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

MAR., 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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Contents

1. History & Background of Feasibility Study

1.1 Background of the Feasibility Study of Modernization:—

The CODELCO (Corporacion Nacional del Cobre de Chile) is one of the foremost enterprises in copper production of the world. The Div. El Teniente is a part of the Divisions of the CODELCO, which is the largest of the world in underground copper mining.

Despite universal decline of the copper price, the CODELCO has a strong cost competing capability, stable management with an abundant capital and corresponding the production increasement program, the new investment schedule has been determined intending to dominate the world copper markets.

The Republic of Chile has been depressed socially and economically due to the abrasive political transition and subsequent economical policy confusion in 1970s but the signs of recovery can be seen in 1980s.

According to the scheduled democratic transition of the government incoming 1989, the country evolves a rather hasty aspiration to reconstruct nation's strength and to catch up western advanced countries as soon as possible. The CODELCO has naturally been steadily elaborating the modernization programs in various fields of the activities.

The subject feasibility study of the modernization, which the Government of Japan has been requested and the JICA (Japan International Cooperation Agency) has taken up, is the study on two production processes in two workshops that belong in the Workshops Department (Departamento Talleres) in Rancagua, one of the service dept. in Div. El Teniente. Namely, the Finishing Process (Terminacion) in Foundry Shop (Fundicion) and the Welding Process (Soldadura) in the Plate Shop (Maestranza Caldereria). The perspective view of the above two processes in the CODELCO organization is indicated in attached chart in page 4.

The production processes in above workshops have been placed almost out of the past facility renovation investment programs and been somehow operated with old-fashioned equipment but now collided in its limits.

Industrial safety record also appears worse along with the low productivity level.

Mines in Div. El Teniente, due to the deeper expansion into the underground, has indicated the decrease in copper contents, also, the increase of drilling into the harder rocks (primary rocks), the materials of the equipments to be supplied to the mining dept., increase even to maintain present production amount.

The CODELCO aspires with the results of the feasibility study that the programmed capability gain should be in full bloom by 1989.

1.2 Records of Main Events until the Finalization of the Study

July 28, 1978	Technical Assistance Agreement between Republic Chile and Japan
Mar. 3, 1986.	Agreement of Scope of Works
Jun. 28–July 27, 1986	Actual Field Survey in Chile.
July 22, 1986	Progress Report Approval, Minutes of Meeting
Nov., 1986	Presentation of Draft Final Report
Mar., 1987	Final Report

1.3 Objectives of the Study:—

It is the intention of the study that through the actual field survey of the Foundry Shop and the Plate Shop that belong the Div. El Teniente of the CODELCO in the Republic of Chile, a feasibility of the modernization shall be developed from such an aspect of technical, financial, and economic, in which the stress should be placed especially to the Finishing Process in the Foundry Shop and to the Welding Process in the Plate Shop, thus to compile a Final Report to facilitate the modernization executions.

1.4 Scope of the Study:—

Perspective Comprehensive Study of the Workshops
Study on Production Facilities
Study on Management
Study on Technology
Study on Safety Control
Study on Raw Materials
Study on Demands (Study on Production Program)

1.5 Methodology of the Study:—

Financial Analysis to be carried out according to the Discounted Cash Flow Method (Evaluation by IRR).

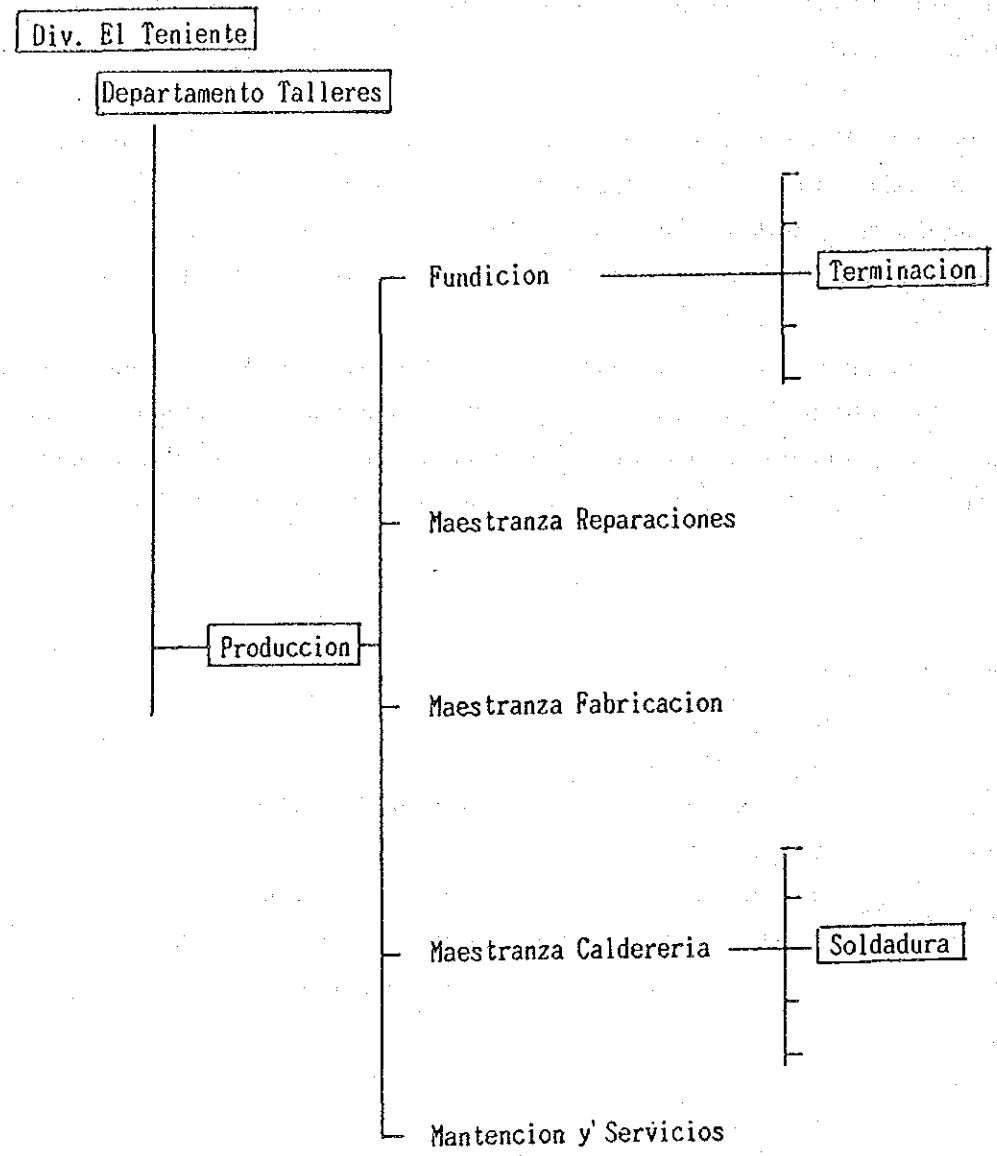
Economical Evaluation shall be quoted on the basis that the Workshops Dept. (Departamento Talleres) is a service dept. of Div. El Teniente and is in a position to solely supply the demands inside of the Division, therefore, Chilean Domestic Demands or the effect of the extra supply to the other Divisions shall not be considered for the Study.

Industrial Safety, as especially emphasized in the Scope of Works, shall be quoted, along with the basis of current unsatisfactory records in the Foundry and the Plate Shop and with the training situation which has decisive relationships to the aptitude, discipline and motivation of the employee and the comprehensive recommendation shall be prepared.

Members of the Study Team;—

Chief	K. Chikaraishi	
Member	N. Ohkawa	Casting Processes.
Member	Y. Isemoto	Welding Processes.
Member	K. Kimura	Machinery, Facility.
Member	K. Miyamoto, Y. Muraki	Financial, Economic, Market & Demands Evaluation.

Perspective View of the Organization as to Finishing & Welding Processes.



2. CODELCO, Div. El Teniente and Workshops Department in Synthesis Description

The Republic of Chile is placed amongst major nations of the producers of copper in the world with U.S.A., U.S.S.R., Zambia and Canada. The annual output is about 1.3 million tons, in which the CODELCO, a national corporation, has a majority of the share of 1 million tons and other 300,000 tons are from the rest of private companies.

The CODELCO is an enormous, sound conglomerate that can represent the Republic of Chile and has a total employment of 26,000 personnels. It is divided in 4 Divisions according to the geography of the mines, namely, Chuquicamata, Salvador, Andina and El Teniente, in which the Chuquicamata (Openmining and El Teniente (Underground mining) are among the largest, producing 300,000–400,000 tons annually each.

The mines of the El Teniente has been explored since the beginning of 20th century by U.S. Capitals and now is the largest underground copper mine in the world. 80 years of the exploration by the North American enterprise has spurred continuous gigantic investments, provisions of rigid organizations and systems, accomplishing stable outputs and the highest cost competing capability inside whole CODELCO.

The annual production is above 300,000 tons and mining tunnels are advancing into the Andes Mountains at the rate of 40 Km per year; the deposits of the ore, notwithstanding present huge output, has been confirmed for another 100 years and more.

Extraction of the copper require 3 consecutive major processes.

Firstly, the copper ores of contents of about 1% are excavated and crushed (Crushers) to be transported to secondly process of floatation separator system (Floatation Tank) which would increase the contents of the copper to 40% (in the process, the Molybdenum is extracted) and then finally transferred to the smelting with the reverberatory furnace-converter to be extracted as the final ingots of more than 99% purity.

The base camp of the Div. El Teniente is located in the city of Rancagua (80 km south of Santiago) and the mining sites are in Colon (46 Km from Rancagua) and in Sewell (53 km from Rancagua), both are connected by an exclusive highway to transport ingots products, which is connected by another exclusive railway to the port of San Antonio for export to the world.

The total employment of Div. El Teniente is about 8,500 in which the Workshops Department represents 515.
The Workshop Department can be designated as Engineering Service Dept. for the mining dept., responsible to maintain smooth mining operation through productions, recuperations and repairs of the mining machines and the equipments.

Annual output of the Workshops Dept. is about 9,000 tons according to 1985 record. The organizations and the systems have been well established in the enterprise; the actual operations of the Workshops are carried out in close cooperations with the Industrial Safety and Higiene Dept. and Training Dept. which are in direct controls of Div. El Teniente.

Various production activities are executed under established regulations, standards and manuals with predetermined programs.

The nature of the operations require sufficient qualifications of the job, so that the age group and the experience years of workers represents majority of middle age brackets.

2.1 Current Status of the Foundry Shop

The Workshops Department (Departamento Talleres) is responsible to supply machinery and equipments which are operated in the Mining Dept. of Div. El Teniente. The Foundry Shop (Fundicion) has a responsibility to supply the cast-produced parts of the mining machines, which include supply of the consumables, recuperations and the repairs.

The main products are varicties of Liners of the Crushers, accompanied with the Casings & Imperers of the Pumps, Ladles, Wheels and Brake-shoes of the ore carrier wagons. Majority of the material is of abrasive-resistent type, in which there are High-Cr Cast Iron, High Carbon and High Mn Cast Steel. And there are slight amount of Non-Ferrous Casting Products such as Bronz-alloy.

The production amount is 4,600 tons/year (380 tons monthly) in 1985 record.

Entire productions are carried out inside the Department; as for the Foundry Shop, facilities and capacities are available for relevant processes from Pattern-making to Molding Sand Processing, Moulding, Melting, Finishing, Heat Treatment, Final Finishing and to Inspection.

While the previous investments have been carried out in accordance to conform various requirements along with the developments of the enterprise, there exist several factors of restrictions on the Factory Buildings and Layouts due to the historical background since the founding of the enterprise.

The Finishing Process (Terminacion), as one of the items of the Study, include processes after the Melting process such as Shake-out, Cleaning, Cuttings of Risers, Heat Treatment and Final Finishing.

Existing machines include rather heavy-duty tools as Shake-out machines, Swing Grinders, Double-head Grinders, Oxygen-Acetylene Gas Cutting and Arc-Air Gouging. As the products have a wide variety in types and sizes, the facilities and machines should be prepared to match entire range of the work, which, in another word, might not be provided in the most efficient arrangement and capacity for entire range of the individual product.

Amount of the personnels are 159 in total including modelling process, in which the Finishing Process has 51 personnels. Qualifications of the casting process require long experience and training; the age of the workers are composed with the middle age brackets.

High temperature, heavy physical work in dust & fume condition affect unfavourably to the safety records along with undesirable lightings and transportations due to superannuated factory buildings. The data indicate among the worst in the Department; the immediate improvement shall eagerly be expected.

2.2 Current Status of the Plate Shop

The Plate Shop is responsible, as in the case of the Foundry Shop, to supply the steel structures which are to be utilized for the mining activities in Div. El Teniente.

Items of productions include new constructions and the recuperations of the existing equipments.

Among the welded structures, there are 100-ton ore carrier wagons, 25-ton wagons, the reinforcement structures of the mine tunnels and the floatation tank structures.

The recuperations include hard-facing weld build-ups of the various crushers and the ladles, which are in constant demands.

Due to the overhead crane capacity restrictions inside of the Plate Shop, namely 10-ton and 5-ton each, the difficulty is that the larger products have to be assembled on a transportation carriage or at the outside of the Shop.

The materials are of mild steel and of high tensile steel, which are solely supplied from a Chilean Steel Mill, CAP (Comp. Acero del Pacifico) and the sizes and types are not said to be in exact fitness for the products. For example, the Arch Reinforcement Structures of underground mining tunnels would be more than simple if H-type Sections have been produced in the Steel Mill, contrary to the weld-built-up constructions.

Amount of the productions is 3,038 tons in 1985 which is 253 tons in monthly productions.

From inherent character to supply immediate service to the mining dept., it is difficult to have finite future estimates on items and on amounts of the Plate Shop products.

And also, the Plate Shop has a responsibility to produce various outfitting pieces such as wire nets and ladders, even if unfit to the nature of the Shop.

Welding procedures are mainly manual arc weldings and the open-arc semi-automatic welding is partly tried.

Training of the welders are systematically carried out at INACAP (Instituto Nacional de Capacitacion), also at the facility of a Chilean Welding Material supplier, INDURA.

As Regrettable enough, the industrial safety record is among the worst in the Department with the Foundry Shop. Analysis shows the factors affecting the record are not the process or procedures, but due to the circumstance, the layout of the Shop and also due to human factors in conjunctions with the welding position.

3. Modernization Program

3.1 Basic Principles

For the given propositions—to compile Modernization Programs in the Workshops Department (Departamento Talleres) on the Finishing Process in the Foundry Shop (Terminacion de Fundicion) and also on the Welding Process in the Plate Shop (Soldadura de Caldereria) with circumference considerations relevant aboves, the basic principles are as follows.

1) Compiling future vision of development in Div. El Teniente and in the CODELCO as a whole, the Modernization Programs of above-mentioned 2 processes shall be projected in an ideal concept of the integral layout plan of the Department which can be negotiable for the expected expansion of the production beyond 1989.

2) Keep the prestige to dominate world market as the foremost copper producer, and to place heavy governing power along with the advanced countries of U.S.A., U.S.S.R. and Canada.

3) As a leading company in the Republic of Chile, the CODELCO shall be expected to maintain high level of technology in the country.

As concretely indicated,

4) For the present time being, corresponding to the production increase program by 1989, the integral hardware systems of the high productivity to be introduced.
A technically feasible hardware shall be thoroughly reviewed in advance before the financial analysis.

5) Principles shall be based on the CODELCO philosophy of "Human Respect" and safe, job-enriched, pleasant environments shall be pursued.

6) The effects of the investments shall be analyzed financially by the Discounted Cash Flow Method and the acceptance shall be judged by the designated Internal Rate of Return (IRR).
In the course of the analysis, the instruments which are technically feasible but are exceptionally expensive and therefore, are apparently of the cost increase, shall be excluded from the conclusions to be transferred to future installations.

7) As there are some fields of difficulty to determine economical feasibility analysis quantitatively, when the value of IRR appears below designated criteria, the conclusion shall be carefully guided, taking account into each philosophy mentioned above.

8) Along with the introduction of the hardwares, the composites of the improvements in softwares such as the Production Management, Technical Engineering and Industrial Safety Control, shall be proposed; because, while it is "Human Being" who operates the machinery and even if the newest facilities having been adopted, the expected results could not be obtained, unless concentration of the motivations of the employees would not be acquired.
There is an urgent demand upon above-mentioned 2 processes, of the immediate improvement of the industrial safety records, on which, it shall be splendid opportunities to renovate additional improvements of the management.

In addition to the Modernization Programs, immediate, mandatory requirements to reinforce or to improve the immovables and the transportation equipment, due to recent size increases and the congestions of the production processes, in strict conformance with Statutory Safety Acts, shall be demonstrated in the Appendix with the Basic Concept Design and rough estimation of the cost.

These must be taken up by the management side without delay, as a social responsibility of the enterprise.

3.2 Candidates of Modernization Facilities

The projection of potentiality of Div. El Teniente, as seen from the Synthesis Description and from the Economic Evaluation, is the brightest among whole CODELCO for coming long future. It is expected to play a role of powerful locomotive to pull up national economy. The Workshops Department (Departamento Talleres), on the other hand, has subsequently been expanding since the founding in early this century, along with the increasement of the production. But historical development indicates additional erections of shops immovables and also additional installments of machinery and equipments in the given layout, which have considerably obstructed fair productions in the production flows and the transportations. In the anticipated environment of decrease of the copper ore contents and of drilling into harder primary rocks, the products to be supplied to the mining dept. would naturally increase in their sizes and amounts. So, it is clearly expected to renovate entire Workshops layouts, sometime in future, as a milestone of the expansion. Chapter 3 of the Final Report describes the ideal series arrangement plan of the Workshops, the

most favourably conforming the progressions of the production flows, in which the following machines and equipments shall be studied, as the Candidates of the Modernization Investments.

1) Finishing Process in the Foundry (Terminacion de Fundicion)

* Sequentially controlled 4-face CNC (Computerized Numerical Control) Automatic Grinding Machine
* Swing Grinder with Constant Peripheral Speed Device
* Fixed type Double Head Grinder with Constant Peripheral Speed Device
* High Frequency Grinder
* Turn-Table

2) Welding Process in the Plate Shop (Soldadura de Caldereria)

* Flux-cored Wire CO_2 Gas-shielded Arc Welding
* Submerged Arc Automatic Welding
* Positioner & Manipulator
* CO_2 Gas Distribution Piping System

4. Financial Analysis & Economic Evaluation

1) Demands & Production Program

The Workshops Department (Departamento Talleres) under study, is responsible to supply, recuperate and repair the machinery and equipments of the mining of the Div. El Teniente. There are a few of the supply to the other Divisions than El Teniente, the amount of which does not affect the productions programs, and there exists none of the schedule to subcontract to the outside of the enterprise or to have the imports until the target 1989 of the finalization of the Modernization, therefore, the production program shall be exactly the same of the demands estimates in Div. El Teniente. The production program on which the modernization plan is to be based on, is directed from the CODELCO.

The amount of the copper production in Div. El Teniente is scheduled to be almost constant but due to the decline of copper contents of the ore, with the increasement of the hardness of the ore rocks (primary rock), the production program indicates the increase in the Workshops Dept. Namely, in the Foundry Shop, 5,540 tons of the productions in 1986 shall be projected to 8,000 tons in 1989. In the Plate Shop, 4,554 tons of 1986 to be projected to 6,100 tons by 1989, which indicate approximately 1.4 times increase.

2) Financial Analysis

"Discounted Cash Flow Method" is to be adopted for the Financial Analysis and 15% of IRR (Internal Rate of Return) is determined to judge the decision of the investment.

Results of the Modernizations shall be realized by a projected reduction of the costs. A comparison shall be performed in following two categories. The cost without any modernization investment, which in other words, with existing facilities and equipments, also by the dense operations with increase of personnels.

The cost with the modernization investment and also by the operation with higher productivity to attain the projected production target.

The difference of the above two categories shall be taken as the profit due to the modernization.

The conditions of the calculation are that the depreciations to be 10 years and the remainder of the value to be 5%.

★ Foundry Shop

The proposed investments of the facilities to attain given production program are

Swing Grinder with Constant Peripheral Device	4 sets
High Frequency Grinder	6 sets
Turn Table	4 sets
Amounts of the investment	US$ 156,000.

The effects of the Modernization Investment would be foreseen in the areas of Industrial Safety Improvement, Environment Improve, Interface and Coordination Improvements between Shops and relevant processes, especially in the field of material distributions and transportation, and also resulted in the Motivation Increase of the employees, which are difficult to evaluate quantitatively but are surely significantly expectable.

While these qualitative effects are hard to take into consideration in the Financial Analysis, the analysis is to be conducted on the directly calculable Man-Power Costs and Fixed/Indirect Costs.

To accomplish the target productions without any modernization investment, shall be attained with the increase of the personnels to have more of operation density. The personnels with the production increasement of 40% shall be estimated as 204 as total in the Foundry. Also, in indirect cost, the Maintenance & Service would require additional 10 personnels due to the production increase, in which 85% shall be covered by the Foundry Shop cost.

While in the case of modernization investment, due to the productivity increase, the total personnels shall be limited as 198, where reduction of the man-power to be 6 persons. The results of the calculation of IRR in the Discounted Cash Flow Method indicate about 16%. (for details, see Chapter 4 in the Final Report)

★ The Plate Shop

Items of the Modernization Investment		
Flux-cored Wire Gas-shielded Arc MIG Welding Machine		18 sets
Submerged Arc Automatic Welding Machine		1 set
Positioner & Manipulator	each	1 set
CO_2 Gas Distribution Piping System		
Amount of the investment	US$ 467,000	

Without any modernization investment, to accomplish the target production increase, the total amount of the personnels are estimated as 124. Also, 15% of 10 personnels increase in the Maintenance & Service shall be covered by the Plate Shop cost.

While in the case of the modernization investment, the increase of the welders would be discounted due to the productivity improvement, the totals are estimated to be 99, which indicates reduction of 25 personnels.

Results of the IRR calculation in the Discounted Cash Flow Method indicate about 22%. (for details, see Chapter 4 for the Final Report)

The results from the Financial Analysis show in the Finishing Process in the Foundry, that the available investment would be small because the expected decrease of manpower rather being small and in the Plate Shop, the prospects of the new investments are significant due to the considerable increase of the welding productivity.

For the reference, the summation of the investment of both the Foundry and of the Plate Shop would indicate IRR of 21%, which is sufficiently high in the Workshops Department as a whole.

3) Economic Evaluation

The CODELCO is a national corporation to represent the Republic of Chile and responsible to be a leader in the area of the mining industries of the country. Of the production amount of copper, the CODELCO composes 80% of the country, which is 1 million tons annually.

The percentage of the mining products in the export of the Republic is 50–60%; as for the copper shows 40–50% that indicates the importance for acquirement of the foreign currency of the country.

Cost competing capability of the CODELCO is fairly good in comparison with the foreign countries, also in superior position even compared with other mining enterprises in Chile.

The confirmed deposits in Div. El Teniente indicate the life of the activity will continue over 100 years, provided keeping 300,000 tons annual production of the present level; the Div. El Teniente is expected to have a stable activities for longer period in the CODELCO.

Investments projects of the CODELCO is fairly huge as compared with other national corporations, which affect considerably to the Chilean Economy. The amount is about 200 million US dollars annually.

Though the Modernization Project under study, is intended to the production processes in the Workshops of Engineering Service Department, the new innovations in technology and in management will surely contribute to activate the enterprise and to the progress of the country.

It should be stressed that the CODELCO shall have a responsibility as a national corporation to raise technical level of the industries in the country and also, as a leading company in the Republic of Chile, the CODELCO shall be responsible to demonstrate and to maintain high level of technology in the country.

The present investment project under implementation or planning are

* Expansions of Mines and Concentrators
* Replacement of the Floatation Installation in Sewell
* Carem Tailings Dam Construction
* Replacement of Convertors in Caletones
* Exhaust Gas Process in Caletones

Future investments corresponding to the production increase program, will be directed to

* New Mining Technologies, Energy Saving Systems and Environment Control.

5. Conclusions & Recommendations

5.1 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 deposites 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 services including the supply of the mining machines and equipments 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 Workshops 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 are 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 automations 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.

5.2 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 varieties 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.

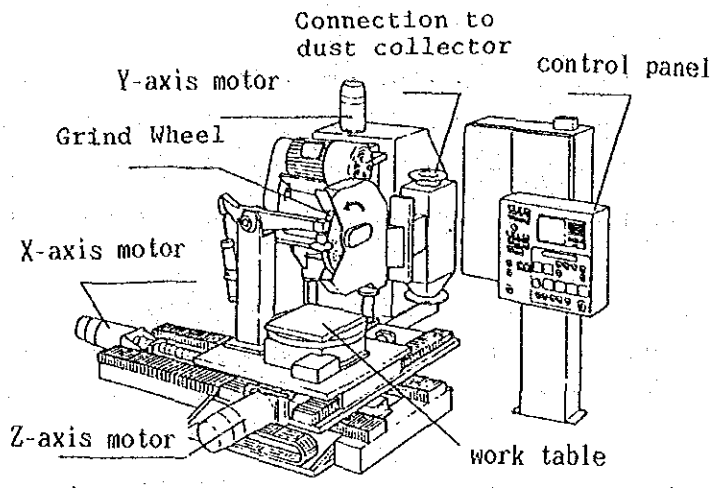
And to facilitate the maximum welding efficiency, the down-hand weld shall definitely be employed, for which a Positioner and a Manipulator shall be introduced to acquire efficient continuous work.

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 Peripheral Speed Device, the other being an adoption of the High Frequency Grinder. The constant peripheral 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.

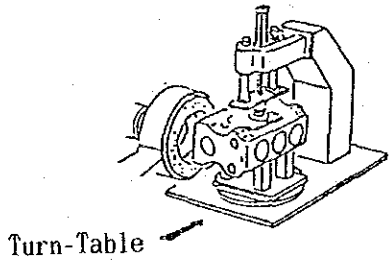
The high frequency grinder is excessively lighter compared with the conventional type, with good maneuverbility and high revolutions, thus contributing to the efficiency.

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 cored wire open arc 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.



Four-face CNC Automatic Grinding Machine

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



Four-face Grinding

5.3 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 Workshops 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	each 1 set
CO_2-Gas Distribution Piping System	
Amount of Investment	US$ 467,000.

5.4 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 hardwares 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 grindings.

The Foundry Process is a field of industrial technology, where enhances precious history and tradition and accumulated experiences and know-hows sustain present casting technology. Despite importance in the area of technology, as the work process accompanies dust, excessive heat, smoke and fume, it is difficult to get out from the image of the heavy, dirty work of previous century primary industry. While other shops of the Workshops Dept. are steadily transferred from manual work to semi-automatic, automatic process and even to the automation/un-manned 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 movements 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 4-face CNC Automatic Grinding Machine", is exceptionally expensive at present stage (US$ 375,000); "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 Machine 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-installation cost of existing Shot Blast), while unsignificant in productivity gain due to the exclusions 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 gloval context of the philosophy in the Workshops Dept. as a whole. The items to be analyzed shall include a CNC Automatic Grinding Machine 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 Surface 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 Un-Manned Automation shall be discussed.

5.5 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 personnels in the continuous activities, it would be difficult to attain expected results without intended concentration of the total motivations.

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 hardwares of equipments are 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 Workshops Dept., designated as the year of Software Renovations.

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 Management 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 demands, expanding the company operations and thus, acquired profits can contribute for the progress of the society as well as for the improvements of the life of the personnels in the whole enterprise.

As for a slogan, QA represents exact conformance to the customers' requirements and QC to be the persistent endeavor 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 troubles.

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 attitute 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 minds through entire stages of the production developments.

Engineering Pre-Study and the Design Review are among the effective ways and the creations 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 endeavor 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 environments or abrupt change of the weather, during the implementations. When the difficulties arise, easy compromise at the down-stream of the organization shall not be permit-

ted; 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 managements.

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 cooperations 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 every one 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 members 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.

5.6 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 1987–1989. To make sure the productivity increase by new investment of automations & Semi-automatic 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 fulfillment 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 members 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 equipments 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 Workshops 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 coordinations and transportations 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 increase and then, a policy of introduction of unmanned automations 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.