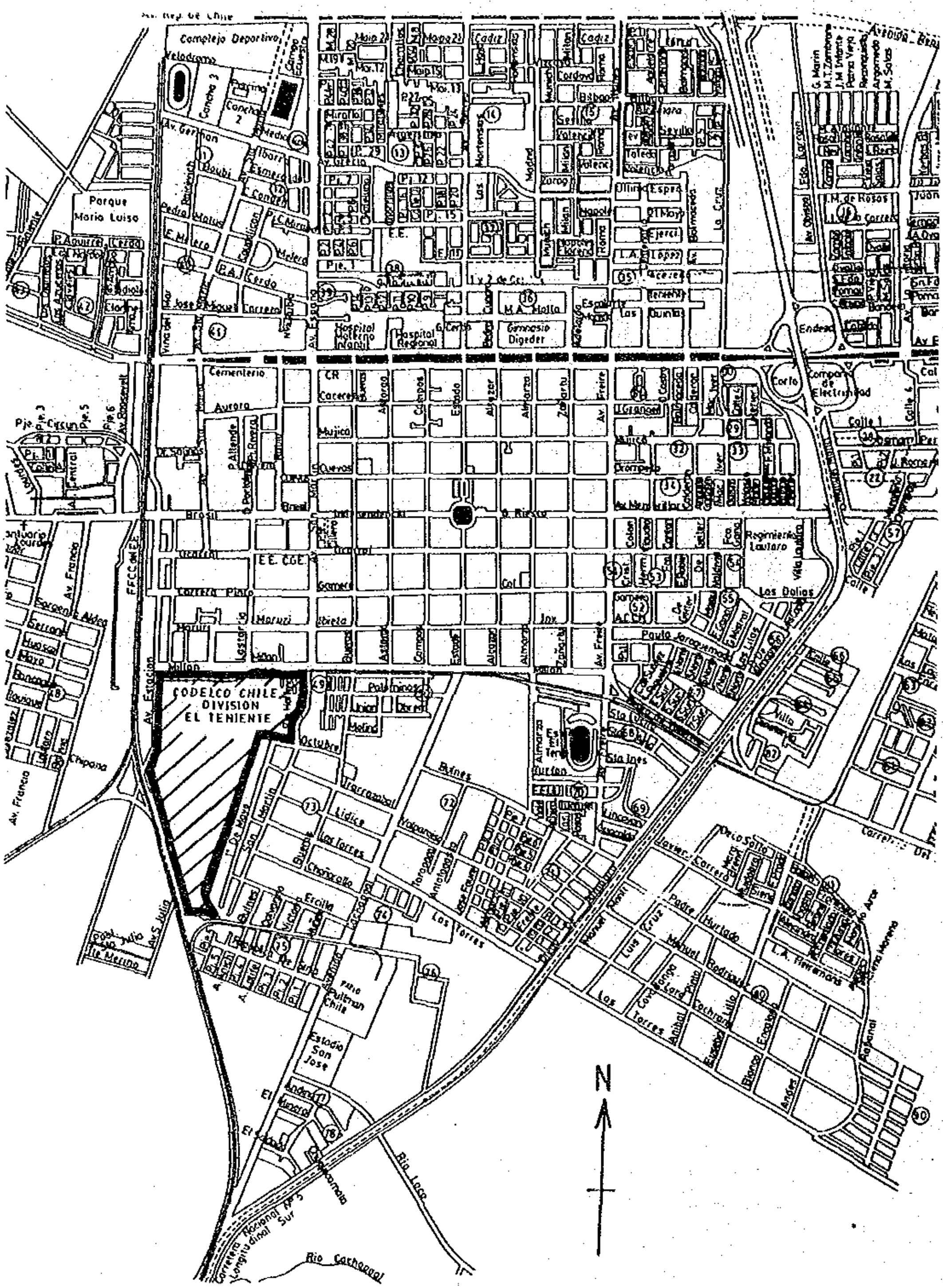


Fig. 2.1.1-2 Location of El Teniente Division in Rancagua

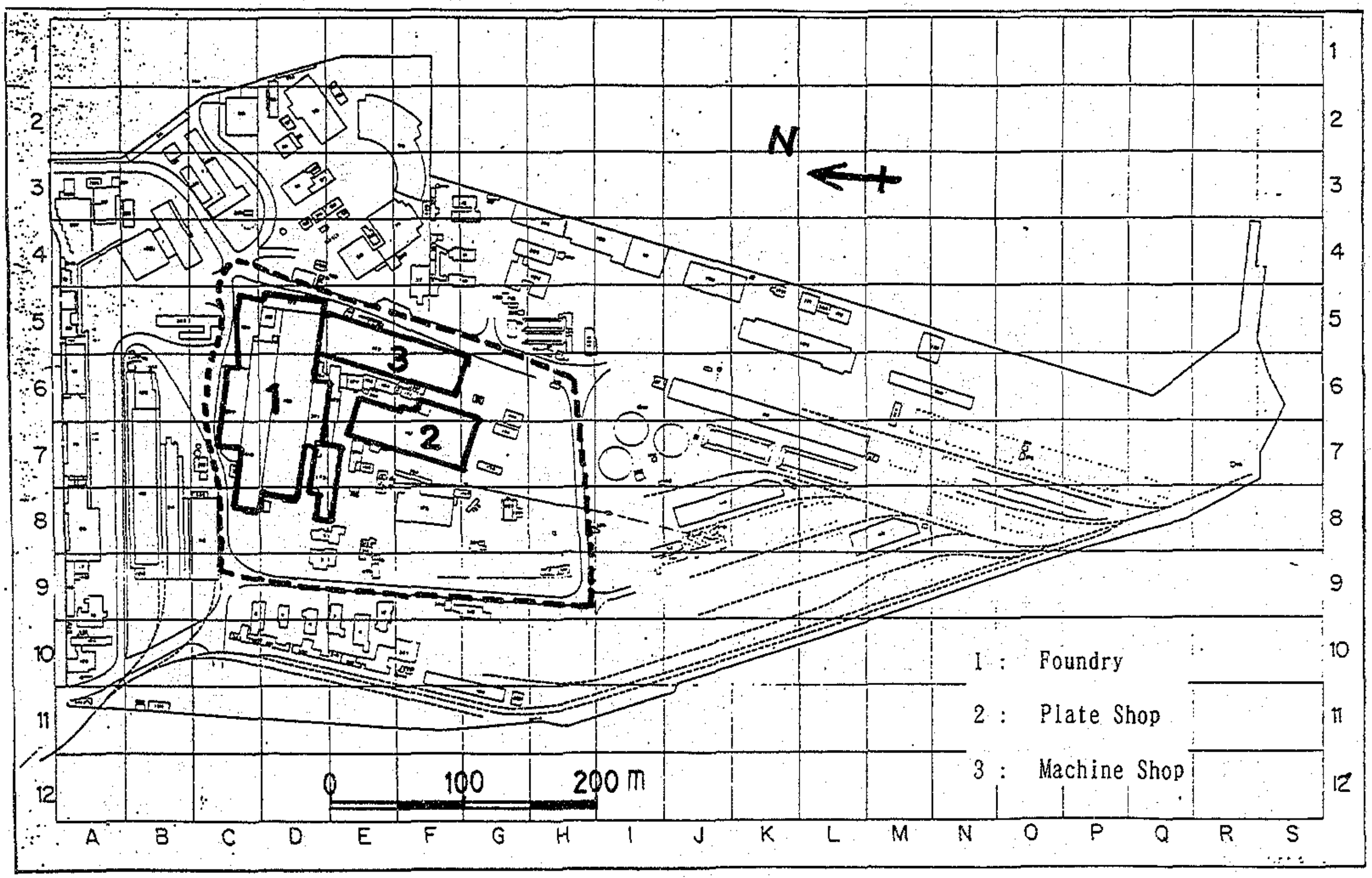


Fig. 2.1.1-3 Location of the Workshops Department within El Teniente Div.

2.1.2 Outline of manufacturing activities

The Workshops Department of the El Teniente Division includes Foundry, Plate, Machine and Repair Shops, of which the Foundry and Plate Shops constitute the objectives of the present study.

1) Foundry Shop

The products of the Foundry Shop are primarily components for mining machinery and equipment intended for use in the El Teniente Division, amounting to around 4,600 tons/year, or about 380 tons/month.

The function of furnishing consumable supplies and spare parts for manifold mining equipment inevitably calls for the manufacture of a multiformity of parts and pieces. The components produced in largest number include liner elements of crushers. Among other notable products are casings and impellers for pumps, brake shoes for ore cars, ladles for copper casting, gearing, axle shafts, furnace components, shield plates.

The product materials are principally cast iron and steel, mainly of abrasion-resistant quality.

All foundry processes—from pattern making to finishing and heat treatment—are performed throughout within the Foundry Shop.

2) Plate Shop

As in the case of Foundry Shop, the Plate Shop also serves almost exclusively the El Teniente Division with its products. These products include:—

- Welded articles, such as cars for carrying ore, and arches for supporting mine ceiling
- Wire mesh for ore sieves
- Forged gads
- Forged bolts for fixing liners
- Reinforcing bolts used in mine gallery.

Repair work by welding and overlaying is also undertaken, such as on crushers and associated equipment, and on large ladles.

The materials welded are mostly ordinary mild, and 50 kg/mm^2 class high-tensile steel. Some work has been done on T-1 steel imported from Brazil.

Production of mine gallery supplies and welding repair work provide a fairly constant work load, but welded articles, with the exception of support arches, are manufactured on order from the Division in small lots, and cover every description of welded products—from ore cars and flotation equipment to buckets for shovel cars. The precludes possibility of drawing up production programs in advance.

Yearly production of the Plate Shop totals 3,000 to 3,600 tons, or 250 to 300 tons/month.

2.1.3 Outline of facilities

1) General

The Workshops comprise:

(a) Foundry shop
(b) Plate shop
(c) Machine shop
(d) Repair shop,

as well as outdoor scrap yard, material store-yard, and depository for articles to be repaired (see Fig. 2.1.3-1).

As already mentioned earlier, the establishment dates back many years: Most of the buildings were constructed in the 1930's, and were successively extended to keep with the progress of mining activity. Much of the equipment has seen 30 to 40 years of service.

Having thus developed and grown with the progress of the El Teniente Division, in a location bounded by the administrative buildings of the Division, the present layout of the Workshop buildings, facilities, yards and roadways has come to be far from ideally functional for the flow of materials and operations in the production process.

For instance, in the foundry shop:—

- Shortage of available space has resulted in the melting line and the medium size molding line coming to be located incommodiously close to each other.

- Heat treatment furnaces are scattered far and wide, requiring wasteful distances to be traversed by the pieces to be processed.

- The scrap yard is located inconveniently far from the melting furnances.

In the Plate Shop:—

- The Paths of incoming materials and outgoing products coincide, and in general, the roadway network is incommodiously intricate, to obstruct smooth traffic and efficient transport.

What is more serious, however, is the rapid progress seen in recent years of the product sizes, which has led to work pieces exceeding the capacity of cranes requiring to be manufactured and repaired, with consequent occurrence of crane overloading, and of welding operations having to be performed under unsuitable conditions in the Machine Shop premises.

Such instances of incommodious conditions of work, with inevitably attendant poor efficiency and compromise of work safety, have undermined the laudable efforts of the El Teniente Division management in introducing modern equipment such as eye tracer and machining center—both equipped for numerical control.

What is of primary urgency is to enhance the overall efficiency of manufacturing operations through rationalization of the entire Workshop layout, renewal of key facilities, and strengthening of the material handling equipment.

2) Foundry Shop

The Foundry Shop is provided with equipment for:

(1) Pattern making
(2) Sand preparation
(3) Molding
(4) Melting
(5) Pouring
(6) Finishing
(7) Quality control.

The currently existing equipment is described in detail in 2.4.1, and listed in Table 2.4.1-1. Key equipment includes:—

- For pattern making: Lathes, milling machine, planner, band saws, circular saw, sanding machines, drilling machines, ...
- For sand preparation: Set of equipment for green sand
- For molding: Jolt-squeeze molding machines, motive type sand slinger, portable electric dryers, large molding pits
- For melting: Heroult furnaces, induction furnace, crucible furnaces, ladles
- For finishing: Swing grinders, double-disk grinders, shot-blast machines (table, drum), gouging machine, welding machines, heat-treatment furnaces

- For quality control: Set of metal testing equipment, set of chemical analyzing equipment, set of molding sand testing equipment, set of nondestructive testing equipment.

The foregoing foundry equipment permits all the processes from patternmaking to the final product to be undertaken within the premises.

The currently existing equipment is described in detail in 2.4.1, and listed in Tables 2.4.2-1 to -4. The key equipment includes:—

- For cutting: Vertical band saw, sawing machine, shearing machines, nibblers, automatic gas cutting machines
- For drilling: Radial drilling machine
- For plate bending: Press brake, bending rollers, angle bender, horizontal straightening press
- For welding: Semiautomatic Welding machines, AC manual Welding machines, rotating Positioner, turning rollers
- For wire mesh manufacturing: Set of automatic net-weaving equipment
- For forging: Bolt forging machine, hammers, heating furnaces, set of threading equipment, wall cranes.

No.	Item
①	Road
②	Offices
③	Pattern Shop
④	Sand Shop
⑤	Moulding Shop
⑥	Melting
⑦	Finishing
⑧	Machine Shop
⑨	Maintenance Shop
⑩	Plate Shop
⑪	Electric Shop
⑫	Storage Yard of Plate Shop
⑬	Scrap Yard

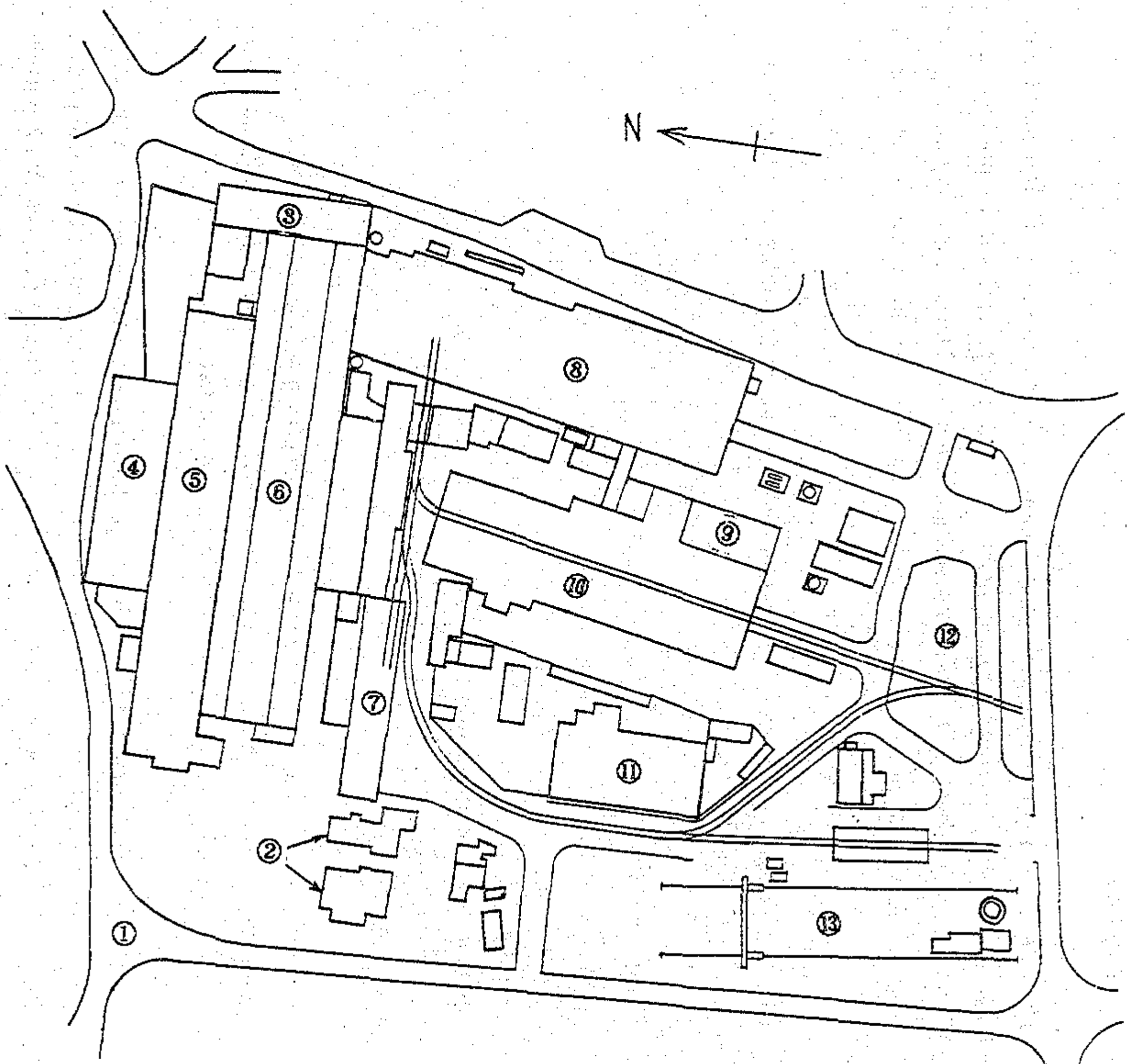


Fig. 2.1.3-1 General Arrangement of Workshops Department

2.1.4 Outline of engineering capability

1) Foundry Shop

The Foundry Shop serves the mission of manufacturing and furnishing replenishment and consumable parts for copper mining machinery and equipment, and its products are chiefly iron and steel castings of abrasion-resistant property. The Foundry equipment, as well as its engineering capability is thus intrinsically centered around the production of such castings.

The engineering capability of the Foundry Shop will be discussed below in the order of the flow of work through foundry, i.e.—

- Patternmaking
- Molding
- Melting
- Finishing
- Quality control and product quality.

(1) Patternmaking

Patterns are made to suit their use—for hand or machine molding. The patterns are mostly of wood—principally white pine. White pine is easy to work, and little liable to warping, and thus quite suitable for normal patterns.

The procedure to be adopted in the pattern-making work is not all indicated in the relevant drawings, but in the case of patterns of new type and which should present difficulties, the drawings give indications on risers and parting surfaces. With particular respect to trial models, drawings containing detailed work procedures are issued by the Engineering group.

Patterns are made with pertinent instructions given by skilled workers based on their experience extending over more than 10 years. The patterns produced are finally inspected in reference to relevant drawings. No inspection records are prepared, but check indications are made on the drawings. Dimensional measurements are performed mostly using shrinkage scale.

(2) Molding

Both hand and machine molding is practised. Green sand is mostly employed, facing and backing sands being used separately. Apart from normal silica sand, olivine sand is used for high-manganese castings, and in part zirconium and chromite sands for special purposes.

Cores are made mostly of green sand and constant use also being made, in part, of special sands for cold box molding. Large hand-rammed molds are of green sand. These molds are formed by circular strickling, and by pattern, without rolling over.

The largest castings produced measure 3,600 mm diameter, and weigh 23-tons. The mold is set in a large pit measuring above 5 m×5 m. Small and medium castings are machine-molded using jolt-squeeze type machines.

(3) Melting

A Heroult arc furnace is used for melting both iron and steel; Ni-hard is melted also in induction furnace, copper alloys in crucible furnace.

The ladles for receiving the molten metal range from 800 kg to 14 ton capacity—all of top pouring type. The ladles are preheated by oil burner.

Of the three Heroult furnaces, one is of fixed-roof type, charged from side, and the other two of top charging type. Side-charging is more time-consuming.

(4) Finishing

The castings are removed from mold by shake-out machine; manual operation is also practised on occasion. Fettling of ordinary steel castings is by oxyacetylene torch, for removing risers, runners, gates, ...; certain alloy steels liable to crack are fettled by grinder cutting. On iron castings, risers are knocked off by hammer.

Rough finishing is done by swing grinder: Efficiency is poor, on account of the outdated equipment.

Heat treatment of steel castings is applied in manner adapted to the particular grade of material: High manganese steel is quenched in a water bath installed close to the heating furnace.

Upon finishing, the products are inspected by the Quality Control group.

(5) Quality control

For controlling the quality of molding sand, a complete set of testing equipment is available.

Analyses of molten metal and of casting composition are conducted by a set of requisite analyzing equipment. The mechanical properties of product castings are determined by appropriate testing machines.

Certain products like liners are inspected radiographically for internal defects.

(6) Level of casting product quality

The reject rate of castings has averaged 6 to 8% in past years—4 to 5% for steel and 8 to 14% for iron castings—with appreciable variations from one year to another.

The most common defects are shrinkage cavities and cracks.

2) Plate Shop

The Plate Shop manufactures and repairs mining machinery and equipment, almost exclusively for the El Teniente Division. One consequence of dispensing with consideration for producing commercially marketable goods is attention directed mainly toward ensuring adequate product strength, with rather little heed to the external appearance of products.

An evaluation of technical level is presented in what follows, process by process.

(1) Marking, cutting

Marking is undertaken by skilled workers, based on the detail drawings issued by the Engineering group, followed by gas cutting.

Two eye tracers are used for performing long parallel cuts, for mass cutting of identically shaped plates, and for cutting out complex shapes. The unit newly acquired this past April is a high-performance machine embodying numerical control, and capable of cutting pieces measuring up to 3.0 m×3.0 m×200 mm thick. Other pieces are cut by portable automatic cutters.

The cut edges have been observed to be rather rough, and intersperced with notches. Even accounting for a recent conversion from 60 to 50 Hertz made on the power source following damage to the electric power system sustained from heavy rain, the performance is far too poor. Considering the amount of work wasted in grinding the edges to shape and the consequent lowering of work efficiency, as well as the detrimental effect on product quality, radical improvement of the gas cutting technique would appear to be called for—with particular respect to cutting speed, gas pressure adjustment, choice of cutting torch, and to standards governing cleanness.

(2) Drilling, bending

Drilling and bending prior to assembly in readiness for welding are performed using appropriate equipment such as radial drilling machine and press brake or bending roller.

During the Site Survey, bending was in progress on a 35 mm thick plate using the press brake, which happened to suffer cracking. Upon examination of the workpiece surface, the leading edge was found not to have been chamfered. Also, the die used for bending was provided with excessively small round-off radius, and the workpiece surface was bestrewn with innumerable scratches. It is an instance that evidences insufficient considration given to selection of the correct die, in respect of such matters as round-off radius matched to material properties and plate thickness, indicating that the available equipment is not being used to best effect.

(3) Assembly, mounting

Observation of assembly and mounting operations being performed at the time of Site Survey impressed the Survey Team members with the experience and skill with which the workers on shop floor put together an ore car—a product of fairly complex structure.

Room for improvement, however, still exists in certain details, such as welding gap provided at assembly, which exceeded 10 mm at some points. This can be a cause of poor welding efficiency and weldment quality. Such deviations will likely prove more troublesome when robotized welding machines are introduced.

Better accuracy in assembly/mounting should be strived after.

(4) Welding

Welding in flat position is performed by semi-automatic welding machine. In all other positions welding is performed manually. The degree of automation attained would be around 35% in terms of the quantity of weld material consumed, but in terms of manhours, not more than, say 10% of the work would appear to have been automated.

The equipment for welding includes:—

- Positioner
- Turning rollers
- Manipulator (homemade).

Efforts to make the most effective use of available means were manifest. Considerations for improving the working environment were also noted in such aspects as welding fume abatement, with almost all welding posts provided with dust collecting device.

The shielded arc welding rods used are mostly of low hydrogen quality (AWS E7018), and yet no consideration at all was observed to be given to drying the welding rods before use: The rods delivered from supplier were seen stored bare in warehouse, and issued without further treatment. At worksite, the welding rods are treated deplorably: Unused rods are strewn all over the floor, trodden over and their coated flux torn off.

Good welding work could not possibly be expected from such careless treatment of welding rods: A general awakening to the care requiring to be taken of welding rods for doing good welding work is a matter to be given foremost priority in welder instruction/training.

Improvements on such basic matters should contribute decisively to enhancing productivity and product quality in the Welding Process, since many of the welders were seen to possess experience and skill that would pass muster on the international scene, and since consistent efforts are being applied to maintain and enhance welder skill, with qualification tests regularly administered since last year.

2.1.5 Corporate organization

The Corporacion Nacional del Cobre de Chile—CODELCO—was established in 1976, to take over and unify the activities of 5 independent nationalized copper enterprises. What was undertaken by the 5 enterprises is today carried on by the 4 CODELCO Divisions of Chuquicamata, Salvador, Andina, and El Teniente.

The 4 Divisions are operated autonomously in respect of their productive activities, with the Head Office taking charge of such matters as establishing corporate policy, commercialization of the Divisions' products, deciding the corporate program of production and investment, and the financial aspects of corporate business.

Available data for 1983 indicate that, at that time, the CODELCO personnel numbered 25,924, of which 38% worked in the Division of Chuquicamata, 18% in Salvador, 7% in Andina, 34% in El Teniente, and 3% at the corporte Head Office.

The upper organizational structure of CODELCO is reproduced in Fig. 2.1.5-1, and the progress to 1983 of corporate personnel size in Table 2.1.5-1.

The El Teniente Division—subject of the present Plan of Modernization—originated in 1905 in a mine first excavated by Braden (U.S.), which became a subsidiary of Kenecot in 1915, and was nationalized by the Chilean Government in 1967, to become one of the 4 Divisions of CODELCO upon its establishment in 1976.

The Division operates the El Teniente Mine, together with the facilities for ore concentration at Colon and Sewell, and for smelting at Caletones. Ancillary services include the Workshops—subject of the Modernization Plan—as well as the groups charged with transport and construction. Other groups are charged with procurement, engineering, personnel administration. The total personnel numbers 8,952.

Table 2.1.5-1 Annual transition of CODELCO personnels

unit; person

1976	1977	1978	1979	1980	1981	1982	1983
30, 948	30, 765	30, 920	30, 799	30, 146	29, 308	26, 756	25, 942

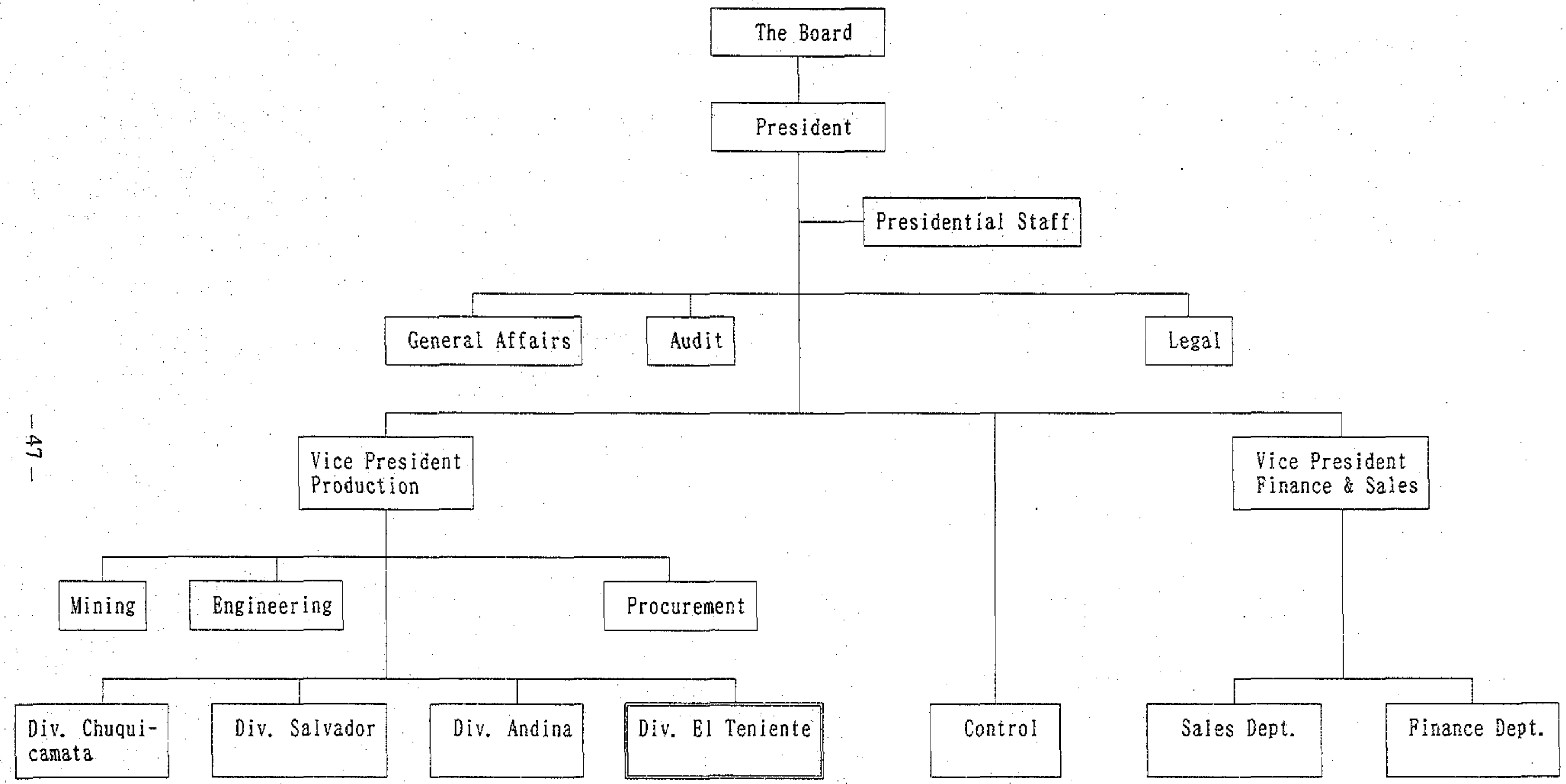


Fig. 2.1.5-1 Organization of the CODELCO Head Quarter

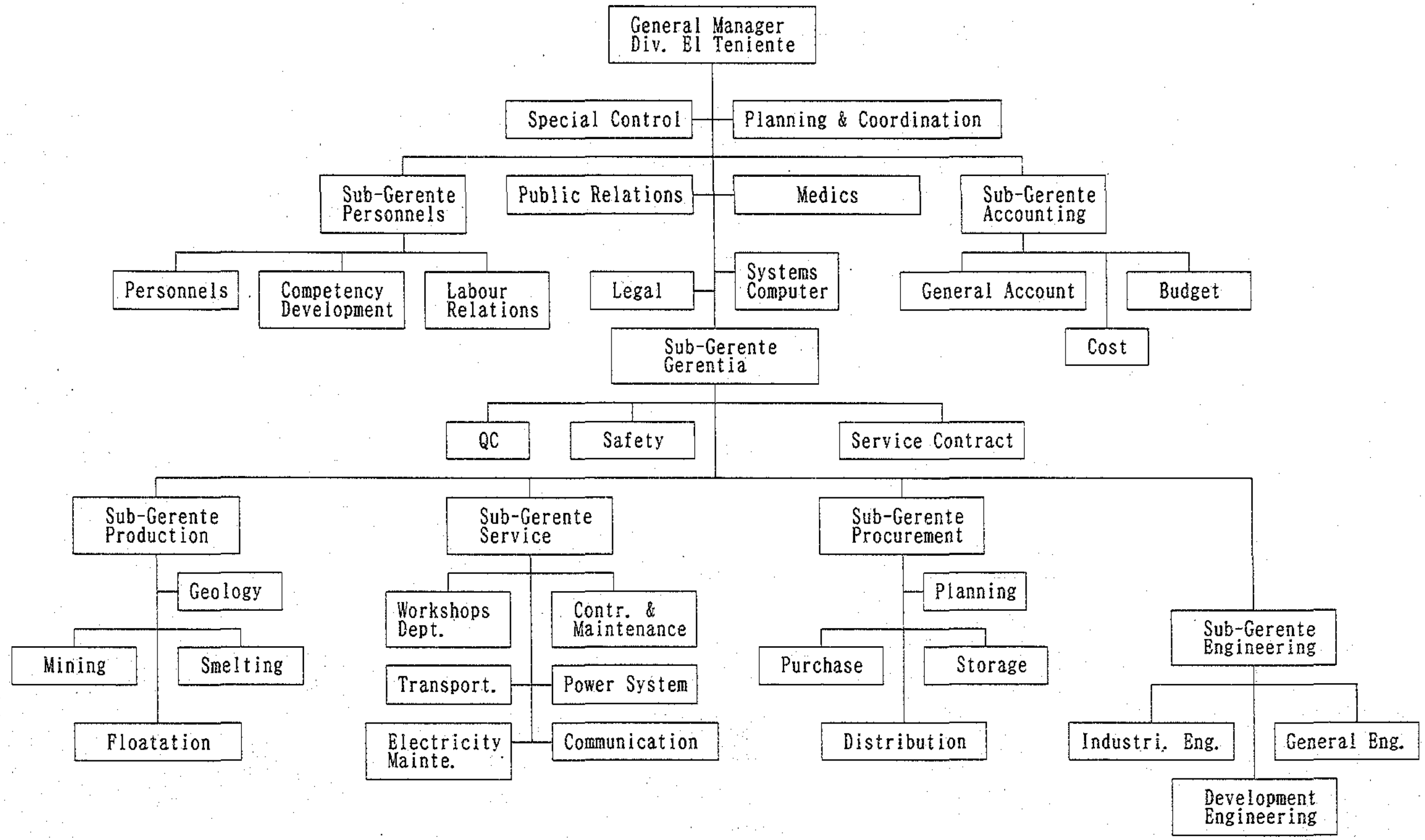


Fig. 2.1.5-2 Organization of Div. El Teniente

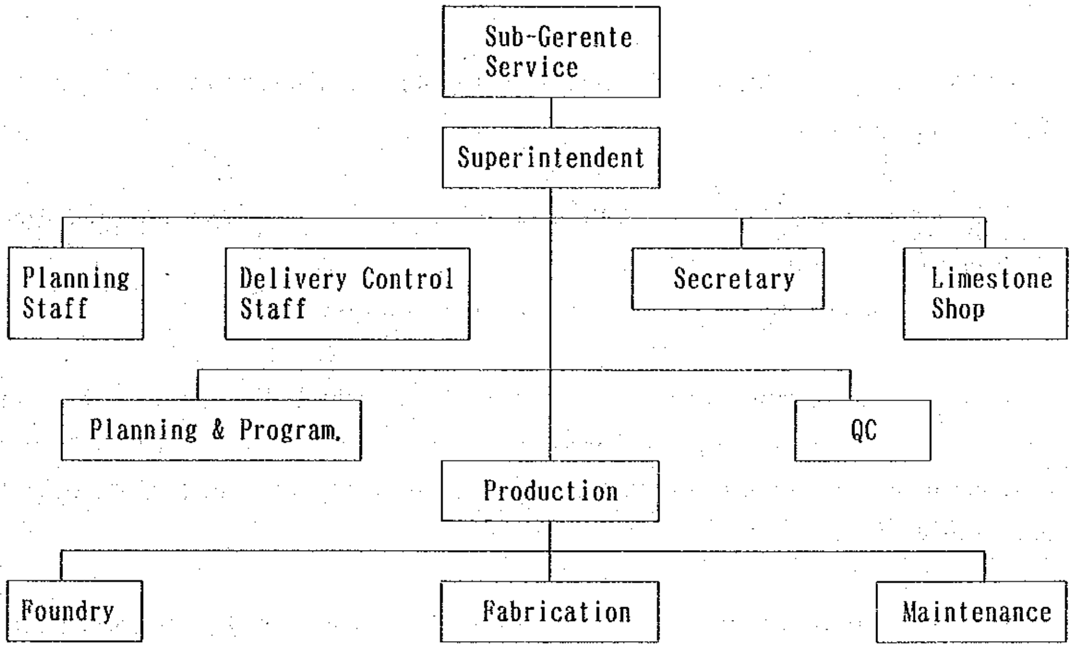


Fig. 2.1.5-3 Organization of Workshop Department

2.1.6 Instruction and training

The basic principle underlying instruction and training administered in CODELCO is to impart to employees—

- The technical knowledge and skills required by employees in their respective functions
- The qualification necessary for advancing to superior positions.

To this end the department charged with Personnel Capability Development draws up the instruction and training programs based on the requirements submitted from the relevant departments, to organize courses for employees—ranging from key Division officers to shop floor workers.

The trainees not only follow courses held within the premises, with instructors chosen from Division personnel, but may also be assigned to follow courses organized outside—in universities or at INACAP (National Institute for Capability Development).

Examples of subjects treated include:—

- Application of minicomputers to the solution of engineering problems
- Programming and control of numerically controlled machines
- Quality control techniques
- General notions of foundry practice
- Welding methods
- Various aspects of administration and management.

In addition, seminars at universities are attended, while assignments for instruction and training in foreign institutions are also given, e.g.:—

- For visits to advanced centers of machining work, to be trained in machining, on new materials and products
- For attending courses in computer programming and system operation.

Instruction/training courses are systematically organized under the initiative of the Personnel Capability Development department. During 1986, the programs covered in all 32,932 hours, with the cumulated participation of 11,292 employees, for a total employee force of 8,654. For the total volume of 17,441,064 hours worked during the same year, the above instruction and training work represented 1.89%, which is close to the 2% approved by the United Nations.

2.2 Productive Activities

2.2.1 Foundry Shop

Most of the castings produced at the Foundry Shop are intended for use in the El Teniente Division—equipment, spare parts and consumables for copper ore excavation, crushing, concentration and smelting.

1) Articles produced

Representative among the multifarious items produced at the Foundry Shop include:—

- Ore crusher components =
  = For primary crushers: Liners, mantles
  = For secondary crushers: Liners for ball and bar mills.
  These liners are consumable, and constitute the staple product of the Foundry Shop.

- Pump components =
  = Casings
  = Impellers
  = Guide vanes

- Smelting equipment components =
  = Ladles
  = Slag pots
  = Converter spouts

- Ore car components =
  = Brake shoes
  = Wheels

– Transmission gearing components =
  = Gear wheels
  = Pinions
  = Bearing boxes
  = Shafting
  = Bushing

– Other articles =
  = Water turbine nozzles and other components
  = Rock drill blades and other components
  = Ore concentration buckets and other components.

2) Casting sizes

Casting sizes range from less than 1 kg to over 20 tons. The articles most commonly produced—crusher liners—measure 1,000–1,200 mm×300–400 mm, and weigh 100–400 kg. The largest castings are ladles, which have significantly grown in size in recent years, and have come to reach 3,600 mm in diameter and 2,600 mm high, to weigh up to 23 tons.

3) Casting materials

The castings produced are mostly steel and iron; some copper alloy castings are also produced.

Apart from ordinary iron and low-alloy iron castings, the fact that the products are intended for use in mining equipment results in their being in large portion of abrasive-resistant grade.

Representative products are:—

– Steel castings:
  Mostly high-carbon alloy steel.
  Other grades include =
  = High-manganese
  = Carbon steel.

Some steel castings are also produced in stainless and heat-resistant grades of steel.

- Iron castings =
  = High-chromium
  = Ni-hard.

Some iron castings are also produced in low-alloy and ordinary iron.

4) Production

The quantities of castings produced during the past three years have progressed as given in Table 2.2.1-1.

Table 2.2.1-1 Quantities of castings produced during past 3 years

Unit: Tons

	1983	1984	1985
Steel castings	3,193	3,286	2,321
Iron castings	1,250	1,356	2,136
Copper alloy	111	89	134
T O T A L	4,551	4,741	4,621
Monthly average	380	395	385

From Table 2.2.1-1, the yearly average production is around 4,600 tons, or about 380 tons per month.

The proportion between steel and iron castings, which was roughly 70:30 in 1983, is seen to have shifted to around 50:50 in 1985. While the inherent mission of the Foundry to fill orders from the mine should inevitably result in wide fluctuations from year to year of production items and materials, it can be expected that liners, which would tend to be consumed in increasing quantity, should maintain the tendency to raise their proportion in the coming years, to keep enhancing the percentage contributed by iron castings.

The quantities cited in Table 2.2.1-1 are regrouped by kind of product in Table 2.2.1-2. From this table, it is indicated that, in 1985, 60% of castings were intended for crushers—liners and other parts.

Table 2.2.1-3 represents a breakdown in further detail of Table 2.2.1-1. It shows that, again for 1985, 70% of the steel castings were contributed by abrasive-resistant steels (high-carbon and high-manganese). As for iron castings, 85% was high-chromium.

Copper alloy castings contributed barely 3%. The articles were bushing and sleeves; small articles are subcontracted out.

Table 2.2.1-2 Quantities of castings produced—by kind of product

Unit: Tons

	1983	1984	1985
Liners for ball/bar mills	2,150	2,392	2,319
1ry/2ry crusher components	462	520	562
Bearing supports/bushing	180	150	163
Gearing. shafting	212	196	223
Brake shoes, bearing housings	163	130	90
Pump components	182	191	210
Turbine components	80	80	87
Ladles, buckets, converter components	356	405	370
Shield plates, miscellaneous articles	766	677	597
T O T A L	4,551	4,741	4,621

Table 2.2.1-3 Quantities of produced of castings—by material

A. Steel castings

Unit: Tons

	1983	1984	1985
Ordinary steel	465	478	375
Low-alloy steel	280	161	107
High-carbon abrasion-resistant	1,731	1,784	1,049
High-manganese	508	721	622
Low-carbon martensite stainless	93	73	51
High-carbon ditto	92	47	76
Austenite stainless	20	12	28
Heat-resistant	4	10	13
T O T A L	3,193	3,286	2,321

B. Iron castings

Unit: Tons

	1983	1984	1985
Ordinary iron	122	88	83
Low-alloy, ductile, martensite	81	72	98
Ni-hard ("DURTEN")	562	133	56
High-chromium	484	1,059	1,813
High-alloy special grade steel	1	4	86
T O T A L	1,250	1,356	2,136

C. Copper alloy castings

Unit: Tons

	1983	1984	1985
Bronze alloy	111	89	134

Records are kept of product sizes distinguished in 3 categories of casting sizes:

A: Below 20 kg/piece
B: From 20 to 100 kg/piece
C: Above 100 kg/piece.

The record covering the period September to December 1985 is reproduced in Table 2.2.1-4, revealing the average unit weights of the castings produced of Categories A, B and C to have been respectively 7.7, 56 and 443 kg. Table 2.2.1-5 gives the figures for the same period converted to monthly averages, with additional data on the percentages contributed by each size category, both in terms of number of pieces and of weight. It is seen that, in terms of weight, castings of size category C represent a preponderant portion of 92%, betokening the large share of liners among the products of the Foundry Shop, and the Shop can thus be regarded as a facility devoted to producing relatively large castings.

Table 2.2.1-4 Castings produced—by size category (September—December 1985)

Unit: kg

SIZE CATEGORY	Numb. of pieces produced (kg)	Total quantity (kg/piece)	Aver. weight
A: 20kg ea.	2,518	19,346	7.7
B: 20 - 100 kg ea.	2,291	128,254	56.0
C: 100 kg ea.	3,692	1,635,832	443.0
T O T A L	8,501	1,783,432	210.0

Table 2.2.1-5 Castings produced—by size category—monthly averages

Unit: kg

SIZE CATEGORY	Numb. of pieces	Tot. qu'ty produced (kg)	Average wt. (kg/piece) of pieces	Percentage by number (%)	Ditto by by weight (%)
A: 20kg ea.	630	4,837	7.7	30	1
B: 20 - 100 kg ea.	572	32,063	56.0	27	7
C: 100 kg ea.	923	408,958	443.0	43	92
T O T A L	2,125	445,858	210	100	100

2.2.2 Plate Shop

Most of the products of the Plate Shop are intended for use in the El Teniente mine and ancillary or concentration and smelting facilities—including equipment, spare parts, replacement components.

1) Articles produced

Representative among the multifarious items produced at the Plate Shop are described below. Other articles produced, that do not involve any welding work—reinforcing bolts for mine gallery, wire meshing for ore sieves, gads produced by forging, liner fixing bolts—are omitted consideration in this Study.

(1) Weld-assembled structures

a) Ore cars

Bogies are imported from Brazil; ore boxes are fabricated by welding together steel plates; the cars are assembled, packed, painted, test run, and shipped out.

Manufacture started in 1985, since when, 11 out of a total order for 16 100-ton cars (steel structure weight 23 t) had been completed at the time of Site Survey, the 12th car was being welded, the 13th being assembled, and the remaining 3 still to be fabricated.

Already completed and shipped were 11 25-t cars (9.3 t steel structure).

No orders are currently on hand for further cars to be manufactured for the time being.

b) Gallery support arches

Arches for supporting mine gallery can be expected to see constant orders for manufacture. The current rate of production is 200 per month of arches each weighing 180 kg.

The arches present a cross section measuring 187 mm deep×8 mm thick and 200 mm wide×12 mm thick. A corresponding product could be manufactured at appreciably lower cost by adopting an H section of similar strength, but the current built-up design has been chosen with the view to utilizing domestically available material (H sections not produced in Chile).

c) 1,500 ft^3 flotation equipment

The driving motor and pump impeller are imported; the tub is fabricated, the equipment assembled together, and shipped.

No manufacture was in progress at the time of Site Survey, nor any orders on hand.

d) General welded structures

Spot manufacture of relatively small welded structures is undertaken on order for the El Teniente mine. Articles of this category currently being manufactured include hoppers, shovel car buckets, pipe-structure ladders measuring 2 m×300 m wide.

(2) Repair work by overlay welding

a) Worn parts of crusher components

Orders for repair are received almost constantly, with tendency to increase. Components subject to repair of worn parts are mostly crusher components— head, bowl, adjustment ring, main frame, ...

b) Ladles

Ladle parts eroded by melt also are regularly required repair by overlay welding, and the demand can be expected to continue.

The large 23-t ladles are not repaired at the Welding Shop, being too large for the cranes available at the Shop: They are sent to the Machine Shop for repair.

A sample record of production at the Plate Shop is presented in Table 2.2.2-1, covering the past 3 years; Table 2.2.2-2 similarly summarizes the welding repair work performed at the same Shop.

2) Product sizes and materials

In Principle, the size of articles manufactured at the Plate Shop is limited by the available cranes: The 2 cranes—1 each of 5 and 10 tons capacity—would only permit lifting up to 15 tons, working in tandem, but there has been a case of an 80-ton cylindrical structure measuring 17 m×4 m diameter, being fabricated, utilizing the rail track traversing the Shop, with the workpiece mounted on dolly, and by welding together 7 pre-assembled segments each 2.5 m long.

Almost all the raw plating material used is furnished from the domestic Comp. Acero del Pacifico, in the specifications given in Table 2.2.2-3. The material of articles repaired by overlay welding is as given in Table 2.2.-4.

Table 2.2.1-7 Production Record of the Plate Shop

unit: Ton

	1983	1984	1985
Welded Structure	1,289	1,332	1,049
Hard-Facing, Recuperation.	530	179	379
Bolts (Underground Mining)	522	1,972	1,509
Forgings	256	166	101
Sum.	2,597	3,649	3,038
Monthly	216	304	253

Table 2.2.1-8 Recuperation Records of Past 3 Years

	1983	1984	1985
Crusher Main Frame	2	2	4
Adjustment of Ring	4	2	6
Bowl	1	1	2
Head	10	6	10
Ladle	8	4	6

Table 2.2.1-9 Steel Material

Standard	Chemical Composition (%)					Mechanical Properties		
	C	C+1/6 Mn	P	S	Si	TS kg/mm²	YP kg/mm²	EL %
A37-24ES	0.20	0.40	0.04	0.05	0.30	37	24	24
A42-27ES	0.20	0.42	0.04	0.05	0.30	42	27	22
A52-34ES	0.20	0.43	0.04	0.05	0.60	52	34	20

(July 1976) (CAP)

Table 2.2.1-10 Materials of Welded Recuperations

Standard	Chemical Composition (%)						Hardness (NDB)
	C	Mn	Si	Cr	Mo	Si	
ASTM A-27 Grade 70-36 or 80-50	0.20~ 0.35	0.60~ 1.00	0.25~ 0.60	−	−	−	143~187

(Instruction Book of Repair Works for Crusher)

2.3 Current Shop practices

2.3.1 Foundry Shop

1) Engineering/work standards

Upon inquiry at site, no written standards were found covering the practical work procedures to be followed in any of the processes in Foundry work. It is difficult to believe that no such standard exists at all, but on the other hand, the fact that much of foundry work is repetitive is liable to lead shop floor personnel to consider their work to be more properly learned by practice, and that written standard work procedures could well be dispensed with.

It should however be noted that foundry operations largely depend on work in team, which calls for the team members to posses a common basis of skill and capability, and it should be useful and necessary first to compile an objective description of the operations constituting the current normal foundry practice. Such a written description should serve as basis for considering improvements in the work procedure, which should be constantly sought.

2) Casting plans

Casting plans—indicating the gating system to be adopted—are a criterion for judging the engineering capability of a foundry. A foundry where sound casting plans are drawn up can generally be expected to possess high engineering capability, and to operate on systematic principles.

At El Teniente, casting plans are established by the Engineering group for trial models, but for normally produced castings, the gating system is left to the judgment of the patternmaking shop, which consults the molding shop on occasion.

It is advisable to have casting plans drawn up for all castings.

3) Patternmaking

The patternmaking shop at El Teniente is well equipped, and manned by personnel of fairly high experience and skill. The technical capability for patternmaking can all in all be considered ample for the patterns used in the Foundry.

(1) Wood used for patternmaking

The wood used for patternmaking is 60 percent white pine imported from Canada, and the balance domestic wood. The white pine appears to be a wood free of knots, deforming little after shaping, and ensuring good yield. In respect of plywood, and stout boards exceeding 25 mm in thickness are used for machine molding boards, but are unfortunately not of water-resistant quality.

Metallic and epoxy resin patterns are also used, but not other resins like polystyrene and polyurethane foam. These latter materials have been tried, but found unsuitable for the castings produced, apart from difficulties presented in their molding technique.

(2) Indications to guide patternmaking

Casting plans are not drawn up for routine work, as already mentioned. The drawings received at the patternmaking shop do not give all pertinent indications such as the shrinkage scale to be used, finishing allowance, parting plane, risers, runners, gates, core prints and other pertinent items.

The Survey Team was given to understand that, if not otherwise indicated in drawings, a finishing allowance of 1/4" (6 mm) was invariably provided as accepted practice.

It is considered advisable to have the drawings carry all pertinent information relevant to patternmaking.

(3) Dimensional tolerance

No written standard exists on the tolerance allowed on deviations from drawing dimensions shown by the patterns. Where tolerances are given in the drawings, they are respected, but where not specified, the acceptance criterion is left to the judgment of the pattern shop.

(4) Actual size drawings

Drawings representing the actual size of the patterns are not always prepared, but when drawn, they may be on plank, plywood or paper.

In the case of trial models, the actual size drawings are preserved until the product casting is accepted. When drawn on plank or plywood, the lines are planed off after used, in readiness for reuse. Some of the drawings are preserved, but not all.

(5) Patternmaking

The type of pattern to be adopted is decided, and the mode of pattern assembly determined, these operations being undertaken by a maestro: No writhen or drawn indications are prepared; the maestro directly proceeds to making the pattern, based on his experience.

Hand molding is practised predominantly by solid pattern, with minimum use of cores. This applies, for instance, to the case of ladles and crusher mantles, and the practice appears to be based on the desire emanating from molding shop.

(6) Pattern inspection

Patterns are inspected by the Chief and his Assistant—the Supervisor—at the pattern shop.

The inspection is made in reference to drawings, but no check mark is left on the drawing to indicate that the check had been made. Some means needs to be adopted to mark off the dimensions that have been checked and found conformable, since inspection records are not compiled.

(7) Storing of patterns

Close to 30,000 patterns are said to have been made during the 30 years of Foundry Shop existence. The patterns are stored here and there, but judging from the samples shown to the Survey Team of the patterns in store, they are well arranged in good order, particularly the small patterns. Only some of the large and medium patterns appeared to need better arrangement. Catalogs of the stored patterns are also well maintained in the form of filed cards.

The stored patterns themselves are distinguished by colored lacquer—red for iron castings, blue for steel, yellow for nonferrous.

4) Molding sand

Green sand is used for both iron and steel castings, and for both machine and hand molding. Sand control is ensured by well-equipped relatively modern facilities occupying a space of 1,140 m^2, comprising drier for new moist sand, sand mixer, sand reclaiming equipment, silo, and other equipment.

The types of sand used include silica, olivine, zirconium, chromite. The silica sand is brought from coastal dunes in the vicinity of Cartagena and San Antonio, and arrives carrying 4–5% moisture. Monthly consumption is around 250 tons. The drier has a capacity of 2.5 t/h, and is thus being currently utilized only to 14 or 15 percent of capacity. The sand mixer is capable of dealing with 6 t/h of facing and 24 t/h of backing sand, and with 380 t/month of green sand being currently processed, the equipment is today utilized only to about 2/3 capacity, leaving ample margin for expansion.

Examples of blending ratio are reproduced in Table 2.3.1-1.

Table 2.3.1-1 Examples of molding sand blends

(Unit: % by weight)

INGREDIENT	TYPE OF SAND					
	Silica	Chromite	Olivine	Zirconium	CO2	Relleno
Sand -						
- Silica	85 - 90				85 - 90	85 - 90
Olivine #40			45			
- Ditto #70			45			
- Chromite #55/60		92.5				
- Zirconium				92		
Binder, Adhesives -						
- Silica flour	3 - 5					
- Bentonite	5 - 6	4.5-4.6	4.5-5.5	3.5-4.5		1 - 2
- KODLIH						2 - 3
- Dextrine	0.3-0.5	0.3-0.5				0.5 - 1
- Mogul				0.5-1.0	0.3-0.5	
- Water glass					10 - 15	
- Pitch					0.5-1.0	
Moisture	4 - 4.5	2.5-3.2	3.5 - 4	2.5-3.5		4.5-5.5

Table 2.3.1-2 Standard molding sand properties

	Moisture (%)	Permeability (AFS)	Compress. strength (psi)
1. Green sand (facing)	3 - 4.2	140 - 200	7 - 12
2. Steel casting (dry)	3.5 - 6	160 - 200	5 - 25
3. Ditto (facing)	3.5 - 4.5	115 - 165	8 - 10
4. Iron casting (facing)	3.8 - 4.5	155 - 230	15 - 18
5. Ditto (dry)	3.5 - 5.5	60 - 120	10 - 12
6. Steel casting (olivine)	4.5 - 5.2	190 - 230	7.5 - 10
7. Zirconium (facing)			
--for iron casting	1.8 - 2.2	40 - 60	8 - 10
8. Ditto (for steel casting)	2 - 3	40 - 60	8 - 10

It is observed in this Table that, the value of 10–15% given for water glass in CO_2 sand is inordinately high.

While it would depend to some extent on the molecular ratio, which is unknown in this instance, the normal water glass content is around 6%.

The physical properties of the molding sand thus prepared are controlled by the Quality Control group, which has established—see Table 2.3.1-2—and assembles measured data.

Of the above 8 types of sand, those numbered 4 and 7 are for Ni-hard liners, but are today little used. Chromite sand is used only to the extent of around 0.5 t/month.

Tests on molding sand to determine moldability (degree of sand filling) and cinterization (tendency of sand to burn in) are also performed from time to time. The relevant data are stipulated to be controlled by the Quality Control group, and some records have been seen preserved from the past, but the practice does not appear to have been regularly maintained.

Backing sand is stipulated to be sampled 15 times a day; other sands 3 times a week: In practice, for instance, records for March 1982 indicate 9–12 samples to have been taken per day, and for August 1985, 1–4 samplings performed on both backing and facing sands, but limited to those for steel castings.

It was explained to the Survey Team that in the past there were 3 employees charged exclusively with sand control, which operation currently has to be performed by only 1 person, who has other duties as well in his charge. Under these circumstances, sand data are taken only when problems arise.

The foregoing situation needs to be remedied, and requisite control of sand quality should be regularly undertaken: Measures for preventing the occurrence of nonconformity are premised on regular routine control of sand quality, and it is only on the basis of normal data accumulated regularly that effective countermeasures can be set up to deal with nonconformities upon their occurrence.

5) Molding

Steel and iron castings—constituting the bulk of the Foundry products—are being produced at a rate of about 380 tons/month, the proportion of iron and steel being currently roughly half and half. The productive capacities of the molding equipment are:—

- Hand molding line using sand slinger as necessary, and covering all sizes of mold: 150–200 t castings/month
- Machine molding line covering liner molds: 200–250 t castings/month
- Ditto for small castings: About 20 t castings/month.

It is observed that the hand molding line is relatively modern, and operating smoothly.

This is not the case with the machine molding lines: The line for small castings (Badische machine) relies on hoisting the cope and drag one by one for mold assembly. The productivity of the small molding machine should improve appreciably by modifying the mold assembly system into a semi-automated line.

The molding line for liner castings is incommoded by insufficient floor space available for mold assembly and pouring. The mold assembly bay being housed in the same building as the melting shop prevents full use being made of the two cranes, which are forced to remain idle on account of interference with other operations proceeding close by. Lack of space for mold assembly has led to utilization for this purpose of the furnace-front floor, which is hopelessly fouling the operation.

Considering that liners are expected in the coming years to constitute the staple product of the Foundry, rationalization of this molding line for liner castings should be accorded foremost priority.

The use of green sand for large hand-rammed molds—even with use made of sand slinger—should advisably be discontinued: The inherently insufficient strength possessed by green sand calls for reinforcement by arbors and other means, which is time consuming, calls for special skills, and liable to cause defects in casting—burning in, rat tail, scab etc. Replacement of the green sand by self-curing sand with furan resin added as binder should vastly improve matters, by permitting the production of good castings more easily in higher quality, and without requiring special skills to be mastered on the part of shop floor employees.

Skilled molding shop workers able to mold anything with their spatula will become increasingly difficult to replace, it should be wise to consider conversion in the future to new molding materials that dispense with special skills on the part of the molding shop workers.

The grain size of sand—silica sand—is around AFS 50, which is normal. But the silica content amounts only to about 86%, which is insufficient. For steel castings, sand composed of 95–97% silica is recommended, and efforts should be made to find domestically available sand of this grade.

Frequent occurrence of burning in of sand on casting surface was noted by the Survey Team, and the shortcoming noted above of silica content may be a factor. Other conceivable factors include insufficient ramming, which should be performed with more care.

Heat insulting sleeves are used on risers of diameter as small as 300 mm: For such sizes of risers, exothermic sleeves should be more effective.

In other foundries, chills are widely adopted for steel castings—susceptible to high shrinkage—in order to induce suitable directionality in solidification, but at El Teniente indirect chills appear to be little used, with the exception of insert and surface chills at the root of ribs.

Both side and top risers are used, but side risers of blind form are not used, whose adoption should contribute to improving yield.

Ladles are of top pouring form—whether for iron or for steel castings: It was explained that bottom pouring ladles had been employed for steel castings until about 10 years ago, but had been discarded on account of leakage trouble. Top pouring of molten steel is liable to involve slag inclusions despite slag scooping practised at start of pouring. The sense of endeavor toward prevention of leakage is called for, instead of following the line of least resistance—of dropping the method upon encountering difficulty.

Ceramic pipes are used for sprues, which are useful for preventing erosion of sand. It is recommended to extend the application of ceramic piping to runners and gates.

Pouring temperatures for steel melt are:

1,540–1,550°C for ordinary and low-alloy steels

1,620–1,630°C for 18-8 stainless steel

1,320–1,335°C for high-chromium steel.

For stainless steel, the pouring temperature is a little too high. With the exception of thin-wall castings, it should not exceed 1,600°C. High-chromium iron castings, on the other hand, should be poured at higher temperature—normally 1,370–1,430°C: The low pouring temperature currently practised is liable to create cold shut and misruns.

Measurements by instrument of actual temperatures do not appear to be practised, and further attention should be paid to controlling the differences in actual melt temperature between beginning and end of pouring.

Pouring rate was learned—from verbal description—to be somewhat as given below:

POURED WEIGHT (kg)	POURING TIME (sec.)
50	5
100	15
500	35
1,000	50
2,000	60 - 90 (1 - 1.5 min)
10,000	180 - 240 (3 - 4 min)
20,000	360 - 420 (6 - 7 min)

If the above figures are actual net pouring time not including additional time taken for ladle transfer and positioning, the mold strength should not hold if a time as long as cited above are taken for pouring 10,000–20,000 kg.

In machine molding, the assembly is guided by dowel pins: For correct alignment, proper fit between the pin and matching bush is essential, but upon inquiry, no checks on the fitting accuracy are being carried out. The acccuracy of dowel pin and bush fitting should be regularly checked, using male and female gauges prepared for the purpose.

6) Melting

For melting, 3 Heroult furnaces and 1 induction furnace are installed, together with a crucible furnace for copper alloy. The largest Heroult furnace is a new acquisition dating only from last year, and is currently undergoing test operation.

The 3 Heroult furnaces have nominal and actually utilized maximum capacities as given below.

(Unit: Tons)

DESIGNATION	NOMINAL CAPACITY	ACTUALLY USED MAXIMUM CAPACITY
P	2	5
2-PT	10	13
3-PT	3.5	7.5

The actual capacity exceeding nominal value has been realized through modification of the furnace walls, which were originally thicker than practised in modern furnaces. For instance, the P furnace of 2-ton nominal capacity was enlarged to the present 5-ton maximum capacity by reducing the wall thickness from 15 to 9 inches.

Typical operating cycles practised with the 3 furnaces are as given below.

	P	2-PT	3-PT
Furnace charging (hours)	1	0.5	0.5
Melting (hours)	4	3	4
Number of cycles/day	3	2	2

NOTE: The operating cycles indicated above apply to the case of operation at the actually utilized maximum capacities of the respective furnaces, as given in the preceding Table.

The relatively long time required for charging the small P furnace is on account of its form requiring charging from side, with the material having to be placed in a rectangular steel holder for charging from the side door.

Other problems with charging are the remote loaction of scrap yard, and the furnaces situated in the middle of the casting shop, which hampers smooth transfer of the materials.

The induction furnace is of 1.5-ton capacity. Charging takes 0.5 hours, and melting 6 hours. It used to be operated about once a week, particularly for melting Ni-hard material, and also for cast iron and copper alloy, but is no longer much utilized. The reason given was that its relatively infrequent use tended to generate furnace wall cracking. Lining refractory was imported from Austria.

Altogether, the furnaces currently average less than 50% capacity utilization, and doubling of output could be achieved with ample margin still remaining.

Quality of melt is well controlled by the Quality Control group, which is equipped with the necessary facilities for analysis.

What most needs remedy is the overall layout of the melting shop. The present layout is the outcome of successive extensions and modifications brought to the shop in the course of its history, and has come to present a most incommodious arrangement.

In consideration of further future developments, the present building should be reserved for exclusive use as melting shop, provided with concrete flooring, with the furnace front space properly cleared, and with passages for traffic properly marked off. Ladles, currently left lying here and there, should be assembled in one place, for proper storage and custody.

7) Finishing

The Finishing Process is the principal subject envisaged for the Foundry Shop in the present Modernization Project. This Process covers operations from shaking out—removing the casting from mold—to packing in readiness for shipping out of Foundry Shop. The procedure will vary with the casting material: In particular respect of steel castings, it is complicated by the requirement of heat treating.

Of the operations constituting this Process, those of sand stripping, fettling and grinding are apt to be considered of lesser importance compared with what is regarded as the principal operations—patternmaking, molding, melting, pouring and heat treatment—and to be treated lightly also in technical respect.

The Finishing Process at the Foundry Shop follows one or the other of the flows charted in Fig. 2.3.1-1. Among the processes, those designated Nos. 1 to 4 are for different steel castings, Nos. 5 and 6 iron castings, and No. 7 copper alloy castings.

The operations indicated in the flow charts by circled numbers are as described below:

SUBSTANCE OF OPERATION

CIRCLED No.	
1	Patternmaking
2	Molding
3	Pouring
4	Shaking out
5A	Shot blasting
5B	Ditto after heat treatment
6A	Removing risers after preheating
6B	Ditto without preheating
6C	Powder cutting
6	Secondary fettling
7	Grinding
8	Heat treatment
9	Final finishing
10	Inspection, packing, shipping out.

Of the foregoing operations, those from 4 to 10 comprise the Finishing Process.

The individual operations comprising the Finishing Process are discussed in what follows, with particular emphasis laid on grinding.

(1) Shaking out

The casting is shaken out of mold after being left standing to cool. This cooling time is normally reduced to minimum with the view to economizing the overall operation schedule, which means that the product casting is subjected while still quite hot to mechanical impact, to biased loading by its own weight, and to localized cooling, with consequent risk of deformation, stress cracking, residual stress, and other casting defects. This calls for particular care in shaking out.

At the Foundry Shop, shaking out appears to be practised mostly during night shifts.

Specific instructions on shaking out are issued from the molding shop, including the time to be accorded to each mold for cooling down before shaking out. Requirements such as cooling down time should be standardized, but no written standard would appear to exist.

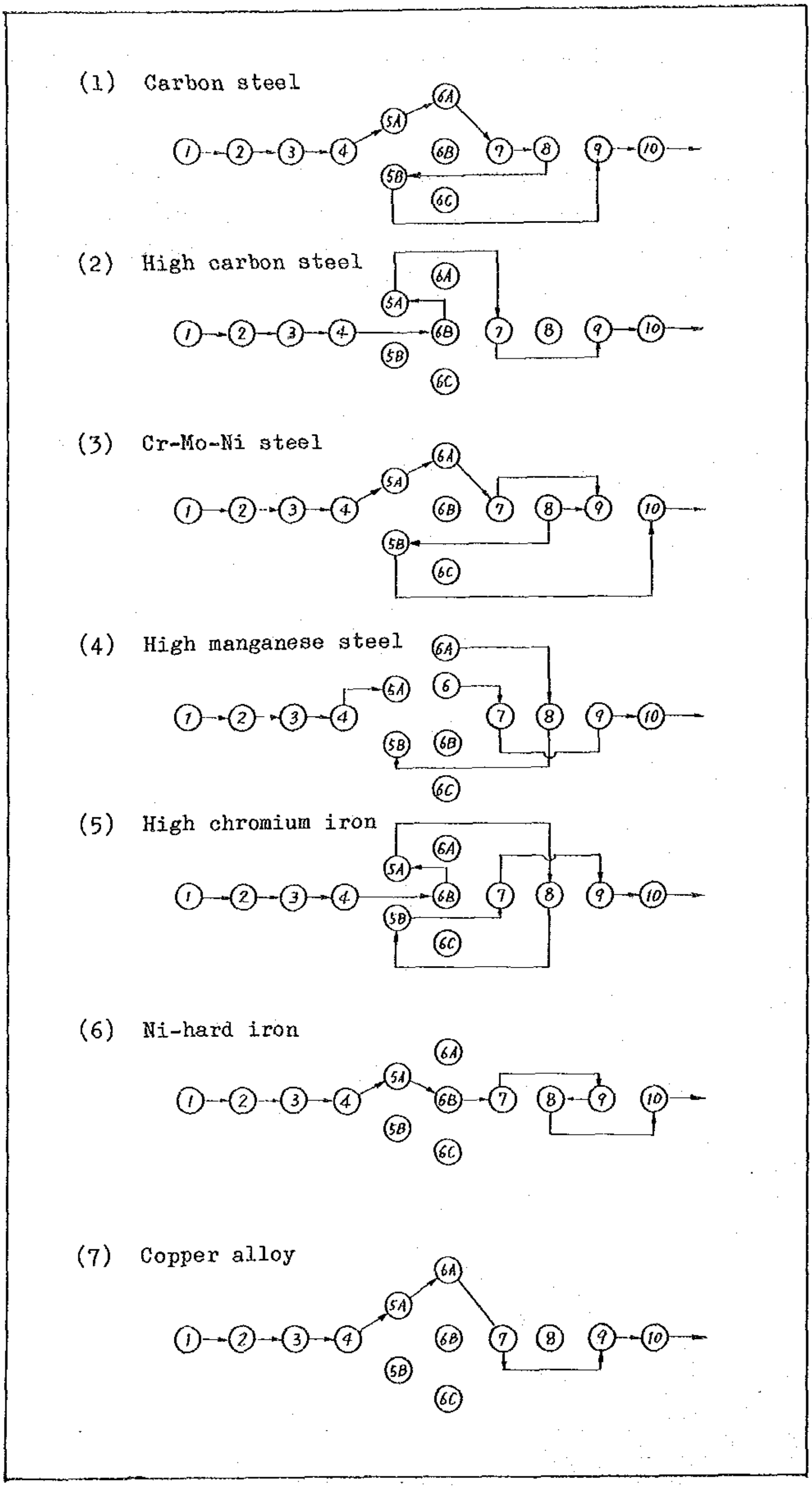


Fig. 2.3.1-1 Process flows followed by different castings

In normally accepted practice, shaking out is undertaken when the casting in mold has cooled down-

- Below 450°C with normal steel castings
- Below 200°C with high-chromium iron and steel castings, which are susceptible to hot tearing.

As a rule of thumb, the cooling time accorded to molds should be:

12 hours (shake out during night after pouring) for normal steel castings

24 hours (shake out day after pouring) for alloy steel castings

Two mobile shake-out machines of 5-ton capacity are available for dealing with medium and small machine-mold castings. Large hand-mold castings are shaken out with a stationary machine of 25-ton capacity. Extra-large castings are stripped of mold with crane lifting off the flask piece by piece.

After shaking out, the casting still carrying sprues and risers presents an intricate form for lifting and transfer, with center of gravity difficult to determine. Unsafe and precarious conditions of casting manipulation during transfer have been observed by the Survey Team. The mode of slinging the shaken out casting for safe transfer should be carefully studied and determined at the time when the casting plan is drawn up.

(2) Sand stripping

Cleaning off the sand remaining on the casting surface is normally performed in two stages—before and after heat treatment. In this instance, the observations are limited to the rough sand stripping applied before heat treatment.

As with shaking out, what is of importance in this operation is proper control of the casting temperature: Hastily proceeded with—when the casting is still too hot—will risk generation of excessive temperature differences between the inner and outer parts of casting, causing large residual stress, deformation or even cracking. Here again, no work standards appear to exist, and the operation relies on past experience.

Sand stripping is performed manually on large castings; small castings are stripped by machine. There are available 2 shot blast machines:—

- Drum type machine of 42:.009 (1,067 mm) diameter×48:.009 (1,220 mm) of 60 kg capacity, with cleaning action applied simultaneously by drum rotation and shot blasting. The machine is suited to small castings of 100 to 200 mm size, and was probably intended originally for small railroad accessory castings, but is today used for cleaning much larger pump impellers, for instance, of 500 to 600 mm diameter. Castings of such size are treated during about 10 minutes, which would appear insufficient for adequate cleaning.
  Hanger-type blasting machines are better suited, particularly in the case of impellers and other castings molded with core, for which the system of blasting simultaneously from top and from bottom is extremely effective.

- Truntable-type machine of 3,200 mm table diameter×3.550 mm×2,280 mm high, of 5-t capacity, for treating castings up to medium size.

  The normal operating cycle with this machine is:
  10 min for leading the casting on machine
  10 min for shot blasting
  10 min for unloading.

  ---

  30 min total.

  Same castings require blasting from both inside and outside, which would prolong the cycle duration to 50 min. Again, blasting only for 10 min should be insufficient.

- Manual sand stripping: Large castings like 325 ft^3 ladles have to be sand-stripped manually, after annealing, upon which the sand is more easily dislodged, and is stripped by hand grinder, chisel or other tool. This manual operation should have to be continued for the time being, since the volume of production of the larger castings would not justify the acquisition of crane blasting installation.

(3) Fettling

The normal practice with steel castings is to remove risers, runners, gates, by gas, and applying special methods (plasma jet, flux cutting, ...) in the case of materials of particular properties.

At El Teniente, the castings are largely of abrasion-resistant steel, and risers, runners, gates and other projections are removed mostly by oxyacetylene, by gouging, by cutting grinder, or by powder cutting. No work standards exist to govern the fettling operatins, the reason given being that the workers know thoroughly from experience the mode and manner of cutting.

Preheating before cutting should be more systematically controlled, considering the predominance of special steel castings—containing significant amounts of chromium, vanadium, molybdenum and other temper-hardening elements—in order to anneal and diffuse the segregated carbonates, to reduce brittleness at the time of fettling. For this, these castings should be preheated to 200°C minimum. Yet preheating in furnace appears to be performed only exceptionally, the only treatment applied being to heat the castings locally by oxyacetylene torch, while steels liable to crack—e.g. high-choromium pump impellers—have risers cut without preheating, leaving a 1/2" (13 mm) stump, and slowly little by little.

With high-manganese, the risers are first cut at 200 mm from root, followed by heat treatment (water toughening at 1,140°C), and a second cut leaving this time a 3-6 mm stump. The stumps are finally removed by grinder. In Principle, high alloy steels are cut with grinder, using 9"×1/4"×7/8" wheels of resinoid, imported from Austria.

The much more brittle iron castings are fettled by knocking off with hammer, the risers and other projections being provided with constriction for this purpose. The liner castings carry risers of diameter attaining 100-120 mm, which would demand fairly strenuous hammering with sledge.

(4) Grinding

After fettling, the castings are finished principally by grinding smooth—down to specified dimensions—the remaining stumps, fins and other projections, and to remove all remaining sand adhering to surface.
Available grinding facilities comprise—

- swing
- stationary
- portable

types of grinder, used to suit the circumstances.

a) Swing grinder

The large hanger grinder carries a 24″×12″×3″ wheel of rough 14 mesh. The equipment is outdated and of poor performance. Moreover, with the recent conversion of power supply from 60 to 50 Hz, the rotating speed has been reduced, with resulting diminution of peripheral speed from the rated 45 to 35 m/s. No means is provided to compensate the peripheral speed for reduction of wheel diameter with wear.

Modern foundries are normally equipped with grinders ensuring 60–80 m/s peripheral speed, and barely half this peripheral speed is provided by the current equipment.

Table 2.3.1-3 Results obtained at El Teniente from tests on different brands of grinding wheel

	BRAND OF GRINDING WHEEL			
	TIROLIT (Normal)	TIROLIT (Mant)	NORTON	PHODIUS
Raw data -				
1. Unit price (US$/piece)	113	113	188.5	153
2. Q'ty of workpiece ground off (kg)	55	57	89	61
3. Initial grinding wheel weight (kg)	42	42	39	36
4. Final ditto (kg)	10	9	7	8
5. Q'ty of grinding wheel consumed	32	33	32	28
6. Duration of test	6.7	4.39	10.7	3.4
Analysis				
1. Grinding rate (kg/h)	8.21	12.98	8.33	17.8
2. Grinding wheel consumption rale (kg/h)	4.78	7.52	3.00	8.16
3. Grinding ratio (kg ground off/kg consumed)	1.72	1.73	2.78	2.18
4. Grinding cost/gr. time (US$/kg)	16.78	25.74	17.67	44.59
5. Grinding cost/quantity ground off (US$/kg)	2.05	1.98	2.12	2.50

As instance of the grinding efficiency obtained with the current equipment, the grinding ratio (quantity of workpiece ground off/quantity of grindstone consumed) is 1.72–2.78, obtained at rates of 8.21–17.8 kg/h (cf. Table 2.3.1-3). These rates attest to the high skill of the workers, and such heavy grinding applied to casting surface even raise doubts on whether hair cracks might not have been generated on finished surface.

The grinder dates back to 1928, having thus seen more than 50 years of service, during which a number of improvements have been brought, including the provision of safety cover, but the introduction at this time of a high-performance installation should very appreciably enhance the performance obtainable from the grinding wheels currently used.

The 4 smaller swing grinders were acquired 5 years ago, and provide a peripheral speed attaining 80 m/s. This high performance of these grinders, however, is not being brought out to best effect, on account of the ancillary equipment not being in keeping with the modern grinding machine: For instance, the installation of a positioner on the work table to facilitate varying the position of workpiece should vitally enhance the working efficiency. Also, the grinders could be manipulated much more flexibly, if they were suspended from electric hoist.

b) Double-headed grinders

For small castings, 4 double-headed grinders are installed, which are 10 years old. These grinders could be replaced by modern units provided with means of ensuring constant peripheral speed and assisted workpiece loading, with appreciable benefit in terms of working efficiency and labor saving.

c) Hand grinders

Hnad grinders also are today marketed in much more compact, light-weight, high-performance models operating on high-frequency power supply, and grinding efficiency could be appreciably enhanced by their introduction, without going to the extent of considering automated systems.

While overall automation of grinding operation should not be justified, in view of the wide variety of casting shapes and sizes produced, with particular respect to liners, which are—and are expected to remain in the coming years—the staple product of the Foundry, the introductin of a universal grinding machine should merit consideration.

d) Carbon brushing

Carbon brushing is principally utilized for removing local projections, and fins found on the surface of steel castings containing less than 0.45% carbon, and on alloy steel castings for projections of size that would not thermally affect the material.

Wider utilization of carbon brushing, to obtain a rougly even casting surface, would contribute to reducing the amount of subsequent grinding work.

(5) Heat treatment

The preponderance of alloy steel castings produced calls for a wide veriety of heat treatment processes to be performed—annealing, tempering, quenching/ tempering, water quenching.

For this, there are avialable 4 furnaces—numbered 1, 3, 4 and 5—but are located far from the finishing shop, with consequent considerable loss of time and work in transfer of the workpieces to and from furnace. This incommodity is the result of historical circumstances, but the contemplated Modernization Project should provide a timely occasion to reorganize the overall layout, to eliminate the losses of time and labor, in readiness for future extension.

Heat treatment operations are currently performed in 3 shifts. All 4 furnaces are oil-fired. Furnace No.4 is a large new installation; Nos. 1 and 3 are old; No.5 is a homemade outdoor cylindrical installation arranged for charging from top. The Furnace No.2 was electrically heated; it has been discareded.

a) Furnace No.1

The furnace No.1—of 10-ton capacity—is charged by dolly, with quenching pool located close by. Maximum service temperature is 2,000°F (1,093°C). The furnace is equipped with only 1 temperature sensor, and moreover, not self-recording: this is considered inadequate for proper temperature control and should be replaced by a self-recording system with thermocouples measuring 6 points in the furnace, to permit proper control of furnace temperature level and distribution.

Records of temperature currently taken start from 50°C; after heat treatment, the furnace is opened upon cooling down to 75°C. Temperature is controlled by operator regulating the burners manually. Water toughening of high-manganese steel castings—when required—is performed at 1,040°C on instrument. While this temperature prescription is correct, there remains the question of whether the actual workpiece temperature level and distribution are correctly ensured with the current arrangement for temperature measurements.

b) Furnace No.3

Furnace No.3 is a small single-burner unit of 4-ton capacity, equipped with 1 temperature sensor. Maximum service temperature is 1,950°F (1,065°C). It is already outdated, and is used for small castings.

c) Furnace No.4

The Furnace No.4 is installed outdoors, close to the scrap yard. It is home-made, designed with opening roof, for top charging. Capacity is 30 tons, and is used principally for large castings, and also for heat treatment of ladles following overlay remedial welding.

The furnace is oil-fired—as are all others—and heats up to 970°C for annealing. For removing deformation, castings are heated to around 625°C.

Transfer of workpiece is ensured by truck crane.

d) Furnace No.5

Furnace No.5 is a modern unit imported from France, located at the extremity of the hand-molding line. It is a 40-ton capacity installation for heat treating large castings. The hot gases from oil burners installed at the bottom corners is arranged to circulate through the furnace, to provide a maximum service temperature of 1,205°C. The furnace is lined with heat insulating refractory—not bricks—to ensure heat conservation. Temperature measurements are made at 6 points, and registered by self-recording system.

For annealing, the castings are withdrawn at 50°C above prescribed temperature, followed by forced air cooling. For this operation, the furnace is charged only to half its capacity.

(6) Repair welding

The repair of casting defects by welding is performed on the different casting materials—carbon, chromium, manganese, chromium-nickel, high-chromium ... steels—using welding rods suited to the respective materials. Preheating is not applied except on iron castings, although the accepted practice is to preheat all steels of carbon content of above 0.40 carbon, and in addition, postheating as necessary.

Repair welding performed at Foundry Shop are limited to small casting defects: Castings requiring large repair welding are sent to the Plate Shop, instances being such work on large ladles.

(7) Inspection

Inspection after repair welding is undertaken by the Quality Control group. On small repair, inspection is performed visually, or using penetrant dye; radiographic inspection in applied as necessary. All in all, more care should require to be applied in the fettling operations, in preheating before repair welding, and to be followed by postheating.

2.3.2 Plate Shop

1) Site of Shop

The present Plate Shop comprises a main shop occupying a building 90 m×30 m in size, and two annexed shops respectively for round bar cutting and for sandblasting. The main shop building consists of a principal structure 15 m wide served by one 10 t and one 5 t overhead travelling crane, and flanked by 7.5 m wide lean-to on both sides. Surrounding the building is a large space on the south side, containing a storage yard for materials and for semifinished products. The remaining three sizes to the east, north and west, are closely bordered respectively by the Fabrication, Foundary and Electrical Shops, which limit access of materials and products to and from the Plate Shop to the south side only. This limitation of access to the Plate Shop results in an extremely inconvenient layout for the flow of material in and out of the Shop.

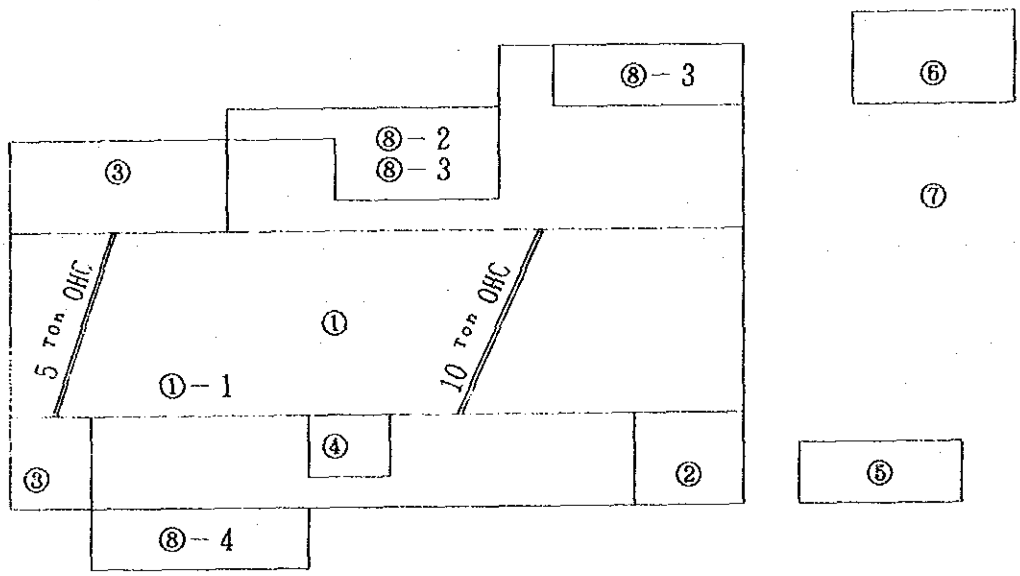


Fig. 2.3.2-1 Present Layout of Plate Shop

The present layout of the Plate Shop is shown in Fig. 2.3.2-1. The numbered areas represent the following facilities comprising the Shop.

1 Area where the principal products of the Shop—ore cars, mine gallery supporting arches—are manufactured, and overlay welding repairs performed on crusher components. The equipment comprises:—

- For plate cutting—2 eye tracers, shear, ...
- For plate bending—bending roller
- For drilling—radial drilling machine
- For welding—manual and semi-automatic welding machines.

No clear demarcation is made between zones for the marking, cutting, assembly, welding stages of plate processing: Operations are conducted where space happens to be available at any particular time for any particular job requiring to be done. The only exception is overlay welding, for which the zone marked 1-1 is reserved.

2 Area where wire mesh is manufactured for ore sieves, measuring 15 m×7.5 m, and equipped with machines for wire corrugating (with raw wire drawn in from outdoors), for wire meshing, for mesh cutting. The wire used ranges from 2 to 10 mm diameter; the finished meshes measure around 1 m×2 m.

3 Forging shop occupying a space of 40 m×7.5 m, producing liner fixing bolts, gads used in mine and other forged articles. Equipment includes oil-, gas- and coke-heated furnaces, hammer, bolt forging machine, screw-cutting machine, double-headed grinder—all more than 30 years old.

4 Reinforcing bolt shop measuring 7 m×7 m, producing mine gallery reinforcing bolts of 25 mm diameter×2 m long. The shop is currently operating in shifts to full capacity.

5 Round bar cutting shop, housed in a detached shelter measuring 20 m×6 m, and equipped with hand saw for cutting round bars used for shafting, and a shearing machine for dealing with reinforcing bolts.

6 Sandblasting shop, separated from the main shop building by 30 m, and housed in a structure measuring 13 m×10 m. Workpieces are brough in and out by dolleys running on rails.

7 Steel yard of very ample space, serving more as depository for material remaining from work and for half-finished products awaiting final welding, rather than for storing stocks of fresh material, which latter do not require stocking in any appreciable quantity, since such material is readily available upon request from the El Teniente Division.

8 Offices (8-1), tooling and consumable store (8-2), maintenance shop (8-3), canteen (8-4). The offices occupy a centralized position in the building, with large windows commanding a view of the entire shop floor. The tooling and consumable store, maintenance shop and canteen also are located conveniently close to the shop, for ready access by employees.

2) Work instructions

The elements of product quality and productivity that determine the performance of any workshop are largely governed by whether or not the jobs performed are adequately studied in advance of actual work taken in hand on shop floor.

At the El Teniente Workshops, any new kind of job requiring to be done is fundamentally studied by key shop staff headed by the Workshop Superintendent, followed by a detailed study on work procedure with the participation of foremen, assistant foremen and skilled workers, to elaborate the procedure to be followed in carrying out the job.

However, the Survey Team was not able to obtain any example of written work instruction sheet describing the work procedure to be followed in proceeding with the job,

3) Shop practices applied at the different process stages

(1) Marking

Plates are marked out by skilled fitters using tape measure, straight-edge, and chalk. The manner in which straight lines and circular segments were being marked, which happened to be the only work in progress at the time of Survey Team visit, well indicated the amply high level of skill prosesses by the fitters in doing their job.

The Team was not able to survey the accuracy of the templates or rationality of template apportionment, since this operation was done outside the shop.

(2) Cutting

The principal equipment for cutting comprises 2 eye tracers and 4 small automatic gas cutting machines, together with shearing machine.

Upon inspection by the Survey Team, the cut edges were found to carry many notches, with shoulders far from uniform, and with varying groove angle. This could not be imputed solely to the recent change from 60 to 50 Hz of power supply. Neither was it possible to check whether or not the cuts properly followed the markings, since offset reference lines were not practised.

It should be useful to introduce semiautomatic curve-cutting machines for dealing with large workpieces (say above 3.5 m×3 m), which are not susceptible to cutting by eye tracer.

(3) Bending

The equipment for bending includes press brake for bending reinforcing bolts, large bending roller and small angle bender. All 9 machines installed, however, are outdated, without means of nose bending or of forming curved surfaces.

For the time being, the work procedure will have to be adapted to the currently available equipment, but the Modernization Plan should include the acquisition of large 4-column boiler press and bending roller capable also of nose bending.

(4) Assembly for welding

Fitters charged with assembly for welding also undertake plate cutting, and constitute a group of multi-skill workers. The group would be considered to hold responsibility also for taking the initiative in feeding back suggestions and advice to the engineering group on points calling for improvement, to facilitate shop practice and to enhance product quality. For instance, the Survey Team observed some weld groove angles to be inordinately wide, and upon inquiry, found the relevant darwing to indicate 80°. The drawing had been issued more than 10 years earlier, and had in the meantime been utilized many times over, but the inpropriety had never been notified to the engineering group. It was affirmed by the person in charge on shop floor that the groove angle was actually modified to 60° in execution, but such arbitrary deviation from drawing indication can be quite dangerous. If a drawing gives incongruous indications, the matter should be properly brought to the attention of those responsible for the drawing, to have the incongruity corrected in the drawing, before proceeding with the work.

Also, upon examination of assembled structure ready for welding, some of the welding gaps were observed to be inordinately wide. Such poor workmanship cannot always be imputed solely to lake of skill on the part of fitter, but calls for study in further depth, to see whether the design itself might involve structural arrangements unduly difficult to assemble, or insufficient accuracy of marking, cutting and bending before assembly, or else misestimation of welding shrinkage allowance against drawing dimensions.

Such problems call for solution through concerted action between the fitters on shop floor and the engineering group.

(5) Welding

The welding stage is the process specified for study in the present Plan of Modernization. The weldments produced at the Shop attested to high welder skill that should pass muster anywhere in the world. Automatic and semi-automatic welding with open-arc flux core is applied in part to flat-position welding in overlay repair jobs. The Survey Team happened to observe automatic welding in progress using this technique on a brake drum overlay repair job: The workmanship left nothing to be desired, showing an extremely smooth bead.

For thin plates, MIG welding is applied in part, but otherwise manual welding is adopted even for butt-welding plates as thick as 25 mm. Submerged arc welding has not been introduced, the reason given being excessive fluctuations of supply power voltage. Manual welding is already outdate, and with the execption of certain materials and jobs necessarily calling for welding by hand, the introduction of semi-automatic and automatic welding machines is advised, in view of the significant enhancement to be expected of productivity. This should at the same time solve the question of untidy shop site—scattered welding rods cluttering the floor—and inadequate control of welding rod drying treatment.