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UNITED NATIONS

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

CHOICE AND FORMULATION OF TECHNOLOGICAL PROCESS ROUTES FOR IRON AND STEEL PRODUCTION IN BOLIVIA BASED ON DOMESTIC RAW MATERIALS AND NATURAL RESOURCES

(SI/BOL/85/802)

CONTRACT NO. 85/59

FINAL REPORT

1986

TECNIBERIA

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INDEX

I. SUMMARY AND CONCLUSIONS

1.1 Purpose of the Study
1.2 Contents
1.3 Summary and Conclusions about the Local Conditions

1.3.1 Background
1.3.2 Market Study
1.3.3 Available resources in Bolivia related to the iron and steel project

1.4 Summary and Conclusions about Selection of Alternatives

1.4.1 Iron ore and limestone
1.4.2 Eventual Alternatives
1.4.3 Continuous Casting (Alternatives I and II comparison)
1.4.4 Alternative III (Rolling Mill)

1.5 Summary and Conclusions about Project Formulations

1.5.1 Alternatives Selection Criteria
1.5.2 Project Definition
1.5.3 Labor
1.5.4 Infrastructure
1.5.5 Financing-economic study

II. PREVIOUS STUDIES, MARKET AND RESOURCES

2.1 Introduction

2.2 Information available on studies carried out

2.2.1 Background
2.2.2 Content of the Studies
2.2.3 Comparison of the McKEE, COBRAPI and Unidad Promotora studies

2.3 Market Study. Past and Present Consumption

2.3.1 Main Steel Consumption Sectors in Bolivia
2.3.2 Consumption distribution
2.3.3 Main Products Consumed
2.3.4 Existing Rolling Mills
2.3.5 Analysis of the Market Study made by Unidad Promotora
2.3.6 Demand curves of simulation prepared by the Technical Commission of the Directorate
2.3.7 Projection of demand for the Future

2.4 Available resources in Bolivia in relation with the Siderurgical project

2.4.1 Introduction
2.4.2 Iron Ore
2.4.3 Manganese Ore
2.4.4 Limestone
2.4.5 Possibility of manufacture of charcoal
2.4.6 Natural Gas
2.4.7 Electric power
2.4.8 Water
2.4.9 Transport means
2.4.10 Human resources

2.5 Bibliographical information

III. SELECTION OF ALTERNATIVES

3.1 Introduction
3.2 Mining and Preparation of Iron, Limestone and Lime

3.2.1 Iron Ore
3.2.2 Limestone and Quicklime

3.3 Possible Alternatives

3.3.1 Introduction
3.3.2 Alternative I
3.3.3 Alternative II
3.3.4 Alternative III
3.3.5 Total consumption of ferric matter

3.4 Alternative I

3.4.1 Charcoal requirements and cost
3.4.2 Charcoal Blast Furnace
3.4.3 LD Converter

3.5 Alternative II

3.5.1 Direct Reduction Processes Selection
3.5.2 Midrex Process
3.5.3 H y L Process
3.5.4 ACCAR Process
3.5.5 Summary of N.G. Direct Reduction Processes
3.5.6 Electric Steel Mill

3.6 Alternatives I and II comparison

3.6.1 Previous considerations
3.6.2 Determination of the number of lines of the continuous casting facilities
3.6.3 Bays
3.6.4 Description of the continuous casting machine
3.6.5 Cranes
3.6.6 Auxiliary Equipment
3.6.7 Labor
3.6.8 Required Investments
3.6.9 Manufacturing Costs

3.7 Alternative III

3.7.1 Introduction and Rolling Mill Definition
3.7.2 Description of Installation
3.7.3 Manpower
3.7.4 Required Investment
3.7.5 Alternatives I and III comparison

3.8 Bibliographical Information

3.8.1 General Revisions
3.8.2 Natural gas processes

IV. SELECTION OF ALTERNATIVES AND PROJECT FORMULATION

4.1 Criteria for Selection of Alternatives

4.1.1 Economic and Efficiency Criteria
4.1.2 Location

4.1.3 Technical criteria

4.2 Project Definition

4.2.1 Location
4.2.2 Buildings
4.2.3 List of Equipment
4.2.4 Raw Materials
4.2.5 Energy

4.3 Manpower

4.3.1 General Listing of Job Positions for Alternative I
4.3.2 General Listing of Job Positions for Alternative III
4.3.3 Local Personnel
4.3.4 Foreign Experts
4.3.5 Training Programs

4.4 Infrastructure

4.4.1 Required Means of Transport
4.4.2 New Highways, Railways and Fluvial Ports
4.4.3 Electric Power Network, Natural Gas, Water, etc.

4.5 Financial-Economic Study

4.5.1 Preliminary Observations
4.5.2 Investments
4.5.3 Financiation of Fixed Asset
4.5.4 Sales and Income Program

4.5.5 Costs
4.5.6 Working Capital
4.5.7 Profitability
4.5.8 Break-even Point
4.5.9 Foreign Currency Investment Recovery
4.5.10 Conclusions

4.6 Foreseen Implementations Planning

TECNIBERIA

UNIDO - 4177

TABLES INDEX

2.1 Foreseen Production Capacities of the Different Studies

2.2 Location of the Productive Units in the Different Studies

2.3 Investments

2.4 Specific Investment in Mining and Ore Concentration (updated to 1985)

2.5 Specific Investment in Pelletizing and Direct Reduction Plants (updated to 1985)

2.6 Specific Investment in the Charcoal Plant (updated to 1985)

2.7 Specific Investment in Blast Furnace (updated to 1985)

2.8 Specific Investment in Steel Shop and Continuous Casting (updated to 1985)

2.9 Specific Investment in Rolling Mill and the Whole Plant (updated to 1985)

2.10 Rough Evaluation of the Investments

2.11 Labour (number of employees)

2.12 Labour Productivity

2.13 Investment per Job

2.14 Bolivia: Imports of Iron and Steel Products in 1982

2.15 Bolivia: Total Yearly Figures of Consumption or Entrances of Steel Bars, Rods and Light Sections according for Several Sources

2.16 Imports of Bars, Rods and Light Sections, according to Several Information Sources (tonnes)

2.17 Per Capita Steel Consumption Steel Consumption in Bolivia

2.18 Per Capita Steel Consumption (kg/inhabitant) in Latin American Countries

2.19 Reserves and Grades of Mutun Iron Ores according to the United Nations Report (1974)

2.20 Reserves and Grades of the Mutun Iron Ores according to the McKee Study

2.21 Reserves and Grades of the Mutun Iron Ores according to Cobrapi and Unidad Promotora Studies
2.22 Maximum Positive Measured Reserves in Mutun. Grades
2.23 Exported Coluvial Ore. Tonnages, Prices and Destinations
2.24 Ore Grades and Sizes of Samples for Shipment and Sales Specifications of the recoverable
2.25 Distribution of the Recoverable Reserves of Iron Ore Clods per Fe Content (Eluvial Ore)
2.26 Eluvial Ore Samples with Phosphorus Content Analysis (Cobrapi I Study)
2.27 Lump Iron Ore Tonnage Distribution per Phsphorus Content (Eluvial Ore)
2.28 Weight and Fe Content of the Coarse Size Fraction of the Run of Mine Eluvial Ore Samples
2.29 Weight and Fe Content of the Fine Size Fraction of the Run of Mine Eluvial Ore Samples
2.30 Weight and Grades of the Concentrates obtained through Dense Liquids (Eluvial Ore)
2.31 Analysis of the Primary Ore, Concentrate and Pellets
2.32 Production Capacity and Actual Production of Charcoal in Bolivia
2.33 Charcoal Prices in Bolivia
2.34 Carbonization Alternatives analized in the McKee Study
2.35 Proved and Recoverable Reserves of Natural Gas Remanent on 1st July 1983
2.36 Remanent reserve at 1st July 1983
2.37 Transport Prices according to the Studies
2.38 Railway Fares

3.1 Summary of Investments in Mining and Iron Preparation Plant
3.2 Summary of Investments in Mining, Preparation Plant and Calcination of Limestone

3.3 Estimate of the Production Cost of Charcoal for different Charcoal Plant Sizes
3.4 Estimation of the Pig Iron Production Cost in Blast Furnace with Charcoal
3.5 Estimation of the Steel Production Cost in LD Converter
3.6 Production Capacity Yearly Increase for Main Iron Ore Direct Reduction Processes
3.7 Iron Ore Direct Reduction Capacity, Cummulative Yearly Increase
3.8 Midrex Direct Reduction Plants
3.9 Midrex Process Cost Estimate
3.10 H y L Direct Reduction Palnts (units)
3.11 Cost Estimate for H y L Process
3.12 Estimate of the Sponge Iron Production Cost through the ACCAR Process
3.13 Estimate of the Liquid Steel Fabricating Cost in Electric Arc Furnace
3.14 Electric Arc Furnace Sponge Iron Use Value Determination
3.15 Santa Cruz Delivered Billet Fabricating Cost Comparison for Alternatives I & II
3.16 Required Investment for Getting Liquid Steel under Alternatives I & II
3.17 Product Mix
3.18 Round Bar Ø 16
3.19 Round Bar Ø 20
3.20 Round Bar Ø 25
3.21 Round Bar Ø 6.3
3.22 Rolling Fabrication Cost Estimate

4.1 Disponibility of Resources and their Cost in Mutun and Santa Cruz
4.2 Rolling Mill Costs comparison in Mutun and Santa Cruz
4.3 Plant Consumptions (except Water and Energy)

4.4 Water Consumption of the Plant in m^3
4.5 Energy Consumption
4.6 Jobs Summary (Alternative I)
4.7 Jobs Summary (Alternative III)
4.8 Investments Summary
4.9 Investments Break Down by Origins (Alternative I)
4.10 Investments Break Down by Origins (Alternative III)
4.11 Investments Payment Schedule (Alternative I)
4.12 Investments Payment Schedule (Alternative III)
4.13 Availability, Return and Interests of the Credits for Fixed Assets (Alternative I)
4.14 Availability, Return and Interests of the Credits for Fixed Assets (Alternative III)
4.15 Payment and Financing Resources Schedule for Total Fixed Assets (Alternative I)
4.16 Payment and Financing Resources Schedule for Total Fixed Assets (Alternative III)
4.17 Depreciation
4.18 Investment in Working Capital in One Typical Year (Alternative I)
4.19 Investment in Working Capital in One Typical Year (Alternative III)
4.20 Cash-Flow without Financing (Alternative I). Sales Price US$ 450/Mt
4.21 Cash-Flow without Financing (Alternative I). Sales Price US$ 500/Mt
4.22 Cash-Flow without Financing (Alternative III). Sales Price US$ 450/Mt
4.23 Cash-Flow without Financing (Alternative III). Sales Price US$ 500/Mt
4.24 Cash-Flow with Financing (Alternative I). Sales Price US$ 450/Mt

4.25 Cash-Flow with Financing (Alternative I). Sales Price US$ 500/Mt
4.26 Cash-Flow with Financing (Alternative III). Sales Price US$ 450/Mt
4.27 Cash-Flow with Financing (Alternative III). Sales Price US$ 500/Mt
4.28 Equity Capital Profitability per Year
4.29 Origin and use of Founds (Alternative I). Sales Price US$ 450/Mt
4.30 Origin and use of Founds (Alternative I). Sales Price US$ 500/Mt
4.31 Origin and use of Founds (Alternative III). Sales Price US$ 450/Mt
4.32 Origin and use of Founds (Alternative III). Sales Price US$ 500/Mt
4.33 Break-even Point
4.34 Costs Structure of the Rolled Products by Origin one Typical Year (Alternative I)
4.35 Costs Structure of the Rolled Products by Origin one Typical Year (Alternative III)

TECNIBERIA

UNIDO - 4177

FIGURES INDEX

2.1 Bolivian imports or Entrances of Bars, Rods and Light Profiles according to I.N.E. and E.N.F.E

2.2 Demand Function Histogram

2.3 Normalized Consumption Function

2.4 Consumption Function Enveloping Line

2.5 Pojections Family

2.6 Comparison: National Inflation Rate
World Inflation Rate
G.N.P
Bars, Rods and Light Profiles
Consumption

2.7 Consumption Function Simulation

2.8 Unidad Promotora Projection

2.9 Technical Commission of Sidersa Projection (Optimistic D = 30%)

2.10 Technical Commission of Sidersa Projection (Pessimistic Without Increase)

2.11 Comparison Unidad Promotora (Technical Com. of Sidersa Optimistic)

09402(367)/86

2.12 Comparison Unidad Promotora (Technical Com. of Sidersa Pessimistic)

2.13 Market Forecast

2.14 Market Forecast

2.15 Histograms of the Annual Consumptiom of Bars, Rods and Light Profiles in Latinamerican Countries. (Source Ilafa)

2.16 Location of Iron Ores, Limestone and Forest Areas

2.17 General Map of the Ferritic formation and Outcrop of Limestone and Dolomite

2.18 Histogram of the P content of the Calibrated Eluvial Ore reserves

2.19 Discovered Fields in Bolivia

2.20 Electric Nets of E.N.D.E.

2.21 Water Courses and Pierced Pits

2.22 Roads and Railway Nets in Bolivia

2.23 Railway Map

3.1 Scheme of the Iron Ore Preparation Plant. Iron Ore and Water Flow Diagram

3.2 Ferritic Material Flow Diagram

TECNIBERIA

UNIDO - 4177

3.3 Midrex Standard DR Process Flowsheet

3.4 H y L III Process Flowsheet

3.5 Accar Process

3.6 Allis Chalmers Demonstration Plant Scheme

4.1 Break-even Point Determination (example)

I. SUMMARY AND CONCLUSIONS

I. SUMMARY AND CONCLUSIONS

1.1 PURPOSE OF THE STUDY

The present report made by a team of experts of TECNICAS REUNIDAS, S.A (company member of TECNIBERIA) corresponds to the contract N. 85/59 of the United Nations for the Industrial Development Organization (UNIDO), with TECNIBERIA, project number SI/BOL/85/802 and pursues the goal of preparing an execution plan for the bolivian iron and steel industry.

The first step to reach this objective was to take into account the previous studies already made by McKee, Cobrapi and Unidad Promotora, in particular from the view point of the technological processes, dimensions, recommended capacities and evaluating their technical merits with respect to:

a) Maximum utilization of the raw materials and natural resources (iron ore deposits at Mutún area, natural gas at Santa Cruz area and hydroelectric energy).

b) Applications of the most optimum choice of technology and formulation of technological process routes, taking into account the physical nature and mineralogical characteristics of the ore wealth/natural resources in the country selecting the technology based inter alia on:

b.1 Direct Reduction of Mutun iron ores after prior beneficiation and pelletizing, if necessary, using natural gas as the reductant to produce sponge iron followed by melting of the sponge iron in the electric arc furnace along with some steel scrap (produced in the steel plant itself during its cyclic operation), steel casting of billets and their rolling in a merchant-steel rolling mill to produce steel bars, rods, and light sections or profiles.

b.2 Blast furnace smelting of Mutun iron ores for pig iron production using charcoal as the reductant following the highly developed technology - mostly in Brazil-, refining the pig iron into steel in LD converter, continuous casting and rolling mill for the production of steel bars, rods, light sections and profiles.

c) Detailed study of the current home market requirements and their future projections including any export possibilities.

d) Formulation of well planned phases for the development of the iron and steel industry in the country based on possibilities such as the following:

d.1 Export of Mutun iron ores to Argentina in exchange for steel billets from the latter for re-rolling in Bolivia.

d.2 Transport of Mutun iron ores through the national rail system to Santa Cruz for its reduction using the Midrex or HYL-III process to produce directly reduced sponge iron using natural gas and its conversion into steel in electric arc furnace, casting and rolling into the finished steel rolled products.

d.3 Utilization of Mutun iron ore in the region of Mutun itself using charcoal - carbonized from the neighbour forest wood - in the blast furnace for iron smelting/production followed by LD oxygen basic steel making in the converter and subsequent steel rolling mill operation.

d.4 Formulation of the steel product-mix required for the domestic market.

d.5 Formulation of capital financing plan for the establishment and growth of the iron and steel industry.

e) For the foregoing technological alternative analysis, the following parameters must be examined:

e.1 Site location and general lay-outs of the different shops, and movement and necessities of raw materials, utilities, consumables and auxiliary services.

e.2 Materials' balance and total consumption of raw materials and intermediate products.

e.3 Consumptions of water, electric power, fuels, fluxes, scrap, etc.

f) Production costs estimates for each of the processes and their different alternatives analized in this study, in order to determine the possible cost and selling prices in the country.

1.2 CONTENTS

Taking into account the purpose of this study, it has been structured in four main chapters with the following contents:

Chapter 1.-

It contains the present summary and conclusions.

Chapter 2.-

It covers the analysis of local conditions. It has been subdivided in three sections. In the first one the previous studies carried out by McKee, Cobrapi and Unidad Promotora are analyzed. In the second one the actual bolivian market for bars, rods and light sections is studied, making a projection for mid-term. In the third section, the bolivian availability of raw materials and other resources related to the project are analyzed.

Chapter 3.-

It includes the techno-economical study of the eventual alternatives for obtaining liquid steel. The most favourable techno-economical alternative is selected and the required facilities for continuous casting and rolling mill are studied at the end of this chapter. That alternative and those facilities are compared with the other alternative of rolling in Bolivia imported billets.

Chapter 4.-

The criteria for the selection of alternative are stated again and the selected project is formulated from the view point of required facilities definition, labor force, infrastructure requirements and its financial-economic study, covering two alternatives and two hypothetical selling prices of rolled products.

The economical data are given in US dollars, having been considered an average exchange rate of one US dollar for one million of pesos bolivianos (1 US$ = 1,000,000 $b) that was prevailing at the begining of October 1985.

The tables, figures and graphics pertaining to those chapters have been included in the text and are located in the following sheet to the one they are first referred to.

1.3 SUMMARY AND CONCLUSIONS ABOUT THE LOCAL CONDITIONS

1.3.1 Background

1) The first study about the Mutun was prepared by United Nations in 1974. It collects the researches and cubages of eluvial, coluvial and primary iron ores of the iron ore deposit.

1) The bolivian iron and steel policy is defined in 1972 by the Supreme Decree N. 10521. SIDERSA (Bolivian iron and steel company) is created in January 1973.

3) SIDERSA, contracts first with McKee and afterwards with Cobrapi, the implementation of two important studies for the development of the "National Iron and Steel Project".

4) The first project of McKee (McKee I), located at Mutun, was based on a production of 450,000 t/year of rolled products to export 410,000 t/year mainly to Brazil. This project included direct reduction with natural gas (from the gas pipeline to Brazil), electric arc furnace, continuous casting and rolling mill.

5) Once revised the agreement of 1977 for the selling of rolled products to Brazil, the second McKee study (McKee II) reduced the plant capacity to 250,000 t/year, substituting the direct reduction for blast furnace with charcoal.

6) Cobrapi made its first project (Cobrapi I) with a capacity for 100,000 t/year located at Santa Cruz and based on direct reduction with natural gas. In February 1984 was issued the version II (Cobrapi II) to be implemented in two steps for 50,000 t/y and 100,000 t/y of rolled products located at Mutun and based on blast furnace

with charcoal. In both Cobrapi versions the production was only for the internal bolivian market.

7) In 1982 was created the Unidad Promotora to give push to the "National Iron and Steel Project". The mentioned Unidad Promotora issued its first report in May 1984 and the second one in February 1985. This report was based on the Cobrapi II study making the adjustment for a capacity of 78,000 t/year and located also at Mutun.

8) The priority of the Unidad Promotora Study by the Supreme Decree N. 24076 was declared on September 25th 1985.

9) The necessary investment given by Cobrapi in Dec. 1983 showed a reduction of 30% with respect to the investment of Nov. 1982. The Unidad Promotora, for calculating the investment of its project used the figures given by Cobrapi in 1983.

10) Comparing the different studies' investment figures with the international ratios one arrives to the following conclusions:

McKee (I and II). Investment comparatively high
Cobrapi I. Investment "in order" with the international ratios
Cobrapi II and Unidad Promotora. Investment comparatively low

11) The highest productivity was obtained in the Cobrapi I study with 82 t/man-year and the lowest in Cobrapi II and the Unidad Promotora study with 32 and 37 t/man-year respectively.

12) The investment per job was about 100,000 US$ in the Cobrapi I and Unidad Promotora studies. This figure is quadrupled in McKee II.

1.3.2 Market Study

13) For the market study, bars, rods and light sections, only have been considered the main consumer of these products being: drawing plants, (wire rod), civil construction, (concrete bars), metal-mechanic (bars, sections and other).

14) The actual geographic distribution of consumption is as follows: La Paz, Cochabamba, Santa Cruz, Oruro, Beni-Pando and Potosi-Sucre-Tarija.

15) Concerning the historical consumption of bars, rods and light sections, there is a big disparity in the consumption figures depending on the source (Statistics Institute, Railway Company, Consumers or ILAFA).

16) Actually there is a single re-rolling mill of some importance in Bolivia, located at La Paz. It will produce round bars from Ø 8 mm up to Ø 25 mm starting from billets of 60 x 60 mm. Its actual production with two working shifts has been deemed about 7,000-8,000 t/year.

17) It has not been foreseen that Bolivia could export rolled products to her neighbour countries.

18) There are discrepancies between the market study of Unidad Promotora and that of Comisión Técnica de SIDERSA. The last

one, considered a historical series of 21 years, while the first one considered 10 years.

19) The market projection made by Tecniberia is based on an oscillating and cyclic type of steel consumption in Bolivia, with 1985 as a minimum. It has been foreseen a recovery towards 1995, to reach again the 1969 per capita maximum consumption of 7.7 kg. (BRLS materials i.e. bars, rods, light sections).

20) The maximum consumption of BRLS materials has been deemed about 65,000 t/year, and the market for the plant is supposed to be 55,000 t/year. Considering that BRLS, represent about 35% of the total consumption, this figure is equivalent to 20 kg per capita of total steel. The actual consumption per capita of Peru and Uruguay is also 20 kg and they are producing steel time ago.

1.3.3 Available resources in Bolivia related to the iron and steel project

21) The iron ores are located in Changolla (Cochabamba) and Mutun. The deposit of Changolla has a high silica content, low Fe content (43,8%) and poor reserves estimated in six million tonnes.

In the Mutun deposit three ore types have been identified: primary, eluvial and coluvial. The cubed reserves reach: Coluvial 38.6 M tonnes, Eluvial 31.8 M tonnes and primary 175 M tonnes. Only the coluvial ore reserves of La Chalera (6.5 M t) and eluvial ore (16.7 M t) have sufficient Fe content for its direct selling after classification, this is without complementary treatments.

22) Up to date 300,000 t of coluvial ore, have been exploited out of which 133,000 t exported. From these, 50,000 t have been sent to SOMISA in 1973 and the balance to Altos Hornos de Zapla

from 1977 to 1984 with big oscillations. This goes from a maximum of 38,000 t in 1978 up to a minimum of 2,250 t in 1977. In 1985 up to October there has not been exported any quantity.

23) In accordance with every the shipment analysis, the calibrated coluvial ore fulfils the specifications of Altos Hornos de Zapla and SIDERSA does not know the actual reasons why Argentina does not carry away their yearly 1985 order (60,000 t). The Fe content of the exported ore is higher than the calculated Fe content of the reserves, and it is to suppose that they are exploiting the richest zones of La Chalera.

24) It does not exist quality control in the mine and the sieving facilities are very rudimentary.

25) The calibrated eluvial ore has similar characteristics to other ores in the international market. It has only a P content quite high but can be used in the National Iron and Steel Project.

26) In order to obtain an average Fe content of 64.5% it is necessary either mixing ore from various blocks or having an ore stock of various qualities.

27) SIDERSA has very few data of the P content in the calibrated eluvial ore and it is necessary - as previously requested by Cobrapi - to do research on the P content.

28) According to the tests made by Cobrapi it is possible to improve the fines quality (sinter feed). It is important to continue performing tests of gravimetric concentration and also to investigate if there is in Argentina (SOMISA) market for this product that could have a Fe content of 60% and P content of 0.1%.

29) It is important to implement tests to check the calibrated (eluvial or coluvial) ore behaviour in the blast furnace.

30) The primary ore would demand an expensive treatment for its concentration and subsequent pelletizing and even with this the obtained product would have a high P content (0.18%). It has not been considered for this project.

31) There is manganese ore at the Mutun area with a content of 46.3% Mn and 11.4% Fe to be used in this project. SIDERSA has a stock of 6,500 t that bought to the former mine's owner. Actually the exploitation is stopped because of the lack of market.

32) Concerning the limestone there is a deposit between Puerto Suarez and Mutun.

33) The Mutun area has a timber potential for the charcoal production of a 2.2 M Hectares forest. The natural growth is deemed in 2.5 m^3/hectare/year with a production of 74.5 m^3/hectare. The ratio wood/charcoal is 7:1. The charcoal production must be based on the reforestation and it is necessary to implement a nursery plan and the exact determination of the plantations area.

34) The bolivian proved reserves of natural gas reaches 4,730 x 10^{12} cubic feet, located mainly at Santa Cruz, Chuquisaca and Tarija departments. The actual production is about 300 million cu.feet/day, 220 million of them being exported to Argentina through pipeline. The internal price for the natural gas is 1.5 US$/1,000 cu.feet.

35) The project of gas pipeline to Brazil through Mutun is actually in study phase and its cost is about 1,000-1,200 million

US$. For that reason it is not possible to consider natural gas for Mutun in the inmediate future.

36) Concerning the electric power, Bolivia has not a high voltage interconnected network covering the hole national territory. The eastern system covers only the local area of Santa Cruz with a power of 117,600 kw produced by gas turbines. Mutun area has no bolivian supply and the electric power is bought from Brazil. The internal price is deemed as US$ 0.045/kwh and when imported from Brazil the price is US$ 0.036/kwh.

37) There is no of water problem neither in Mutun nor in Santa Cruz. In Mutun the minimum flow available when low water is 60 l/seg. The water price has been deemed as US$ 0.09/m^3.

38) The bolivian roads network is poor. Only the Departments of La Paz, Cochabamba, Oruro and Santa Cruz are interconnected through asphalted roads. Mutun has no connection by road with Santa Cruz, only through railway.

39) The railway net is not interconnected. There are two independent nets called "Andina" and "Oriental". The first one communicates with the railways networks of Chile and Argentina and the second one communicates with the Brazilian network through Puerto Suarez (30 km from Mutun).

40) The railway transport cost is different in both networks, depending on the transported product. The stretch Mutun (Puerto Suarez) - Santa Cruz has an actual cost of US$ 50-74/Mt depending on the products. The road transport is deemed now as US$ 0.15/Mt-km.

41) Concerning labor, 6 professional categories actually existing in mining and metallurgy) have been considered. Their costs go from US$ 6,747/year to US$ 2,076/year.

1.4 SUMMARY AND CONCLUSIONS ABOUT SELECTION OF ALTERNATIVES

1.4.1 Iron ore and limestone

1) The iron ore considered for the different alternatives studied in this chapter is eluvial calibrated ore from Mutun with a Fe content of 64.5%. The primary is discarded and same for the coluvial ore that had not similar quality as the eluvial.

2) It is not possible to concentrate the calibrated ores whose Fe content goes from 59.2 to 67.8%. To obtain the average quality foreseen as already has been told it is necessary to know in detail the qualities of each one of the blocks in which the reserves have been divided, to implement a mine exploitation permitting the mix of several qualities and to have regulating stocks with different qualities.

3) It has been foreseen a calibrated ore production of 150,000 t/year, being necessary to exploit 300,000 t/y of gross eluvial ore, equivalent to a capacity of 200 t/h. The exploitation machinery has been foreseen for a single working shift.

4) The foreseen crushing and sieving machinerv is basically the same considered by Cobrapi and the Unidad Promotora, making remarks on the crushing machine, sieving, thickening and transportation of the calibrated ore.

5) The investment figure obtained for crushing, sieving and ore exploitation after analysis of the required facilities, is US$ 5.58 million. The calibrated ore manufacturing cost obtained is US$ 2.5/Mt, similar to the one considered by Unidad Promotora.

6) Concerning the limestone, the investment for exploitation and calcining plant is of US$ 1.04 million.

7) For both iron and limestone exploitation, money for studies and research, prior to the begining of the works, has been accounted for.

8) The limestone and the lime costs of US$ 2.24/Mt and US$ 50.50/Mt used by Unidad Promotora seem acceptable.

1.4.2 Eventual Alternatives

9) For a yearly production of 55,000 Mt of rolled products, 61,000 Mt of billets - assuming a rolling efficiency of 90% - are required. Assuming an efficiency for the continuous casting of 95%, 64,210 t/y of liquid steel would be required. The continuous casting machine and rolling mill have been considered common to alternatives I & II.

10) For obtaining liquid steel, two alternatives have been analyzed:

- Alternative I: Blast furnace with charcoal for pig iron, later on refined into steel through an LD converter.

- Alternative II: Sponge iron (DRI) obtained by a direct reduction process followed by melting and refining in electric arc furnace.

Above alternatives are compared with an:

- Alternative III: Direct rolling of imported billets.

For the two first Alternatives, consumptions of iron ore and scrap have been calculated.

11) For Alternative I, - similar to the one foreseen by Cobrapi II and Unidad Promotora, - investments of US$ 8.4 million for the blast furnace and US$ 10.27 million for LD converter and oxygen plant have been calculated. The production costs consequently obtained are US$ 100.12/Mt for pig iron and US$ 166.9/Mt for liquid steel.

12) The analysis of alternative II includes the study of three direct reduction processes with natural gas in shaft furnace and rotary furnace (Kiln). For each of them, aspects as: process description, existing plants, ore, natural gas and other consumptions requirements, updated fabricating costs and summary and conclusions about the process.

13) Investment estimates have been reached based either on ratios given by the process licensors or on data from available technical literature.

The production costs have been obtained by applying prices in use in Bolivia to unit consumptions. The lowest production cost appears for the direct reduction processes based on shaft furnace, arriving to an average cost of US$ 142/Mt of (DRI) sponge iron with 91% Fe content.

14) It has been necessary to study a complete electric steel shop in order to determine the required investment, reaching a figure of US$ 7.7 million.

15) With DRI at a price of US$ 96/Mt following with an electric arc furnace -with 80% DRI and 20% scrap-, a liquid steel

fabricating cost of US$ 225.3/Mt is obtained, working with scrap of US$ 110/Mt. Operating with 100% scrap one obtains a cost of US$ 25/Mt lower than operating with 80% sponge iron and 20% scrap.

16) With the prices existing in Bolivia, the steel produced in electric arc furnace would become cheaper operating with sponge iron, when the scrap price overpasses US$ 158/Mt. For scraps of lower price is more economical to load the electric arc furnace with 100% scrap.

1.4.3 Continuous Casting (Alternatives I & II comparison)

17) In order to compare Alternatives I & II a continuous casting machine -which for a maximum converter capacity of 10 t casting 100 x 100 mm billets will require 2 strands- has been studied.

18) The required equipment and buildings have been studied reaching an investment of US$ 4.1 million.

19) For Alternative I with liquid steel at US$ 166.9/Mt a Santa Cruz delivered billet fabricating cost of US$ 225.88/Mt is obtained. For Aternative II, with a liquid steel at US$ 225.28/Mt, the Santa Cruz delivered billet fabricating cost becomes US$ 243.33/Mt.

20) As a conclusion and in order to compare with Alternative III, Alternative I -consisting of blast furnace with charcoal and LD converter- has been selected as the most economical route for the production of steel in Bolivia. The selection has been influencied particularly by the low price of the lump ore to be used, only US$ 2.5/Mt. In order to take full advantage of the economics of this low price, the most suitable location for fabricating pig iron, liquid steel and billets would be Mutun.

1.4.4 Alternative III (Rolling Mill)

21) The rolling mill facilities calculation has been made on an average production of 13.75 t/h, equivalent to 55,000 t/y working two shifts or its equivalent 4,000 h/year.

22) It has been foreseen a rolling mill for the production of: wire rod Ø 6.3 - Ø 12.5 mm (25% of the production), bars Ø 6.3 - Ø 32 mm - for concrete (60% of the production), square bars 12 - 25 mm (2% of the production), round bars - Ø 10 - Ø 32 mm (4% of the production), rectangular bars- 25 x 6 mm to 50 x 6 mm -(1% of the production), angular sections- 20 x 3 mm to 50 x 6 mm (8% of the production).

23) For this wide product mix it will be required a versatile rolling mill with a wide speed range in the finishing groups so requiring driving DC Motors.

24) The rolling plan for six characteristic products has been studied in order to determine their productions from their rolling speeds and times. The conclusion that for small diameter - 6.3 to 10 mm - products it is better to begin with 80 x 80 mm billets instead of 100 x 100 billets, is clearly shown.

25) The reheating furnace, has been sized for the maximum production of the rolling mill: 30 t/h.

26) The rolling mill itself, consists of:

- One three high roughing mill Ø 500 mm rolls.
- Five two high preparing mills Ø 350 mm rolls.
- Six two high finishing mills Ø 300 mm rolls for thick products.

- One seven stands finishing group for thin products from Ø 6.3 mm to Ø 10 mm.

27) The investment analysis gives a figure of US$ 26.7 million.

28) When comparing Alternatives I & III we have the following:

Alternative I	Billet cost price: US$ 225.88/Mt Rolled product fabricating cost: US$ 263.1/Mt
Alternative III	Imported billet with a FOB price of US$ 185/Mt. Then, when custom duties, transportation and handling costs are added, a Santa Cruz delivered price of US$ 297.13/Mt is reached, and consequently a rolled product fabricating cost: US$ 342.32/Mt.

29) The rolled product fabricating cost differential will be US$ 79/Mt in favour of Alternative I. This figure does not include depreciation, overhead or financing expenses. These items are studied in detail in Chapter 4.

1.5 SUMMARY AND CONCLUSIONS ABOUT PROJECT FORMULATIONS

1.5.1 Alternatives Selection Criteria

1) The basic criterium for the selection of alternatives has been the economic, in order to avoid a bigger investment. From this viewpoint the most economic alternative (the lowest investment) is the Alternative III of rolling mill with imported billets.

2) Notwithstanding, Alternative I provides the lowest fabricating cost per ton of rolled product. Depreciation, overhead & financing expenses excluded.

3) Alternative I has another technical advantage i.e. to use a well known technology in the area (neighbour countries).

4) Concerning the location, the blast furnace, the LD steel shop and the continuous casting must be located at Mutun to take profit of the low iron ore cost and to avoid the transportation of the liquid pig iron.

5) Nervertheless, the rolling mill costs are lower (US$ 8.2/Mt) if the rolling mill is located at Santa Cruz. The reason is the lower cost of the natural gas in Santa Cruz versus the fuel-oil in Mutun, when used as fuels for the reheating furnace.

6) The difference in price favourable to Santa Cruz increases when the railway transportation cost decreases.

1.5.2 Project Definition

7) A definition is given of the different required buildings and bays either in Mutun or in Santa Cruz. The list of main required

equipment, with their basic characteristics is also given. The most important being: blast furnace, LD converter, continuous casting and rolling mill.

8) Separate tables, corresponding to different fabricating units additionally provide: the annual consumptions of raw materials, water, electric power and fuels.

1.5.3 Labor

9) The manpower has been broken down by categories for every new job, reaching a total of 705 jobs for Alternative I and only 181 for Alternative III.

10) A schedule for training of the foregoing personnel is outlined.

1.5.4 Infrastructure

11) As a new required infrastructure, the development of the river harbour of Puerto Quijarro as foreseen by Unidad Promotora - as well as the construction of a railway branch from Puerto Suarez to the iron and steel plant in Mutun - are first priority.

12) The electric power supply in Mutun has been foreseen imported from Brazil, because its lower price and in order to reduce the necessary investment.

13) The location of the rolling mill in Santa Cruz, will avoid the transportation to Mutun of more than 3,000 m^3 of fuel every year.

1.5.5 Financing-economic study

14) For Alternative I the fixed investment cost reach US$ 59.7 million, with an estimate of 12 % of national funds and the balance 78 % being foreign currency. For Alternative III the now forecast fixed investment reaches US$ 19 million with 16 % from national funds and 84 % in foreign currency.

15) The investment payments schedule, has been distributed through a 4 years period taking into account the foreseen implementation period and the usual payment conditions given by the suppliers when the equipments are not financed by them.

16) For the financing of the fixed investment it has been foreseen a credit of 95% of the investments in foreign currency at a rate of interest of 8%, a grace period of 4 years and return in 20 equal half year payments. Alternative I would require a US$ 44.26 million and Alternative III would require only US$ 15.5 million.

This type of credit is based on the Argentina's Government offer.

17) The credit interests corresponding to the three years of project implementation have been considered as interpolated interests increasing the actual investment in US$ 4.07 millions (Aternative I) and US$ 1.2 million (Alternative III) for the pay-off. The remaining US$ 23.7 & 8.2 million respectively are assigned to the results account of the following years.

18) The sales & revenue schedule has been completed taking into account the following path of plant start-up:

Year	Percentage of maximum production
1	50%
2	70%
3	80%
4 and following	100%

For Alternative I the sales of export iron ore from the 4th year are obtained by difference between 150,000 t/y and the plant requirements. For Alternative III, the whole ore production of 150,000 t/y since year 4 is considered as sales.

19) The selling price considered for the average rolled products is -by comparison with an average international figure of US$ 400/Mt- considered at two levels of US$ 450 & 500/Mt for a sensitivity study purpose. For the export iron ore a price of US$ 14/Mt has been considered as given by Unidad Promotora.

The commercial expenses for rolled products have been estimated 4% and for the iron ores: 11% plus US$ 3.8/Mt as transportation to harbour.

20) in both Alternatives, total variable costs are obtained of US$ 10 million for the first operating year and US$ 20 million from the fourth year on.

21) The working capital is US$ 1.8 million for Alternative I and US$ 0.68 million for Alternative III.

22) Concerning the profitability of the investment as measured through the Internal Return Rate (IRR) for Alternative I, a

figure of 7.4 % is obtained for a sales price of US$ 450/Mt and another of 10.4 % for a US$ 500/Mt selling price.

For Alternative III above figures become 22.2 and 25.5 % respectively with a significant improvem nt.

23) Referring to equity, considering financing and interpolated interests, the newly obtained IRR are:

Alternative I (sales price US$ 450/Mt): 8.3 %
Alternative I (sales price US$ 500/Mt): 16.5 %
Alternative III (sales price US$ 450/Mt): 36.6 %
Alternative III (sales price S$ 500/Mt): 51.8 %

24) The profitability of the equity in conventional terms, is a minimum of 8.8 % for Alternative I with sales price of US$ 450/Mt, and a maximum of 110.9 % for Alternative III with sales price of US$ 5000/Mt.

25) The (BEP) (break-even point) measured on average production n a typical year (51,340 Mt/year) goes in Alternative I from 42,050 Mt/year with a rolled product sales price of US$ 450/Mt till 33,320 Mt/year with a sales price of US$ 500/Mt. In Alternative III the B.E.P is placed on production figures of roughly 50 % of above figures.

26) The investment in foreign currency has been assumed that will be paid-off in less than three (3) years for Alternative I and less than two (2) years for Alternative III.

27) As a summary, Alternative I when compared with Alternative III requires more investment and gives higher fabricating

costs if we consider all items affecting the costs per tonne of rolled products.

28) The basic advantage of Alternative I, is to provide a greater yearly saving of foreign currency than Alternative III, with an estimated balance in a typical year of roughly US$ 6.9 million.

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II. PREVIOUS STUDIES, MARKET AND RESOURCES

II. PREVIOUS STUDIES, MARKET AND RESOURCES

2.1 INTRODUCTION

In this chapter it is collected and analized the information available in Bolivia related to the "National Iron and Steel Project".

An interesting subject that has been worth of the Tecniberia's teams attention, is the analysis of the different studies carried out up to date. This analysis is stated in section 2 of this chapter, and has been made mainly about economical aspects through ratios compared after with the ones actually used internationally.

Following, is analized the bolivian market of bars, rods and light profiles, that are the products which could be obtained in Bolivia in a first stage.

Lastly, are analized the bolivian disponibilities of raw materials and other resources related to the project as are:

- Iron Ores
- Manganese Ores
- Limestone
- Charcoal
- Natural gas
- Electric energy
- Water
- Transport means
- Human resources

2.2 INFORMATION AVAILABLE ON STUDIES CARRIED OUT

2.2.1 Background

The first study in Mutun was the report prepared by the U.N in 1974, covering the investigations and reserves of the coluvial, eluvial and primary minerals of the ore deposits. It also covers data on the manganese ore and the water availabilities in the Mutun zone.

The guidelines of the bolivian iron and steel Policy were traced in the Supreme Decree nº 10521 of October 3, 1972. To carry out the foreseen plan the Empresa Siderúrgica Boliviana, S.A. was created (SIDERSA), as a Decentralized State Company, in January 1973, through D.S. number 10670.

After SIDERSA was created, it contracts two consultants, initially ARTHUR G. McKEE, in collaboration with CIMSA, Compañía de Ingeniería Minera McKee, S.A., and later Cobrapi - Consultora Brasileira de Projetos Industriais, two important studies for developing the National iron and steel Project. The McKee study was delivered in September 1977 and included two variants:

- Rolling mill with a capacity of 450.000 t/y, as of the pelletizing of Mutun primary ore, direct reduction with natural gas, melting in electric arc furnace and continuous casting, Localization of the joint facilities in Mutun.

- Rolling mil with a capacity of 250.000 t/a as of secondary ore calibrated from Mutun, charcoal blast furnace, LD converters and continuous casting. Localization of the joint facilities in the Mutun zone.

The Cobrapi studies, likewise in two variants, were completed in 1982-1983 the first one and February 1984 the second one with the following scope:

Cobrapi I

100,000 t/v rolling capacity locating in Mutun: mining, calcination of limestone and pelletizing, and in Santa Cruz: the direct reduction plant, the electric steel plant, continuous casting rolling mill and auxiliary facilities.

Cobrapi II

50,000 and 100,000 t/y rolling capacity in two stages, Process based on reduction of the calibrated ore in blast furnace with charcoal, LD converters, continuous casting and rolling mill. Location of the joint facilities in the Mutun zone.

The justification of the first McKee Project in the Mutun zone with a solution of direct pellet reduction with natural gas, is based on negotiations carried out on that date for selling natural gas to Brazil through a Santa Cruz-Puerto Suarez gas duct and the commitment of Brazil to purchase 410,000 t/y of iron and steel products during 20 years.

On slackening the interest of Brazil in the purchase of natural gas from Bolivia, the later again negotiated with Brazil the possibility of a new contract for selling 200,000 t/v of rolled products non-flat (commercial bars and profiles), base of the second McKee variant, that does not use direct reduction with natural gas as the project is located in Mutun, where the gas-duct for Brazil would not reach.

The Cobrapi solutions are based on sales of rolled products practically only in Bolivia, locating the reduction plant in Santa Cruz due to the availability of gas. Charcoal variant (Cobrapi II) located the blast furnace and the other installations in Mutun.

In this sense the Supreme Decree 18613 of September 23, 1981 indicated that the siderurgical industry based on the Mutun ore deposits would be installed in the Department of Santa Cruz.

After carrying out both the McKee and the Cobrapi studies, and in order to bring them un to date and adequate the supply to the demand, at the same time that the iron and steel Project was pushed, the Unidad Promotora was created in 1982 through Supreme Decree nº 19151 in which SIDERSA and the Corporación de Desarrollo de Santa Cruz - CORDECRUZ jointly participate.

In May 1984, Unidad Promotora presented to the SIDERSA Directorate a report including as a solution charcoal, blast furnace, LD converters, continuous casting and rolling mill, all this to be installed in Mutun for a minimum capacity of 60,000 t/a of bars and profiles, all of which was approved and ratified by the Directorate on October 3, 1984. The final version of the study of Unidad Promotora according to this solution with a production capacity of 78,000 t/a of rolled products is dated February 1985.

With the socio-economical reform started as of the publication of Supreme Decree 21060 of August 29, 1985, the decentralization of the Corporación Minera Boliviana COMIBOL is foreseen, SIDERSA being called Compañía Minera del Oriente, with home address in Santa Cruz and depending on COMIBOL.

Lastly, on September 25, 1985, through Supreme Decree nº 24076, the Bolivian Government declares a priority on the Mutun

Integrated iron and steel Project. Said Decree aparently shows a contradiction on the technical solution to be adopted, since on the one side the following bases are set in the provisions:

- Location: Mutun

- Process: Reduction in blast furnace based on charcoal, LD converter, continuous casting and rolling mill (Technology, adopted in the Basic Project of the Unidad Promotora).

However, in Article 1 it is stated that the Unidad Promotora the Siderurgy will define the basic project taking in consideration technologies adapted to the optimum productive scale, ecological factors and above all economic factors.

To summarize, the basic information analyzed is composed of the two versions of each of the studies carried out by McKee and Cobrapi, together with the solution of the Unidad Promotora.

Also consulted have been the comment reports to the study Cobrapi I carried out by Technical Assistance Advisors of the Government of Mexico and the Advisor Dr. Emil Lieberman, comments to the study of Cobrapi II by the Technical Commission of the SIDERSA Directorate and the Technical Report on the second Advice Stage to SIDERSA by Engineer Joaquín Gatz.

We have also been provided with the results of the characterization tests of 200 t of calibrated eluvial ore from Mutun, against direct reduction H y L III.

Lastly there is also included a variant appearing in the publication of the Cartagena Board of Agreement dated March 29, 1985, publication J/DI/70 on "Evaluation of the Andean Siderurgical

Industry" which foresees a capacity of 100,000 t/a of wire rod, bars and profiles, starting from sponge iron, electric arc furnace and continuous casting.

2.2.2 Content of the Studies

1) McKee Study

This study comprises the largest base information available in SIDERSA in different aspects of the iron and steel project, such as examination and analysis of the Mutun primary and secondary ore, study of soils and flora the Department of Santa Cruz, infrastructure, etc.

It is an important work presented on 13 volumes, some of them with over 2,000 pages, with the following content:

Volume I.	Summary
Volume II.	Mining an Geology
Volume III.	250,000 t/year Integrated Siderurgical Plant
Volume IV.	450,000 t/year Integrated Siderurgical Plant
Volume V.	Direct reduction
Volume VI.	Charcoal
Volume VII.	Concentration and Pelletizing Plant
Volume VIII.	Infrastructure
Volume IX.	Market
Volume X.	Services
Volume XI.	High Administration and Human Resources
Volume XII.	Economical and finance analysis
Volume XIII.	General Specifications

As activities subcontracted by Mckee we must mention the tests of ore concentration, carried at the University of Minnesota, prereduction trials carried out in the Midrex laboratories and H y L and volume VI (Charcoal) which went to firm Hunt, Leuchars and Hepburn Ltd. of Johannesburg, South Africa.

Due to their importance for comparison effects, we will consider as two independent variants the alternatives of 450,000 t/a (pelletizing, direct reduction, arc furnace) and 250,000 t/a (charcoal, blast furnace and LD converter).

2) Cobrapi I Study

It consists of a series of partial reports of which it has been possible to consult 4 and 6 tomes, these last presented in 13 different volumes, with the following content:

IPM-02 (Vol. I)	Final market report
IPM-02 (Vol. IV)	Final market report. Direct investigation questionnaires
IPT-02	Partial technical report. Final resources report.
IPT-09	Cost of the rolleo product unit.
Tome I.	General Presentation. Summary.
	Part A. Background
	Part B. Summary
	Part C. Presentation
Tome II.	Market and plant capacity.
	Part A. Internal market

Part B. Foreign market
Part C. Plant capacity

Tome III. Resources.

Part A. Consumptions
Part B. Fluids

Tome III. Resources.

Part C. Electric energy. Volume I

Tome III. Resources.

Part C. Electric energy. Volume II

Tome III. Resources.

Part D. Labor

Tome IV. Location of plants and transport

Part A. Location of plants
Part B. Transport

Tome V. Technology.

Part A. Mining
Part B. Iron ore, pelletizing. Calcination, hydration

Tome V.	Technology.
	Part C. Direct reduction
	Part D. Electric steel plant
	Part E. Bar and Profile rolling plant
	Part F. General layout
	Part G. Production flowgrams
Tome V.	Technology.
	Part H-1 Auxiliary services. Vol. I
	Part H-2 Auxiliary services. Vol. II
Tome V.	Technology.
	Part H-3 Auxiliary services. Vol. III
Tome V.	Technology.
	Part I. Planning and development
	Part J. Synthesis of the integral project
	Part K. Drawing and chronogram of implantation
Tome VI.	Financial-economical study.
	Part A. mathematical model
Tome VI.	Financial-economical study.
	Part B. Financial-economical study
	Part C. Socio-economical evaluation

It includes concentration and pelletizing tests in CVRD, Midrex and H y L (USIBA plant).

The market study was subcontracted to the bolivian consulters CAEM - Centro de Asesoramiento Empresarial Multidisciplinario Ltd.

This study introduces as a novelty as regards McKee the location of the direct reduction, steel shop, continuous casting and rolling will in Santa CRuz with a bar and profile capacity of 100,000 t/y.

3) Cobrapi II Study

It introduces the concept of plant construction in two stages of 50,000 and 100,000 t/year capacity of bars and profiles. The location is Mutun and the technology to be used is charcoal blast furnace fed with calibrated secondary ore. It also has LD converter, continuous casting and rolling plant.

This study consists of two volumes, with the following content:

Volume I. Summary. Market and plant capacity Resources. Location of plants and transport

Volume II. Technology. Economical and financial study Socio-economical evaluation

4) Study of the Unidad Promotora

The last version brought to date to February 1985, which is the one analyzed, is based in the solution given in Cobrapi II study, taking into account the conclusion of a new market study made by CAEM.

The study consists of six volumes following a structure and methodology analogous to Cobrapi II, except that applicable to urban ordination, that is studied more deeply. The content is the following:

Volume I. Summary and conclusions

Volume II. Market and plant capacity. Resources. Location and transport

Volume III. Technology

Volume IV. Economical-financial study, socio-economical evaluation

Volume V. Urban development

Volume VI. Electric energy, forest ordination and charcoal production

5) Other reports

The report of advisors Gatz and Lieberman coincide in the conclusion. Which i[illegible]mary taking into account the low bolivian market of bar and profil[illegible]cts and the high investments required, recommends installing the rolling plant only, SIDERSA producing minerals for export. In a second stage it is foreseen to have a direct reduction plant and use of this sponge iron in an electric arc furnace.

This is the same conclusion of the report of the Technical Commissions of the SIDERSA Directorate of August 1984.

Analogous conclusions come from the report prepared by the Technical Assistance Advisors of the Government of Mexico, that in February 1984 advocated the mining development of Mutun and the manufacture of sponge iron for export, covering the Bolivian demand for siderurgical products through a rolling plant processing foreign billets as part payment for the sponge iron exported. The installation of the steel shop and the continuous casting plant would remain, in the opinion of these advisors deferred for a more favorable moment.

6) Study of the Cartagena Board of Agreement

This is the solution appearing for Bolivian within the evaluation of the Andean Siderurgical Industry of March 29, 1985, mentioning SIDERSA as a source. The solution indicated is little documented and consists, such as was summarized in section 2.1 of:

- Pelletizing plant (300,000 t/a) and direct reduction in Mutun

- Steel plants (two 20 t electric arc furnaces - 10/12 MVA). Continuous casting machine with 2 lines and rolling plant of 100,000 t/a capacity (30 t/h preheating furnace, two-three high rolling mill Ø 520 mm at 2.2 m/sec, 8 two-high stands for bars and profiles Ø 380 mm at 7 m/sec, cooling bed 42 x 7 m and 8 two-high stands for wire rod Ø 280 mm at 28 m/sec). All this to be installed in Santa Cruz.

7) Tests with Mutun calibrated ore in Pilot Plant H and L III

From November 16 to December 2, 1983 there were tested in Monterrey 200 t of calibrated eluvial ore with 65.8% in Fe, granulometry + 1/8" - 1".

These tests are deemed very interesting, as they proved the possibility of obtaining sponge iron with a high metallization without process problems. Although the gas consumption is 14 to 20% higher than that obtained with Alzada pellets and brings a larger generation of fines (25.5% of - 1/8" against 3.5% with Alzada pellets).

2.2.3 Comparison of the McKee, Cobrapi and Promoting Unit studies

1) Production capacities

Table 2.1 summarized the production capacities of gross ore, calibrated ore, pellets, sponge iron, charcoal, pig iron, liquid steel and rolled products, foreseen in the various solutions studies.

It is appreciated in said table that the solution of the Unidad Promotora coincides with the first step of Cobrapi II in the capacities of calibrated ore, charcoal and pig iron. The largest consumption of pig iron in the Promoting Unit (as the production capacity of steel is also larger), it is compensated with 12,000 t/a of the purchase of ingots.

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TABLE 2.1

Foreseen Production Capacities of the Different Studies (T/year of product for each Productive Unit)

Study		Gross Ore	Concentrated Ore	Pellets	Sponge Iron	Gross Charcoal	Pig Iron	Steel Shop		Rolled Products
Author	Date							LD Converter	Electric arc furnace	
McKee I	Sept. 77	1,500,000	860,000	840,000	567,500	-	-	-	527,400	450,000
McKee II	Sept. 77	975,000	557,900	-	-	(1) 170,000	295,000	293,000	-	250,000
Cobrapi I	Sept. 83	496,000	296,000	300,000	200,000	-	-	-	113,186	100,000
Cobrapi II (1st Step)	Feb. 84	207,000	113,190	-	-	67,900	(2) 77,000	54,320	-	50,000
Cobrapi II (Final Step)	Feb. 84	340,000	200,000	-	-	111,100	(3) 126,000	113,186	-	100,000
Unidad Promotora	Feb. 85	207,000	113.190	-	-	67,900	(4) 77,000	88,285	-	78,000
Cartagena Agreement	Mar. 85	-	-	300,000	200,000	-			(5) 113,000	100,000

(1) Consumption, 255,000 t/y. It was also foreseen to purchase 85,000 t/h of charcoal from private suppliers
(2) A pig iron excess for selling as ingot of 11,383 t/y is included
(3) A pig iron excess for selling as ingot of 12,509 t/y is included
(4) Purchase of foreign pig iron ingots 12,007 t/y excluded
(5) Estimated values

2) Location of productive units

The summary appears in table 2.2 practically only in Cobrapi I and the project made know to the Cartagena Board of Agreement foresee installing part of the productive units (direct reduction, steel plant and rolling plant) in Santa Cruz. The others locate the total plant in Mutun.

McKee foresaw the possible export of pellets through Puerto Busch. The access to this port is today impossible by land, since the road built in due time by COMIBOL is flooded, with water heights of 3 to 4 m, reason for which Unidad Promotora foresees ore exports through the new Puerto Quijarro, prevised in a location very close to Mutun.

3) Investments

The general summary of investments taken in table 2.3 for each installation of the various solutions has been taken in the respective studies, bringing to date these figures from the reference date to the first quarter of 1985, through the indices of bringing to date of costs of the equipment of M&S (1).

(1) The figure in parentheses are related with the bibliographical information appearing at the end of this chapter.

The reason given by Cobrapi fo lowering these prices is that due to the recession and the exchange of the Cruceiro against the dollar USA, could make the important decrease.

TABLE 2.2

Location of the Productive Units in the Different Studies

Study		Ore	Concen-tration Plant	Pelletiz-ing Plant	Ore shipment for Export	Direct Reduction	Charcoal	Pig Iron	Steel Shop		Rolling Mill
Author	Date								LD	Electric	
McKee I	Sept. 77	Mutun	Mutun	Mutun	Puerto Busch	Mutun	-	-	-	Mutun	Mutun
McKee II	Sept. 77	Mutun	Mutun	-	-	-	Areas I and II as showed in attached map	Mutun	Mutun	-	Mutun
Cobrapi I	Sept. 83	Mutun	Mutun	Mutun	-	Sta. Cruz	-	-	-	Sta.Cruz	Sta.Cruz
Cobrapi II (1st Step)	Feb. 84	Mutun	Mutun	-	-		McKee Study Area I	Mutun	Mutun	-	Mutun
Cobrapi II (Final Step)	Feb. 84	Mutun	Mutun	-	-	-	McKee Study Areas I and II	Mutun	Mutun	-	Mutun
Unidad Pro motora	Feb. 85	Mutun	Mutun	-	Puerto Quijarro	-	Triangle Yacu-ses-Pto. Suarez San Juan	Mutun	Mutun	-	Mutun
Cartagena Agreement	Mar. 85	Mutun	Mutun	Mutun	-	Mutun	-	-	-	Sta.Cruz	Sta.Cruz

TABLE 2.3

Investments (In US$ thousand

Study	Reference Date of the Investment	Mining & Calcining	Pelletizing	Carbonizing	Blast Furnaces	LD Steel Shop + Cont. Casting	Direct Reduction Plant	Electric Steel shop + Cont. Casting	Rolling Mill	Auxiliary Services & Administrative units	Electric Power Generation	Total Investment	Financial Costs	Total Investment	Total Investment up-dated to Jan. 85
McKee I	Sept. 77	49,499	35,272	-	-	-	76,999	88,579	106,547	71,720	69,844	500,460	70,064	570,524	890,329
McKee II	Sept. 77	24,238	-	24,119	70,793	103,198	-	-	62,911	89,744	47,661	422,664	60,936	483,600	754,680
Cobrapi I	Nov. 82	11,993	25,268	-	-	-	49,993	19,320	32,175	26,174	8,788	173,711	25,044	198,755	210,244.1
Cobrapi I (1)	Nov. 82	11,993	-	-	-	-	50,193	19,320	32,175	22,038	6,356	142,075	20,483	162,558	171,986.5
Cobrapi I (1)	Dic. 83	8,395	-	-	-	-	35,135	13,524	22,523	15,427	4,449	99,453	13,923	113,376	117,533.7
Cobrapi II (1st step)	Nov. 82	9,911	6,519	11,670	-	-	27,454	30,790	19,826	115,535	17,250	132,785	140,460.7		
Cobrapi II (Final step)	Nov. 82	9,365	-	15,996	11,000	12,150	-	-	27,454	30,790	19,826	126,581	18,249	144,830	153,202
Cobrapi II (1st step)	Dic. 83	6,232	-	7,566	4,338	7,334	-	-	(2) 15,870	18,670	(3) 4,990	65,000	9,370	74,370	77,097.3
Cobrapi II (Final step)	Dic. 83	6,556	-	11,197	7,700	8,505	-	-	19,218	15,605	19,826	88,607	12,773	101.380	105,097.7
Unidad Promotora	Feb. 85	6,232	-	5,679,1	4,338	7,334	-	-	19,218	23,634	13,709	80,144.1	11,235.3	91,379.4	91,379.4
Cartagena Agreement	Mar. 85	Incluido	Incluido	-	-	-	Incluido	Incluido	Incluido	Incluido	Incluido	Incluido	Incluido	208,000	208,000

(1) The pelletizing plant has been deleted. Consequently the utilities and electric power have been lowered. It includes a briquetting machine in the D.R. plant.
(2) In this first step the wire rod rolling mill was not included
(3) Electric power imported from Brazil. Voltage & frequency change, only, evaluated

TECNIBERIA

The Unidad Promotora takes the Cobrapi II prices of December 1983, in particular for mining and calcination blast furnaces, steel plant and continuous casting and rolled products and deems them fixed February 1985. Really the increase from December 1983 to February 1985 has been 4% that should be taken into account also in the Unidad Promotora as has been done in Cobrapi II.

In Cobrapi I there has been introduced as a variant eliminating the pelletizing plant, as according to the tests made by H y L it is possible to reduce the calibrated ore. In turn there has been an increment of the investment of direct reduction plant in US $ 200,000 value estimated for a hot, bricketing facility, of fines produced in the reduction process.

As in the case of Cobrapi II, to variant Cobrapi I has been applied the 30% discount deemed by the brazilians in December 1983.

a) Comparative Ratios

In order to analyze more in detail these investments following they are compared between each of the individual facilities, which are compared in turn with the international figures brought to date of specific investments (US $/t of year capacity) taken from the bibliography (2), (3) and (4) for plants in the range of capacities here commented. These international figures are the following:

Facility	Investment capacity US/T year for each product	Product
Ore concentration	6.6 - 66.5	Concentrated ore
Pelletizing plant	40 - 60	Pellets

Facility	Investment capacity US/T year for each product	Product
Direct reduction with natural gas	125 - 150	Sponge iron
Carbonization	160 - 320	Charcoal
Blast furnace	110 - 150	Pig iron
LD steel plants and continuous casting	165 - 195	Billets
Electric arc steel plant and continuous casting	200 - 250	Billets
Rollings mill plant	300 - 500	Rolled products

b) Mining and ore concentration

The figures that can be found in the literature go from 6.6 to 66 US$/T of concentrated ore, that means a proportion of 1:10.

This wide range is logical taking into account the very different characteristics that the iron deposits can have: the run of mine Fe content, the concentrate type to be obtained (fine, calibrated, pellet feed and the concentrates production.

The obtained value in paragraph 3.2.1.4 for the Mutún project is of 37.23 US$/T figure that in principle seems reasonable because is similar to the figure of the El Rhein Project in Mauritania (33.16 US$/T).

The figure for Mutún (37.23 US$/T could be improved appreciably in the case that the fines could be commercialized as sinter feed.

The actualized specific investment figures given by the different studies for mining and ore concentration are given in table 2.4 being all except the one given in the McKee study inside the limits considered as normal.

c) Pelletizing and direct reduction

In pelletizing according to table 2.5, specific investments are obtained brought to date in the McKee and Cobrapi I studies of 74.7 and 71.3 US $/t, surpassing by 20-25% the higher limit of 60 US $/t deemed now as reference figure in the investments by t of capacity.

Regarding direct reduction, the figures of specific investment obtained in the same table are 241.3 and 212.6 US $/t of sponge iron are 61 and 41% respectively higher than the upper limit of the investment order figure.

d) Carbonization

Four investment figures are available, taken in table 2.6. In accordance with reference (4), the standard investment in Brazil for charcoal burners through the half-orange furnace method, deemed in the Cobrapi and Unidad Promotora studies, using eucalyptus-culture, goes to about 160 US $/t of charcoal. This figure is about 30% to 60% larger than those obtained as of the Cobrapi and Unidad Promotora investments.

The larger figure obtained in McKee is justified by using higher technology furnaces albeit the figures obtained are 58% higher than those considered in Brazil.

TABLE 2.4

Specific Investment in Mining and Ore Concentration Updated to 1985

Study	Ore Mt/year	US$ x 10^3 Mt Direct investment	Specific Investment US$/Mt/ /year of Plant Capacity
McKee I	860,000	84,982	98.81
McKee II	557.900	28,260.8	50.65
Cobrapi I	296,940	8,084	27.22
Cobrapi II (1st step)	113,190	5,892.6	52.06
Cobrapi II (Final step)	200,000	6,198.6	31.00
Unidad Promotora	113,190	5,664.4	50.04

TABLE 2.5

Specific Investment in Pelletizing and Direct Reduction Plants (Updated to 1985)

Pelletizing

Study	Pellets capacity Mt/year	US$x10^3/Mt Direct Investment	Specific Investment US$/Mt/Year Plant Capacity
McKee I	840,000	62,749.1	74.70
Cobrapi I	300,000	21,407.5	71.36

Direct Recution

Study	Mt/year Sponge Iron	US$ x 10^3 Direct Investment	Specific Investment US$/Mt/Year Plant Capacity
McKee I	567,500	136,982.8	241.37
Cobrapi I	200,000	42,524	212.62

TABLE 2.6

Specific Investment in the Charcoal Plant
(Updated to 1985)

Study	Mt/year Gross Charcoal Capacity	US$x10^3/Mt Direct Investment	Specific Investment US$/Mt/Year Plant Capacity
McKee II	170,000	43,065.2	253.32
Cobrapi II (1st step)	67,900	8,974.12	132.16
Cobrapi II (final step)	111,100	13,280.8	119.539
Unidad Promotora	67,900	6,475.24	95.36

e) Blast furnace

In this facility, according to the data taken in table 2.7, the differences McKee and the others are very notable. The Cobrapi and Unidad Promotora figures are about 50% lower than those considered today as order figures (110-150 US $/t of pig iron), while the McKee ones exceed in over double that.

f) Steel plant and continuous casting

According to the summary of table 2.8, the investment figures nearest to the present reference figures are the Cobrapi I (electric arc furnace) with 15% difference.

In the others, Cobrapi II and the Promoting Unit with LD steel plant are about half, while McKee exceeds in over double the figures of investment per t of billets deemed today as normal (165-195 US $/t in LD steel plant and 200-250 US $/t in arc furnace).

g) Rolling mill plant

According to table 2.9, in comparison with the order figures of today (300-500 US $/t of rolled products), there are under the flower limit those of Cobrapi and Unidad Promotora, while McKee is within said limits.

h) Summary of investments

Table 2.10 summarizes a critical opinion on the quantitative evaluation of the investments inferred from studies analyzed.

TABLE 2.7

Specific Investment in Blast Furnace
(Updated to 1985)

Study	Pig Iron (P.I) Capacity Mt/year	USx10^3$/Mt Direct Investment	Specific Investment US$/Mt/year Pig Iron Capacity
McKee II	295,000	126,403.1	428.48
Cobrapi II (1st step)	77,000	5,145.3	66.82
Cobrapi II (Final step)	126,000	9,133.0	72.48
Unidad Promotora	77,000	4,946.1	64.23

TABLE 2.8

Specific Investment in Steel Shop and Continuous Casting (Updated to 1985)

Study	MT/year	Investment US$/Mt x 10^3		Specific Investment US$/Mt/year Billet Capacity
		LD Steel Shop	Electric Steel Shop	
McKee I	495,000		157,583.9	318.35
McKee II	275,000	184.263.3		670.04
Cobrapi I	110,992		15,982.6	144.089
Cobrapi II (1st step)	63,034	8,699		138
Cobrapi II (Final step)	110,922	10,087.8		90.94
Unidad Promotora	89,519	8.362.1		93.41

TECNIBERIA

TABLE 2.9

Specific Investment in Rolling Mill and the Whole Plant (Updated to 1985)

Study	Rolled Products Mt/year	US$x10^3/Mt Rolling Mill Direct Investment	US$ x 10^3/Mt Whole Plant Total Investment	Specific Investment US$/Mt/year Rolled Product Capacity	Total Specific Investment US$/Mt/year
McKee I	450,000	193,107.4	890.329	429.1	1,978.5
McKee II	250,000	112,329.6	754,680	449.3	3,018.7
Cobrapi I Dic. 83	100,000	26,617.7	117,533.7	266.1	1,175.3
Cobrapi II (1st step)	50,000	18,823.6	77,097.3	376.4	1,541.9
Cobrapi II (Final step)	100,000	22,794.7	105,097.7	227.9	1,050.9
Unidad Promotora	78,000	19,218	91,379.4	246.38	1,171.53
Cartagena Agreement	100,000	-	208,000	-	2,080

TABLE 2.10

Rough Evaluation of the Investment

Study	Ores Concentration	Pelletizing	Direct Reduction	Carbonization	Blast Furnace	Steel Ship & cont. casting		Rolling Mill	The whole study
						LD	Electric arc Furnaces		
McKee I	O.K.	O.K	High	-	-	-		O.K.	High
McKee II	O.K.	-	-	High	High		-	O.K.	High
Cobrapi I	O.K.	O.K.	High	-	-	-	O.K.	O.K.	O.K.
Cobrapi II (Final step)	O.K.	-	-	Low	Low	Low	-	Low	Low
Unidad Promotora	O.K.	-	-	Low	Low	Low	-	Low	Low

It has been considered that the investments are "In order" when thev differ in ±20% the rations taken in section a). They have been designated as "High" when thev are 20% higher and "Low" when they do not reach 20% those ratios.

The general summary of this first approximation, which will be justified in chapter III, is the following as regards said comparative ratios.

McKee (investments I and II):	High investment
Cobrapi I:	Investment in order
Cobrapi II and Promoting Unit:	Low investment

4) Labor

Table 2.11 compares the labor needs in the various solutions analyzed, broken down by facilities.

In order to tie these staffs with the rolled products capacity, table 2.12 calculates the productivitv given in t of rolled products capacity by persons and year, taking into account the purely siderurgical staff and the total staff (including the personnel needs making charcoal).

Maximum productivity is obtained in the Cobrapi I variant (direct reduction without pelletizing plant) with 82 t/person and year, and the minimum for the solution studies for Cobrapi II and the Promoting Unit with 32 and 37 t/person and year.

TABLE 2.11

LABOUR (Number of employees)												
Study	Mine	Pellets	Charcoal	Blast Furnace	LD Converter & cont. cast.	Direct Reduction	Electric arc furnace & c.c.	Rolling mill	Maintenance	Administration & services	Total Charcoal excluded	Total
McKee II	158	-	1,700	168	292	-	-	197	509	395	1,719	3,419
Cobrapi I	54	125	-	-	-	150	180	224	250	365	1,348	1,348
Cobrapi I (without pellletization)	54	-	-	-	-	150	180	224	250	365	1,223	1,223
Cobrapi II	54	-	1,972	128	208	-	-	224	328	193	1,135	3,107
Unidad Promotora	54	-	1,208	80	(1) 134	-	-	160	297	192	917	2,125

Note:

McKee study of direct reduction has not been considered. Because of their high production (450,000 t/y), an important scale factors down factor will apply and the labour force is not comparable with the other studies.

(1) This screw has been multiplied by 1.4 because for equipment working 24 hours a day (LD and cont. casting) it is not possible to apare one working shift:

8 hours/shift x 3 shifts x 7 days/week = 168 hours/week. Working 3 men at the rate of 40 hours/week makes a total of 120 hours/week, consequently:

$\frac{168}{120}$ = 1,4 workers/job

TECNIBERIA

TABLE 2.12

Labour Productivity

					Productivity in Tonnes of products/person and year	
Study	Rolling Capacity Mt/year	Iron & steel plant Personnel	Charcoal Plant Personnel	Total Personnel	Iron & steel plant Charcoal plant excluded	Complete Plant
McKee II	250,000	1,719	1,700	3,419	145	73
Cobrapi I	100,000	1,348	-	1,348	74	74
Cobrapi I (without pelletizing)	100,000	1,223	-	1,223	82	82
Cobrapi II	100,000	1,135	1,972	3,107	88	32
Unidad Promotora	78,000	917	1,208	2,125	85	37

As comparison, a 200,000 t/year plant based on direct reduction and electric arc furnace is estimated as requiring today about 600 persons (5), which would give a productivity of 333 t/person and year, that is, in the order of 10 times that obtained with the Cobrapi II solution and Unidad Promotora including carbonization and 5 times if only the siderurgical jobs are considered.

The 10 countries now comprising the European Economic Community have a production capacity of rolled products of 131 millions t/year and employ a total 1,143,000 person in siderurgy, which gives a productivity of 115 t/persons and year, that is, 77% higher than the theoretical one of Cobrapi II and Unidad Promotora considering siderurgical positions and three times as regards the total staff of this solution.

Lastly, table 2.13 takes the investments by work positions, In siderurgy they are about US$ 100,000/work position for the two solutions Cobrapi I and Unidad Promotora. This figure is quadruplicated in McKee II.

Also considering the charcoal kiln, the figures are appreciably reduced to a minimum of 33,800 US$/person in Cobrapi II and 43,000 US$/person in Unidad Promotora.

TABLE 2.13

Investment per Job (in 1985 US$)

Study	Iron and steel plant	Timber & charcoal plant	Complete Plant
McKee II	439,022	14,187	220,731
Cobrapi I	109,177	-	109,177
Cobrapi I (without pelletizing)	96,103	-	96,103
Cobrapi II	92,597	5,678	33,826
Unidad Promotora	99,650	4.701	43.002

2.3 MARKET STUDY - PAST AND PRESENT CONSUMPTION

To make this market study, taken as a base have been the market studies previously made by McKee, Cobrapi and the Promoting Unit, in a comparison with the data taken directly by the Tecniberia team in Bolivia.

There are also included the curves of simulation of demand prepared by the Technical Commission of the SIDERSA Directorate, deemed the most adapted to the actual situation of the Bolivia market.

Following, a general version is given of the structure and consumptions of bars and profiles, light, in Bolivia and their geographical distribution.

2.3.1 Main Steel Consumption Sectors in Bolivia

We will follow the traditional classification in use by the studies made previously. According to the classification, there exist four sectors responsible for the steel consumption in Bolivia, to will:

1) Drawing plant sector

The manufacture of which is mainly: barbed wire, screws, bolts, etc. The only siderurgical product consumed by this sector is wire rod, that in most cases is imported directlv. It is the only sector making a change in the siderurgical product (drawing), before making the manufacturing operation of the finished product. The other sectors consume directlv without transformations the products they purchase.

The sector is formed by nine ma'n companies, distributed as follows:

FANDA, KALIFRA and ATLAS LTDA in La Paz, EVEREST and KERY-NAVA in Santa Cruz, ACERBOL, HERCULES and MAFAL in Oruro and OSO LTDS, in Cochabamba.

Oruro is the large drawing plant in Bolivia, with a consumption of wire rod of about 60-70% of the total.

During the sojourn in Santa Cruz, EVEREST and KERY-NAVA were visited finding that the first is frankly decadent, going from producing 1000 t/year in 1982 to 300 t/year in 1984 The main reason indicated is the Brazil competition with the assistance of 30% to exports, which brings offering very low prices.

KERY-NAVA however, is a rising industry, with 70 persons in the staff and a production of about 3000 t/year.

2) Construction sector

Consumes only bars for concrete. Depending on the size of the company they import bars directly (large companies) or else purchase them from warehousemen (medium and small). The imports of bars for concrete are about 50% of the total bolivian imports of bars, rods and light profiles (BRLP).

At the end of 1980 there were 176 companies classified in 3 categories according to size (42 first category, 55 second and 79 third). Today it is a sector on crisis.

3) Metallomechanic sector

It shows the poor bolivian industrialization. The sector is formed by workshops and shops without large size companies, the fabrication of which mainly are light structures based on rounds for bays, liquid fuel tanks, truck bodies, trailers, etc.

METAL-MEC was visited in Santa Cruz, the fabrication of which is: tanks, wire-mesh, light structures, car bodies and profiles from plate bending. Its staff is 70 persons working in one shift and its steel consumption is 40 and 80 t/month of plate imported from Brazil.

In general this sector in supplied by distributors and wholesalers.

4) Other consuming companies

This sector covers those companies having a steel consumption of a certain importance, not used as raw material, as is the case of sugar mills, Yacimientos Petrolíferos Fiscales Bolivianos, the Empresa Nacional de los Ferrocarriles, etc.

2.3.2 Consumption distribution

The variation of the consumption distribution among the various sectors has been approximately the following in percentages:

	1977	1981
Drawing plant	16.5	24.4
Construction	64.3	58.0
Metallometallic	18.5	17.0
Others	0.7	0.6
Total	100.0	100.0

The geographical distribution of consumption is the following in an approximate percentage (1981 data).

La Paz	40%
Cochabamba	10.8%
Santa Cruz	21.1%
Oruro	20.7%
Beni-Pando	1.1%
Potosí-Sucre-Tarija	6.3%

2.3.3 Main Products Consumed

Since practically the whole consumption is imported products and there is no ruling for quality control of the siderurgical products, the variety of imported products is enormous. SIDERSA must propose the introduction of regulations in Bolivia, to standardize qualities and forms of the products.

Table 2.14 shows as an indication the structure of bolivian imports of siderurgical products in 1982. The figures of this table confirm the choice of light bars and profiles to be fabricated in the future siderurgy, as the imports (and therefore consumption) of other products, do not justify the investment and even in some cases there are no economical facilities for such small productions.

Shortening the subject only for the non flat products (BRLP), table 2.15 expresses the evolution in recent years according to the various sources available: statistics of the Instituto Nacional de Estadísticas (I.N.E) (National Statistics Institute), statistics of the Empresa de Ferrocarriles del Estado (E.N.F.E), those deriving from the direct polls to the consumer carried out by CAEM, and the ILAFA data.

TECNIBERIA

TABLE 2.14

Bolivia: Imports of iron and steel products in 1982
By origin countries
(In Mt)

	Ingots & semi-products	Bars	Wire rod	Wire & their manufactures	Light sections	Heavy sections	Rail tracks and accesories	Coils for re-rolling	Plates	Medium sheets	Thin sheets	Coated sheets	Strip	Tin-plate	Welded piping	Seamless piping	Total
G.F.R.		90		30		11	18	34					39		3	615	840
G.D.R.														96			96
Spanish North Africa						41											41
Argeria		25															25
Argentina	30	6,537	5,471	396	34	861			26	17	131				1,703	5,051	20,257
Australia									5								5
Belgium		78				143	105		39								365
Brasil		2,733	1,217	138	9	442		120	996	573	1,244	196	23	13	1,206	87	8,997
Canadá		4		5	8	6			21		31					1	78
Northern Korea				7													7
Southern Korea				52													52
Chile				30	36			118	59	184					79	30	536
Continental China				124													124
U.S.A.		22		30	2	52	185		650	6	40		31	1,147	109	2,520	4,794
Spain			102	33													135
France														193			193
Netherland							19							1,341			1,360
Italy				2							7						9
Japan		627		24	181				1,440		10,567	36	27	705	251	1,674	15,532
Perú		37		30		19	1				1					3	91
Poland							5										5
United Kingdoms				5			38		10							244	297
Rep. South Africa							321				47						368
Taiwan				191												17	208
Venezuela															197		197
Total	30	10,153	6,790	1,097	270	1,577	692	272	3,246	780	12,068	232	120	3,495	3,548	10,242	54,612

TABLE 2.15

Bolivia: Total Yearly Figures of Consumption or Entrances of steel Bars, Rods and Light Sections according to Several Sources (Mt)

	INE (Imports)	ENFE (Inlets)	Inquiries from Consumers & Importers	ILAFA
1974	17,818.2	-	-	31,438
1975	17,632.6	17,164	-	24,848
1976	24,957.4	15,437	-	18,576
1977	37,047.1	14,888	27,955.5	40,912
1978	32,233.8	38,220	35,221.8	36,241
1979	31,119.5	30,068	37,753	36,162
1980	17,962.6	42,287	35,948.3	19,772
1981	31,806.7	42,322	35,196.1	48,932
1982	19,070.8	24,740	24,843	18,419
1983	10,733.6	21,191	-	32,074
1984	7,335.0	22,378	-	-

As can be noticed, there is a great disparity in the annual figures depending on the original source.

It must be taken into account nevertheless, that since as we always speak of apparent consumption, there is no consideration of the stocks variations in the period and therefore, it does not look easy that there is coincidence of the entrance figures, according to INE or ENFE, and consumption according to the polls. Now then, the figures should always keep a relation, that does net exist in this case at all (see graph 2.1).

Besides in 1980 and in the ENFE statistics there is a difference of 12,194 t. On the one side, and the information taken by the Tecniberia team, shows entrance figures of BRLP in 1980 of 42,287 t, however, the transcription of a letter from ENFE to SIDERSA dated 13/8/84 shows a figure of 30,093 t for that year.

Attention is also drawn to the ILAFA figures for 1984 of 32,074 t, with a spectacular increase of 74% regarding 1983, when the INE and ENFE statistics show figures much lower and that besides mean a retrocession for 1983.

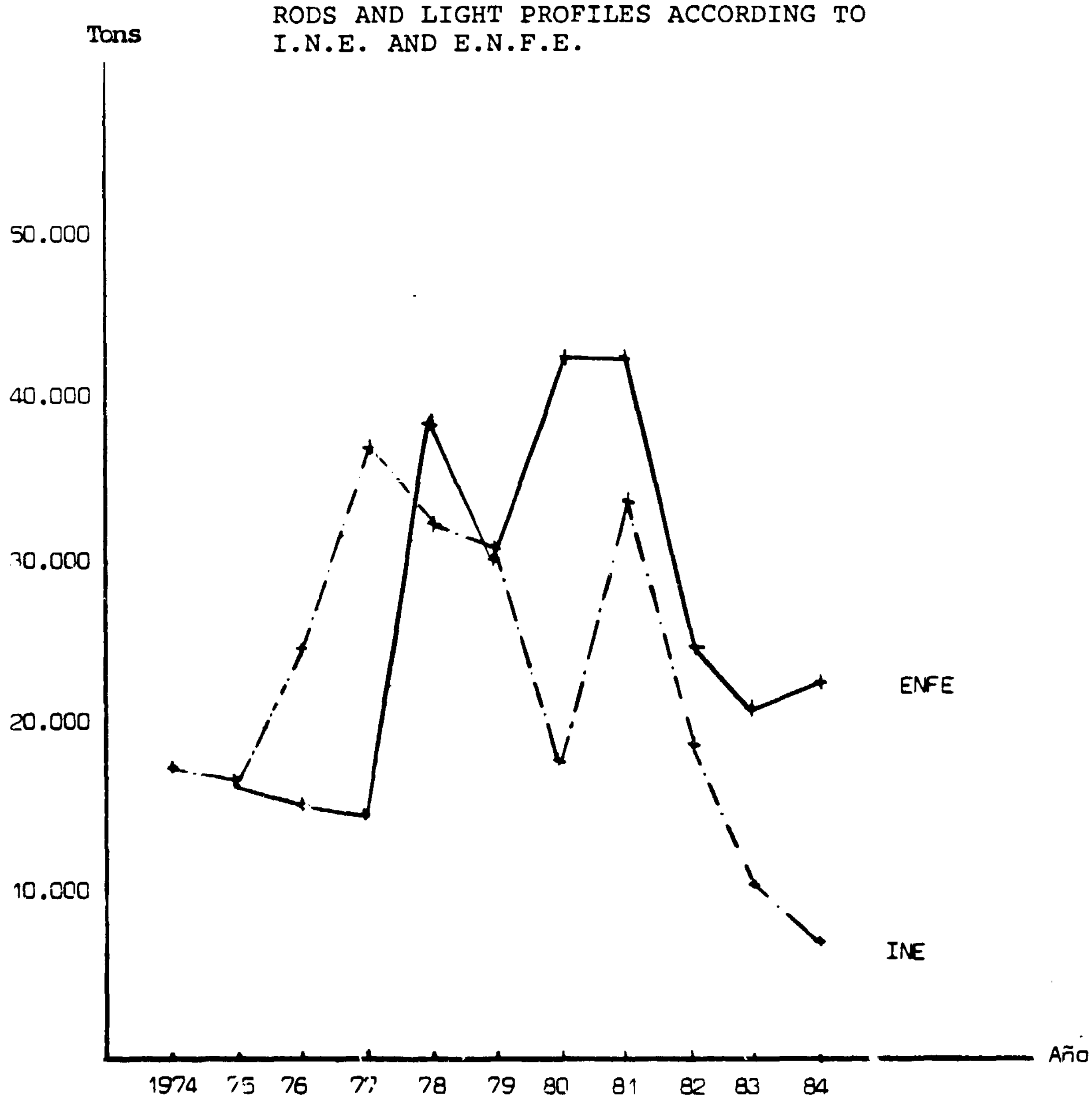
As seen in these figures, it is not easy to make market forecasts not only due to the uncertain economical situation of the country, but also because the starting data may be different depending on the origin.

2.3.4 Existing Rolling Mills

The only rolling mill existing in the La Paz zone, SUNG-SAN LTD; in El alto (La Paz) was visited, in the stage of commission and equipped with second hand equipment. It has a three-high dresser

FIGURE 2.1

BOLIVIAN IMPORTS OR ENTRANCES OF BARS, RODS AND LIGHT PROFILES ACCORDING TO I.N.E. AND E.N.F.E.



stand and five two-high stands, intermediate-finishing stands, all in line.

The rollers are 250 mmØ and 700 mm table, directly by one 750 HP electric motor.

The pushing preheating furnace is 5 t/h, precarious enough, both for insulation and because it has an only fuel-oil burner.

It starts with billets 60 x 60 mm in lengths of approximately 1 m cutting with a disc saw.

To date and in the commissioning stage, they worked one shift, with a low productivity and many problems of breakdowns and lack of spare parts (roller repair is made recharging them with weld cords). The capacity is estimated at about 15 t/shift of 8 hours, that is, 4,500 t/year in one shift. Actual production is estimated at 3,000 t/year pers shift, with a maximum of 7,000 - 8,000 t/year in two shifts.

They will only fabricate bars for concrete from Ø 8 mm to Ø 25 mm. This mill must resolve before anything else the problem of direct coupling of the motor and improve the preheating furnace.

There is no notice of the existence of more rolling mills in Bolivia except a very small one (RELAMINADORA FILAM) that uses points and is located in the Santivañez industrial park in Cochabamba.

At this point one must points out the relative importance of the SUNG-SAN rolling mill for the Siderurgical project. To date, the previous studies have considered that all the Bolivian BRLP market would be supplied by the siderurgical plant, however, and taking large figures, at this time the BRLP consumption in Bolivia is of about

20,000 t/year; if the La Paz market represents 40% approximately and that of concrete bars 50% of total BRLP consumption, it means that the present market of La Paz for bars for concrete is about 4,000 t/year, which may be supplied fully only by the small S[illegible]G-SAN rolling mill.

If it delays more than three or four years for the installation of the rolling mill of the Siderurgical Project, there is the risk that the BRLP market is then saturated.

2.3.5 Analysis of the Market Study made by the Unidad Promotora

Following are indicated the points seeming the least clear of the mentioned market study, as it is the most recent and besides it is the study that is the base of the present conception and dimensioning of the Bolivian Siderurgical Project.

a) Coinciding with the opinion of the Technical Commission of the Directorate of SIDERSA a lack of rigor has been detected in the adoption of criteria, as at the time of defining the most probable consumption (see table 2.16) to 1979 and 1981 the I.N.E. datum is taken and in 1980 and 1982 the figure given by the polls to importers.

b) There are some differences between the data used by Unidad Promotora and those taken directly by the Tecniberia team. As an example, the cement consumption is cited, in which the difference reaches 140,000 t in 1978.

TABLE 2.16

Bolivia: Imports of Bars, Rods and Light Sections, according to Several Information Sources (Mt)

Year	INE	Consumers (*)	Importers (*)	ENFE	More Reliable Figures
1974	17,433.1			not given	17,433.1
1975	16,692.7			23,567	16,692.7
1976	25,181.3			25,862	25,181.3
1977	37,047.1	27,955.5		n.g.	37,047.1
1978	32,223.8	35,221.7		38,220	32,223.8
1979	31,119.6	37,753.2		n.g.	31,119.6
1980	17,962.4	35,948.2	28,110.3	42,287	28,111.3
1981	31,806.7	35,196.1	30,841.0	46,479	31,806.7
1982	16,670.4	24,843.1 (**)	26,933.0 (**)	24,744	26,933.0

(*) From inquiries taken in 1980-81 to 100% of the firms for the period 1977-81.
(**) Inquiries taken in May 1984.

Source: INE, ENFE and inquiries.

	Cement Consumption according to Unidad Promotora	Cement Consumption according to the INE Data
1977	342.700	230.780
1978	391.600	247.350
1979	348.300	258.335
1980	346.900	246.223
1981	379.800	374.581
1982	325.800	324.925

c) Lastly, the consumption forecasts are deemed optimistic for the following reasons:

- There is no consideration of the market part to which private rolling may accede, giving production figures as if all the bolivian market were to be supplied by the Siderurgical Project.

- They considere the possibility of exporting sioderurgical products to neighbor conuntries, when according to data from the Metal Bulletin, latinamerican exports of siderurgical products is foreseen to increase 10% this year, going from 8,650 million tons in 1984 to 9,67 M. tons in 1985. Brazil will export according to forecast 6.6 M tons and Argentina 1.1 M. Besides, steel production in latinamerican countries close to Bolivia has grown in the first semester of 1985 in respect to the same period in 1984 as follows:

Argentina	+0.2%
Brazil	+7.1%
Ecuador	+14.9%
Peru	+21.4%
Uruguay	+17.7%

For all this, although there are countries like Peru, Uruguay or Venezuela with a deficit of BRLP it is not easy to believe that Bolivia is to export systematically to neighbor countries, taking into account that Argentina and Brazil are higly exceeding and Paraguay will begin producing steel in ACEPAR before the Siderurgical Project is underway.

Ocasional and punctual exports are not discarded, provided the price is competitive, but they should not be taken into account when dimensioning the Siderurgical Plant.

2.3.6 Demand curves of simulation prepared by the Technical Commission of the Directorate

Following are given the curves prepared by the Technical Commission of the Directorate of SIDERSA as it is estimated that they are more adjusted to what may be a realistic market forecast.

For preparing these curves, a historical series of 21 years (1964 to 1984) has been taken, which results more representative that that taken in the market studies made previously (concretely the Unidad Promotora considers a 10 years period form 1973 to 1982). See histogram of the demand function in graph 2.2. The mentioned histogram has been normalized by Fourier series obtaining the curve shown in figure 2.3.

Figure 2.4 gives the enveloping curves of maxima and minima of the previous function.

Figure 2.5 shown the demand projections of the market studies made to date as well as the I.N.E. data up to 1984.

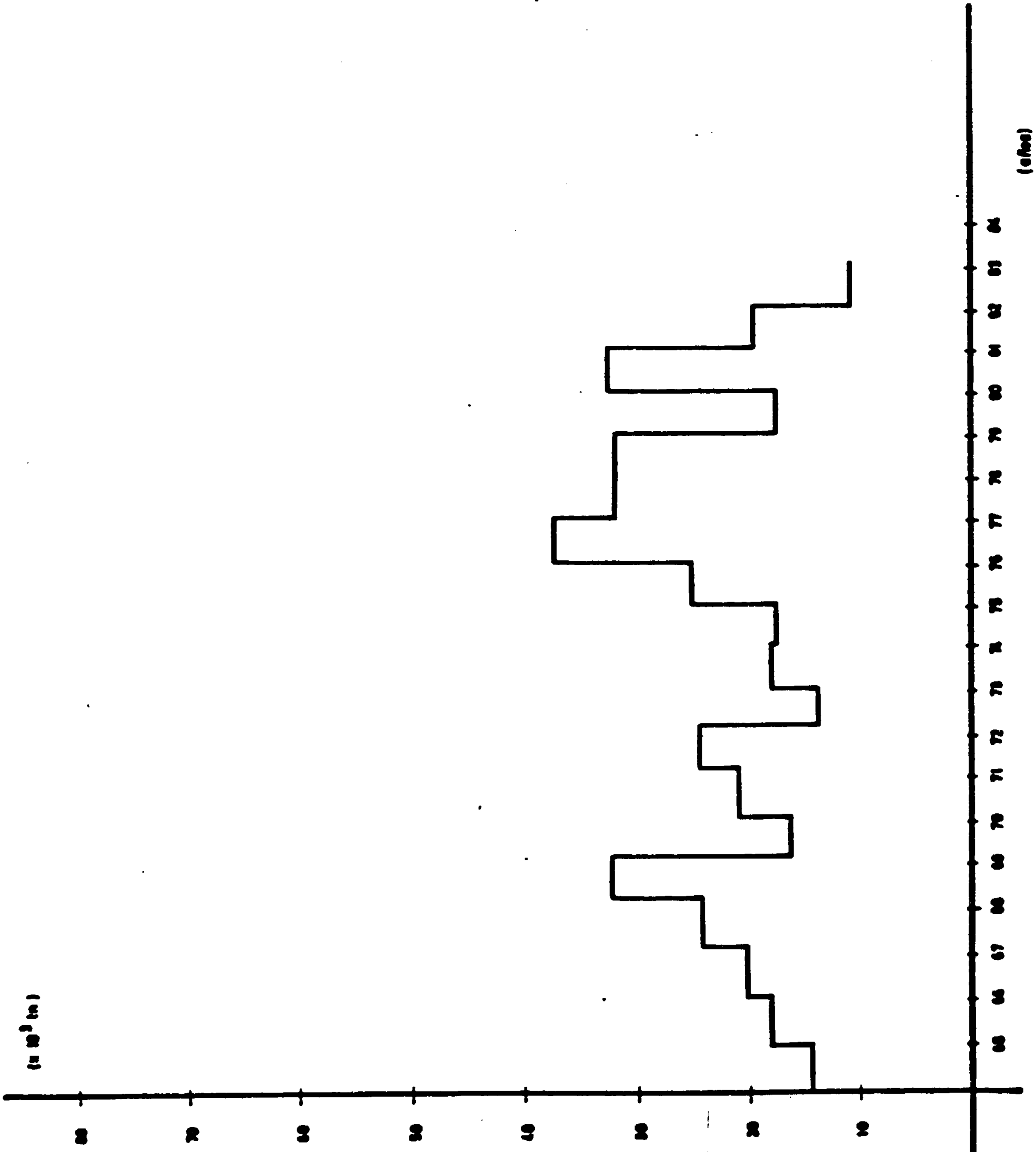


FIGURE 2.2.

DEMAND FUNCTION HISTOGRAM.

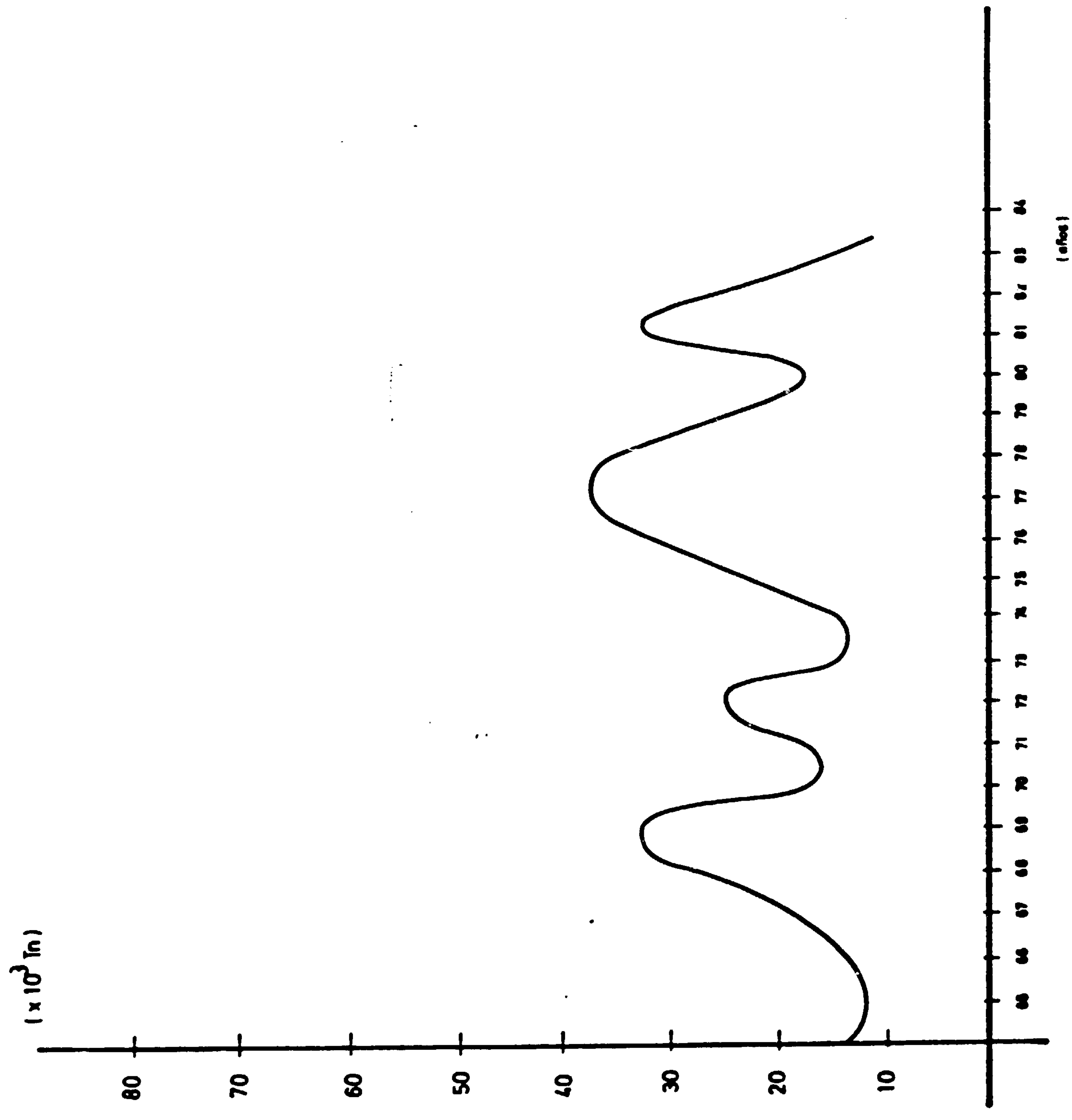


FIGURE 2.3.

NORMALIZED CONSUMPTION FUNCTION.

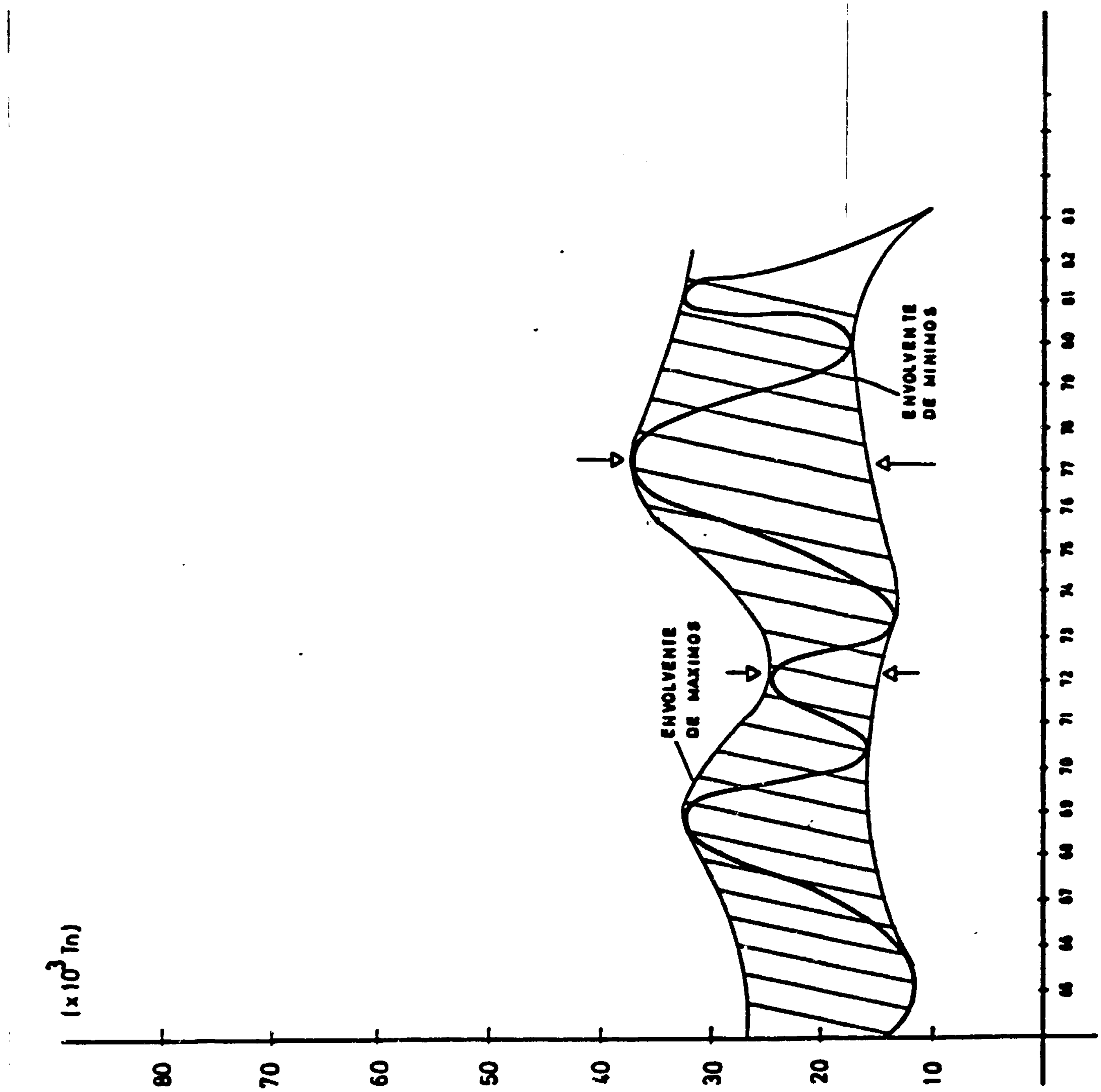
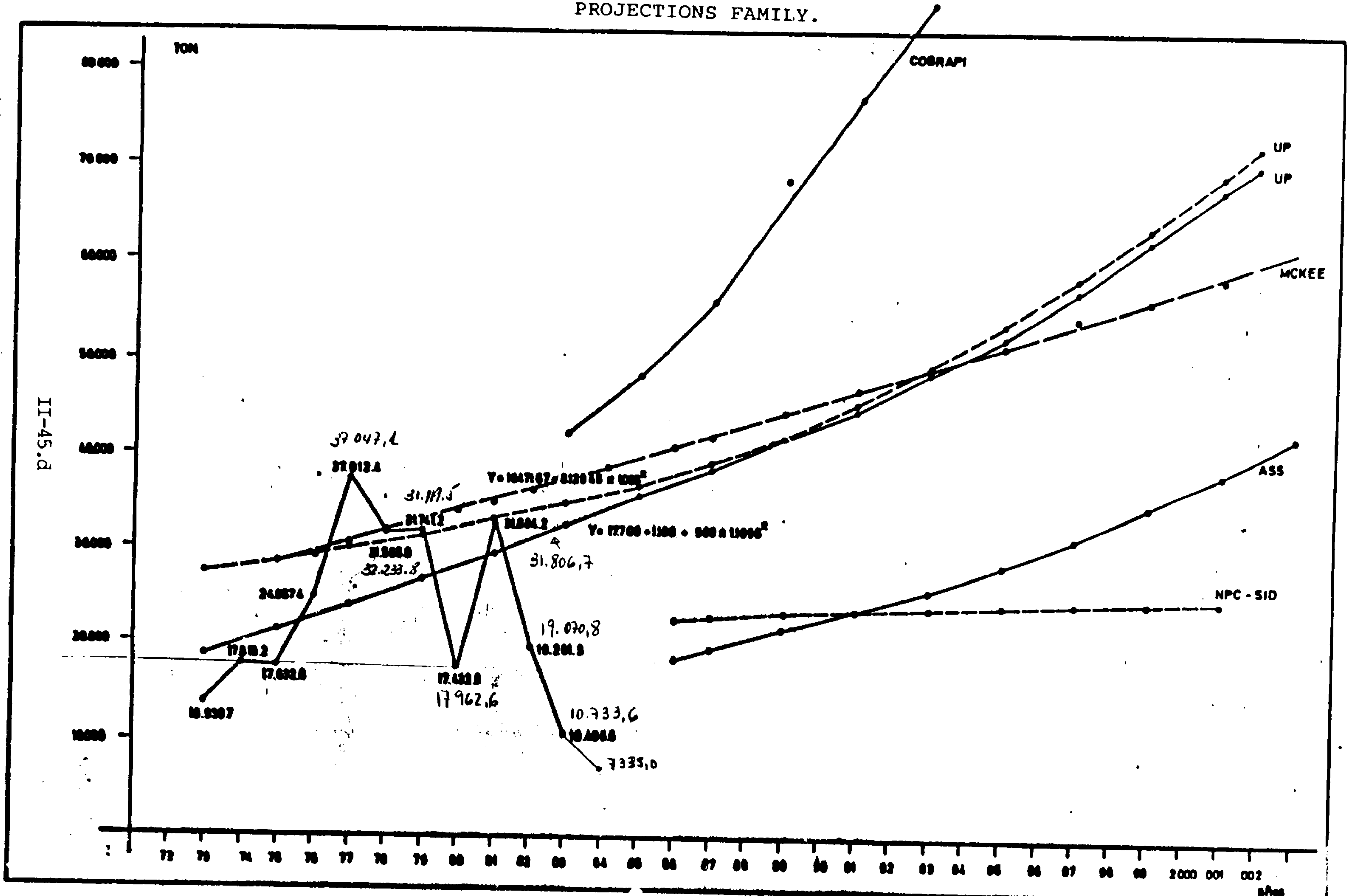


FIGURE 2.4.

CONSUMPTION FUNCTION ENVELOPING LINE

FIGURE 2.5.

PROJECTIONS FAMILY.



It is that the Cobrapi study is excessively generous when foreseeing the demand, the study of the Unidad Promotora is also enough from the present figures and McKee, having taken a series of more years, is the most pessimist of the three and therefore more adjusted to reality.

This graph shows a difference between the figures of the Technical Commission and those taken by the Tecniberia team, but as noted no year exceeds 650 t.

Figure 2.6 sets a comparison in percentage between the rates of bolivian national inflation, world inflation, the Bolivian Gross Internal Product and the bolivian consumption adjust enough to those of the G.I.P.

Figure 2.7 represents three simulation curves of the consumption function, previously calculated by Fourier series, and increasing it respectively in 10% (curve 3), 20% (curve 2) and 30% (curve 1). Likewise, there is represented the demand curve of the Technical Commission of SIDERSA.

Figure 2.8 compares the Projection of demand of the study of Unidad Promotora with the function of optimistic simulation (adding 30%).

Figure 2.9 represents the optimist projection of demand made in the study of the Technical Commission of the SIDERSA Directorate on the simulation curve increased by 30%.

Figure 2.10 is similar to the above but calculated without incrementing any percentage the simulation function.

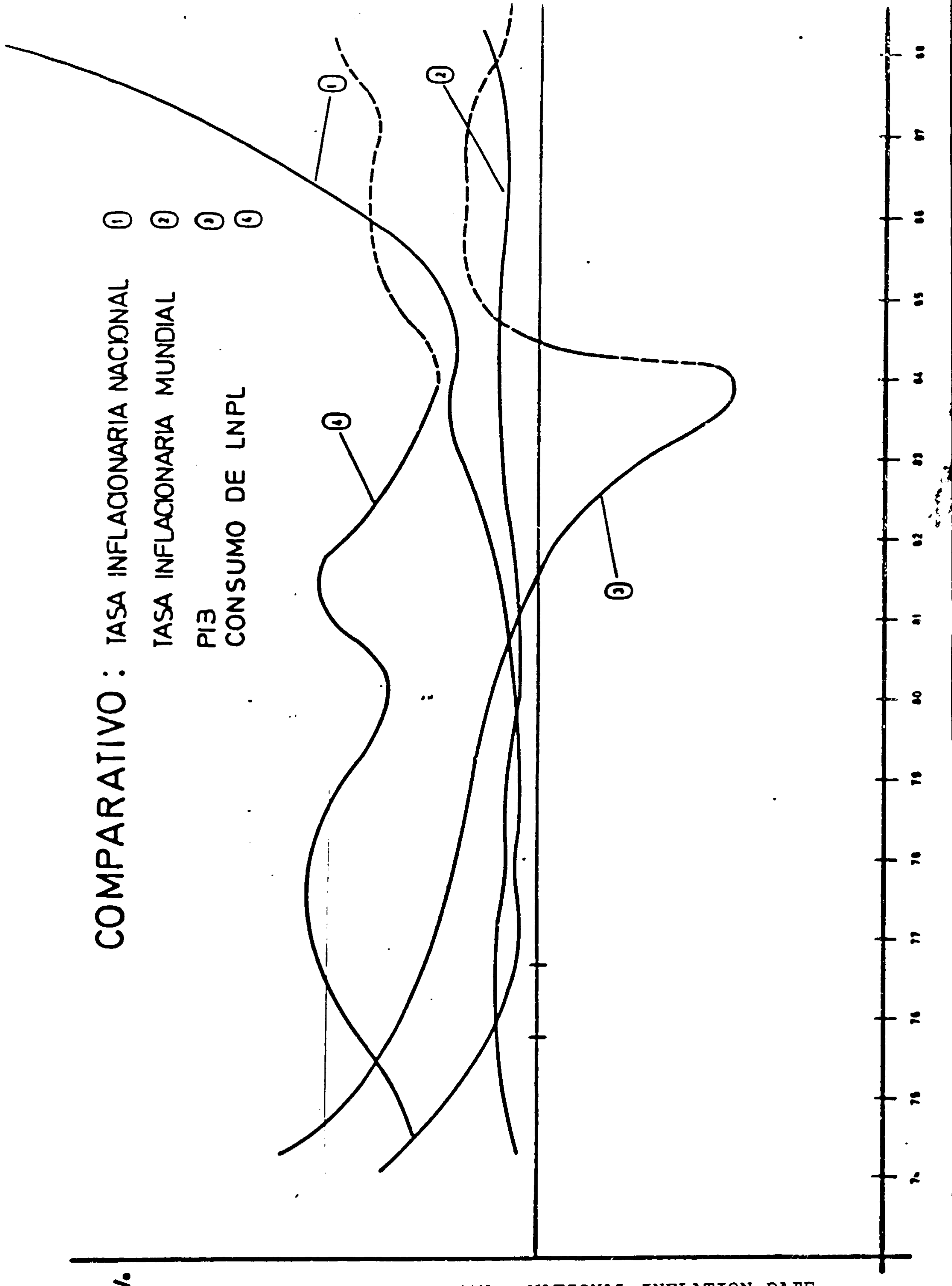


FIGURE 2. 6. COMPARISON : NATIONAL INFLATION RATE.
WORLD INFLATION RATE.
G.N.P.
BARS RODS AND LIGHT PROFILES CONSUMPTION.

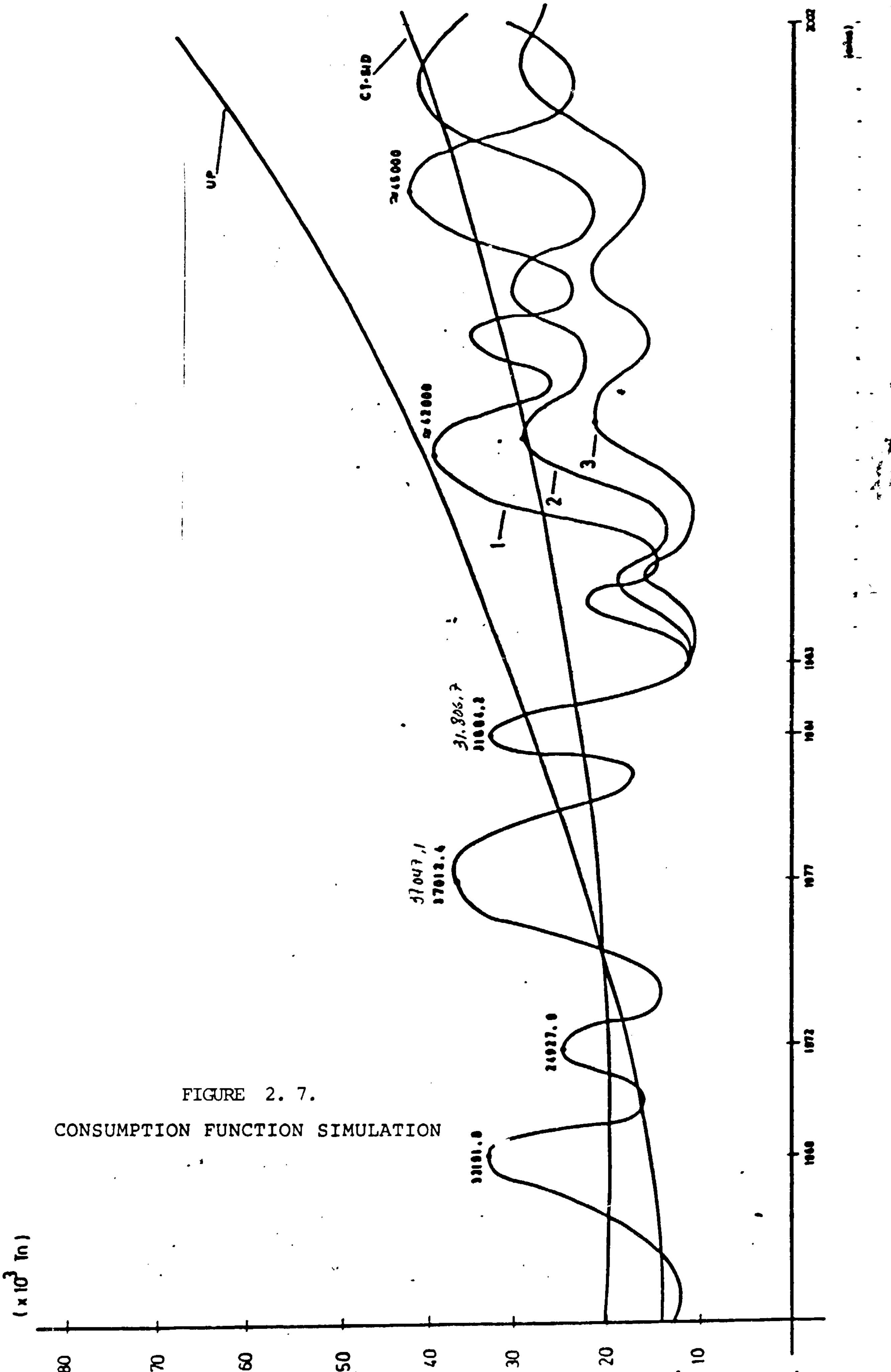


FIGURE 2. 7.

CONSUMPTION FUNCTION SIMULATION

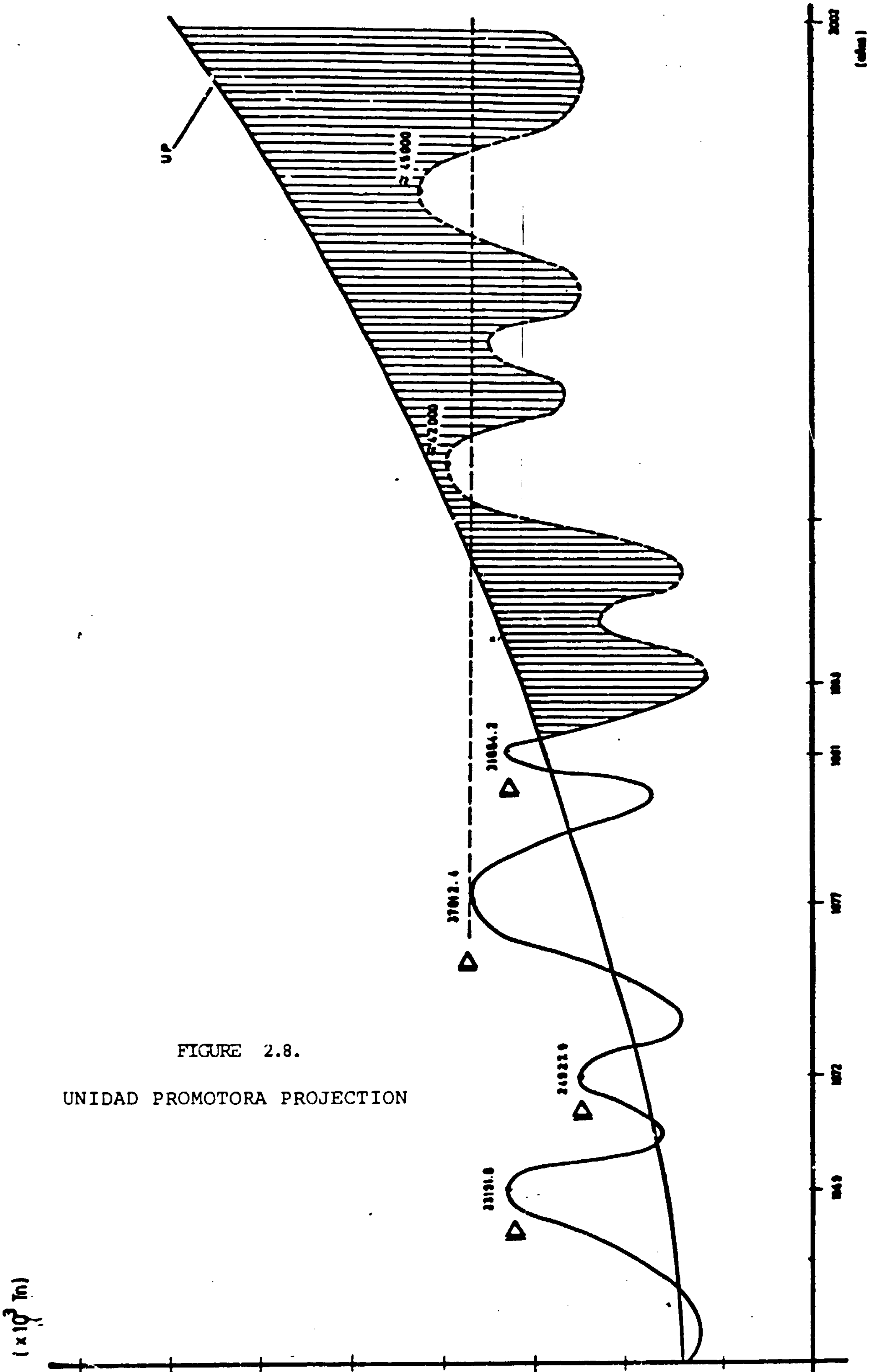


FIGURE 2.8.

UNIDAD PROMOTORA PROJECTION

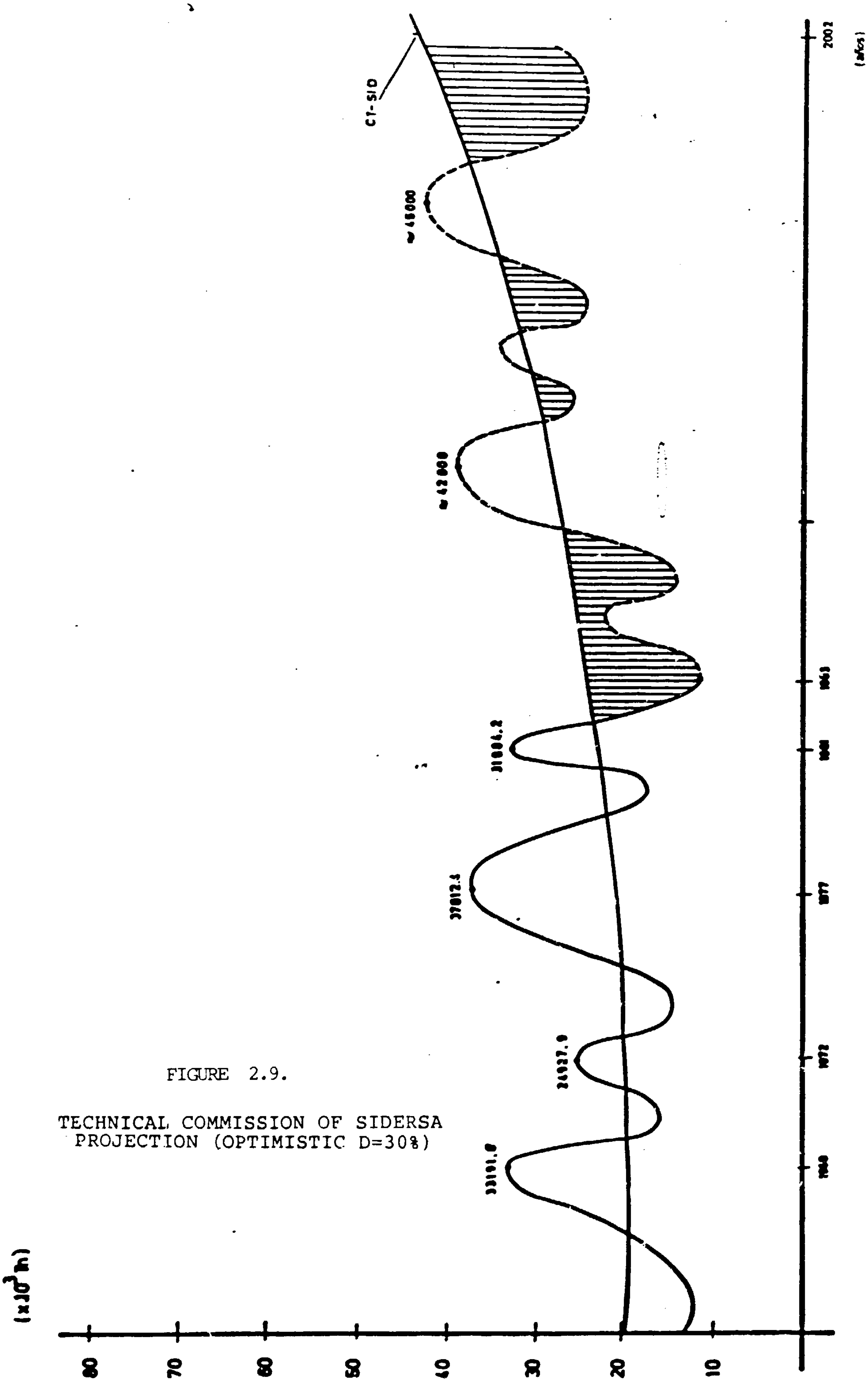


FIGURE 2.9.

TECHNICAL COMMISSION OF SIDERSA
PROJECTION (OPTIMISTIC D=30%)

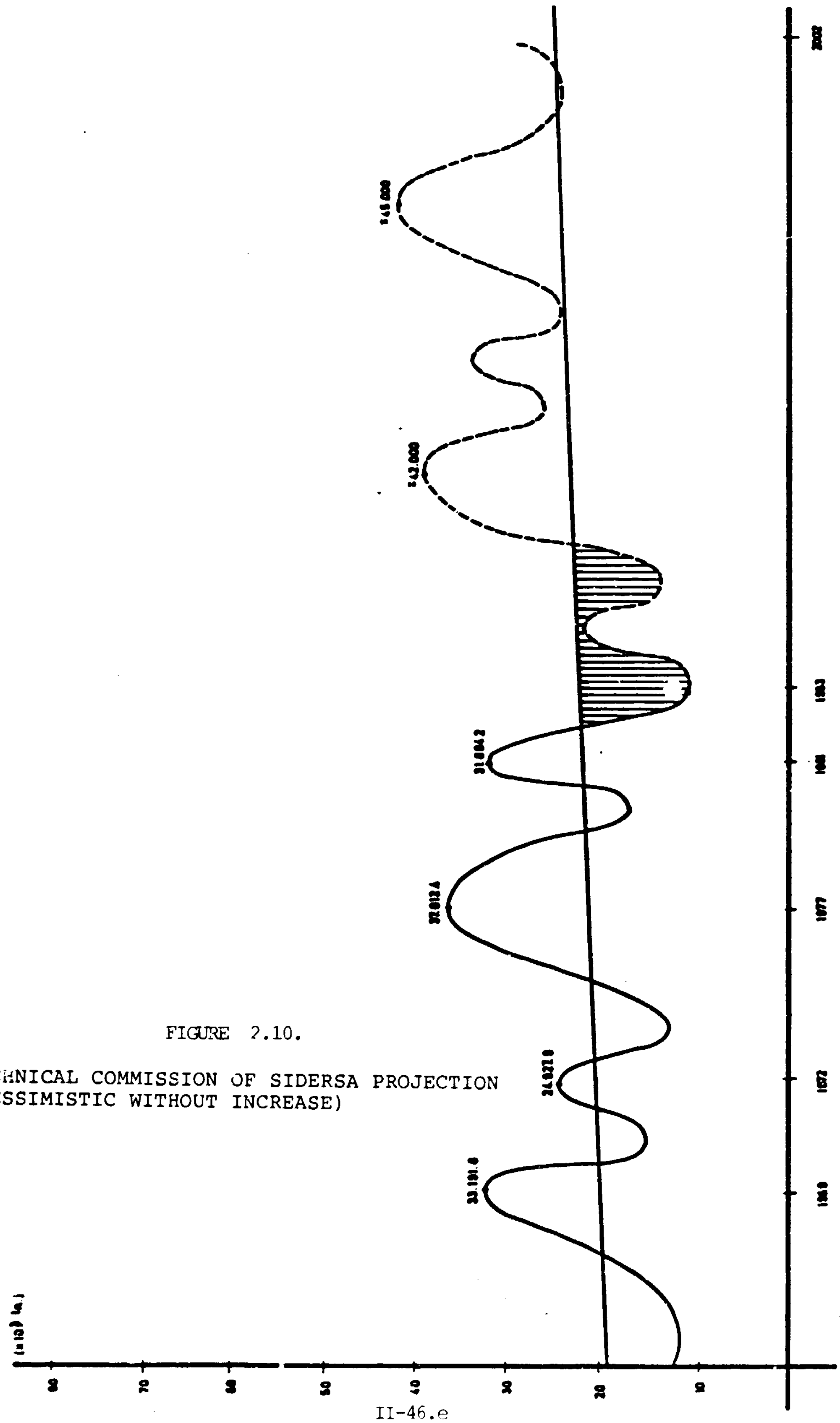


FIGURE 2.10.

TECHNICAL COMMISSION OF SIDERSA PROJECTION
(PESSIMISTIC WITHOUT INCREASE)

Figure 2.11 compares the projection made by the Promoting Unit with the optimistic projection of the Technical Commission. It is notable that in 2002, if the plant were designed according to the previsions of the excess in production would be about 25,000 t as regards the forecasts of the Technical Commission of the SIDERSA Directorate.

Figure 2.12 is ismilar to the previous one but it compares the pessimist projection of the Technical Commission. The difference in this case is about 45,000 t for year 2002.

Figure 2.13 indicates the demand forecasts calculated by ILAFA and 2.14 gives the market forecast for the siderurgical project but taking already in account the rolling mills that may exist and the market quota they have.

2.3.7 Projection of BRPL demand for the Future

Taking into account that making forecasts for the future of any market will always be a simple approximation and even more in the case of Bolivia in which as has been said there is a difference in the same data depending on the origin of the information, any criterium to make the projection is vaiid, provided it is developed with rigor, and using always the same source.

To make the projection, there is adopted as a premise, that the function steel demand is oscillating and cyclic in most countries in the world (see graph 2.15), that shows the consumption histograms of BRPL of various Latinoamerican countries according to ILAFA).

The cycle in Bolivia inferred from the period 1965 to 1984 is repeated every eight or ten years and is as follows:

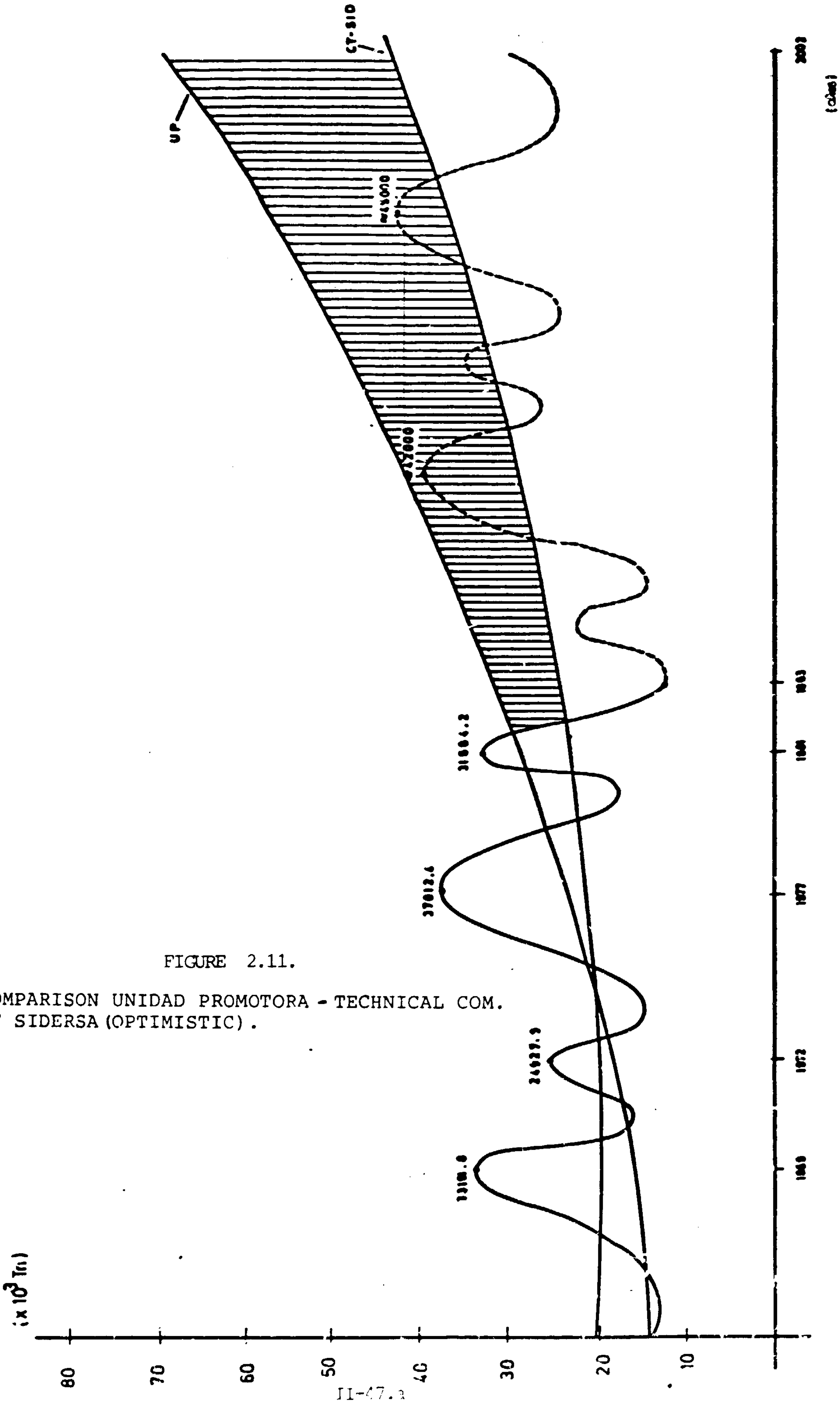


FIGURE 2.11.

COMPARISON UNIDAD PROMOTORA - TECHNICAL COM. OF SIDERSA (OPTIMISTIC).

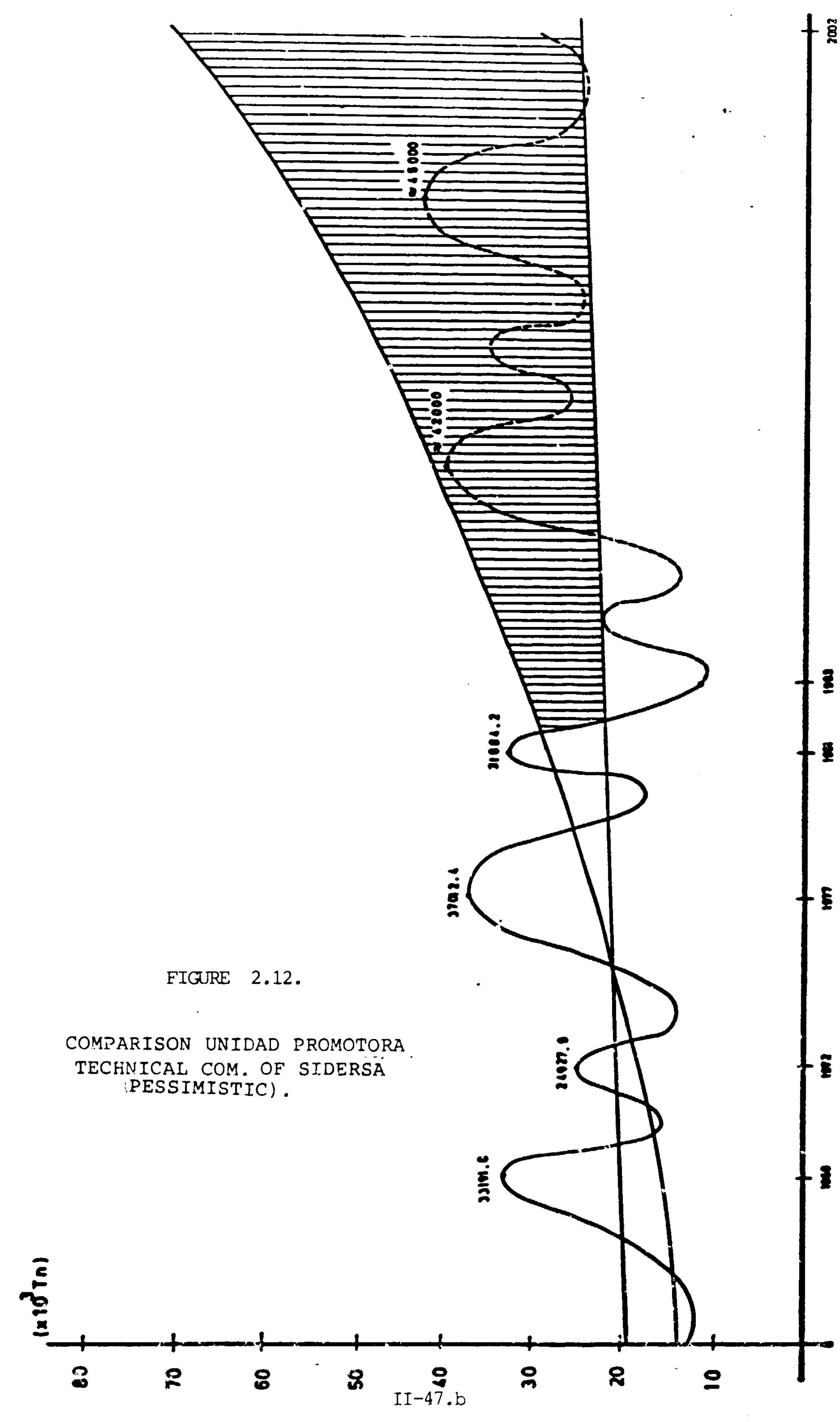
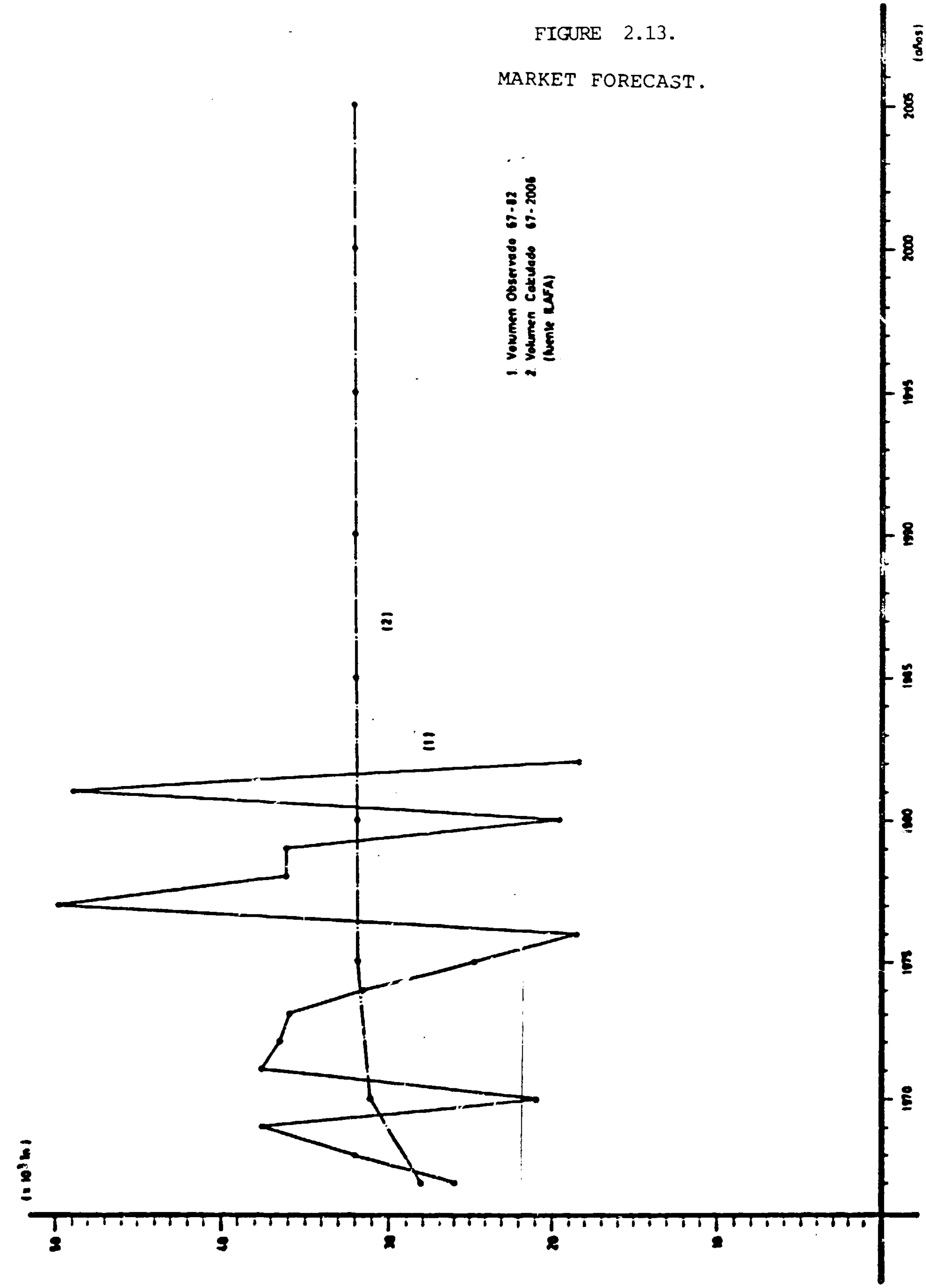


FIGURE 2.12.

COMPARISON UNIDAD PROMOTORA
TECHNICAL COM. OF SIDERSA
(PESSIMISTIC).

FIGURE 2.13.

MARKET FORECAST.



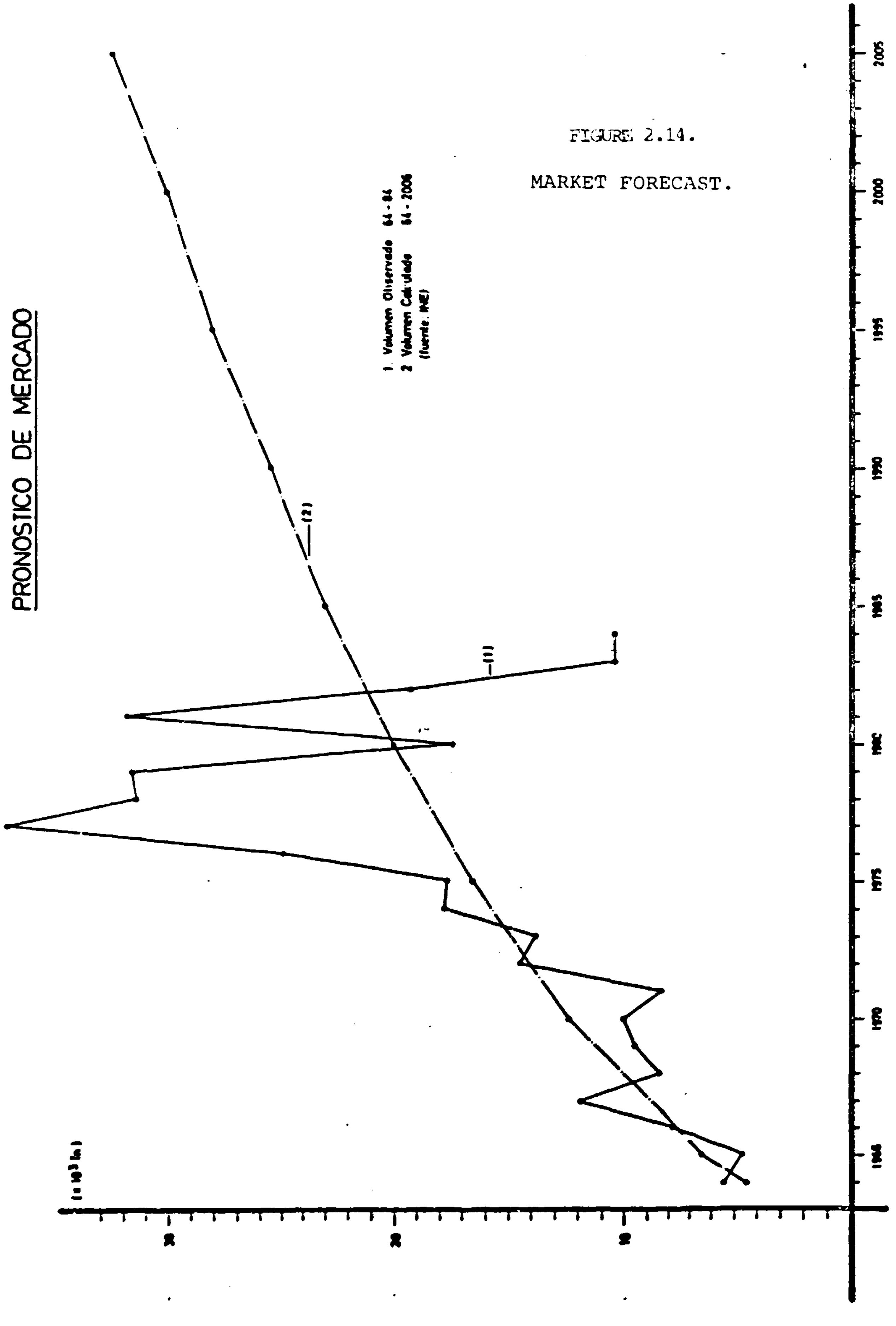
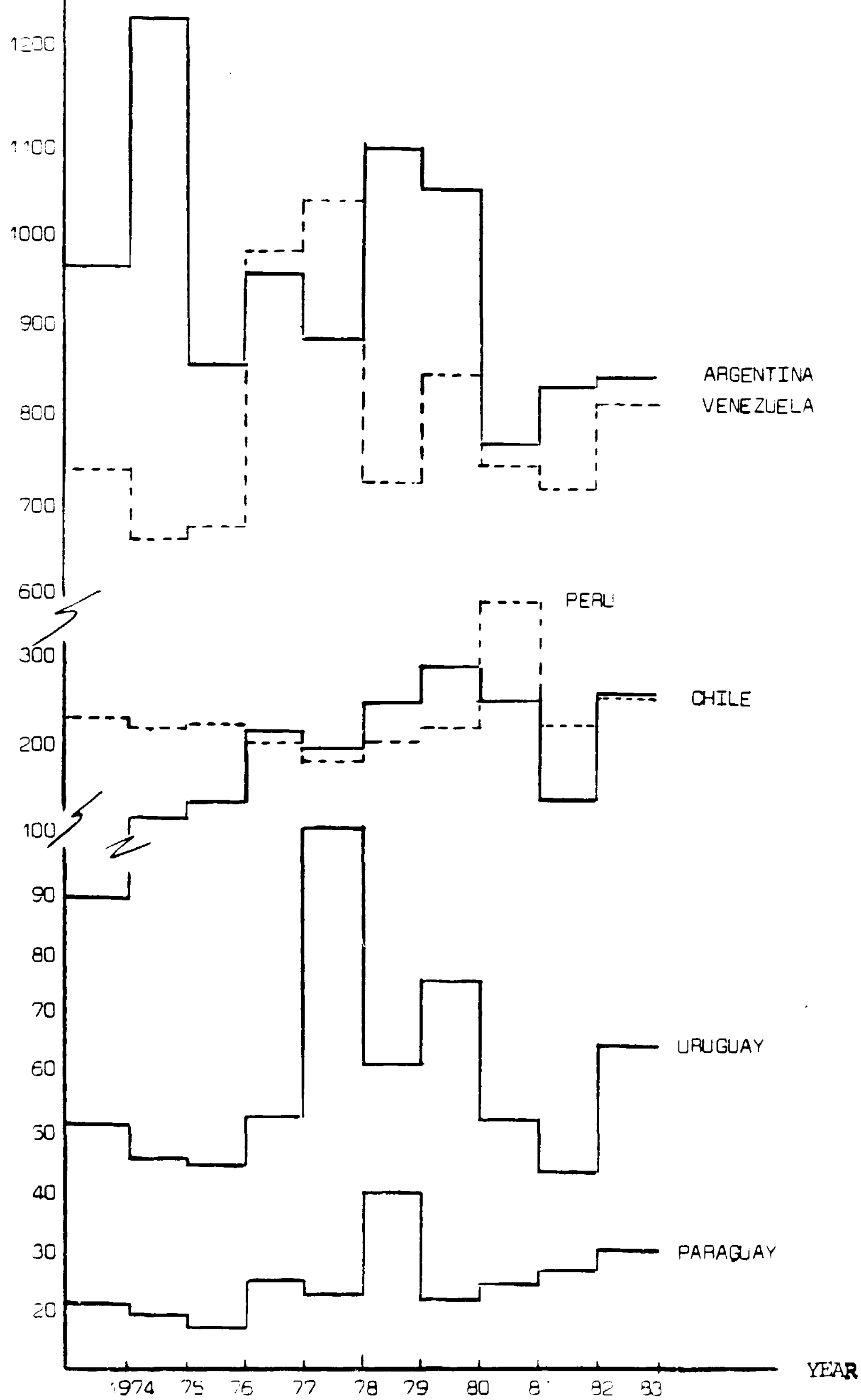


FIGURE 2.14.

MARKET FORECAST.

FIGURE 2.15.

HISTOGRAMS OF THE ANNUAL CONSUMPTION OF BARS, RODS AND LIGHT PROFILES IN LATINAMERICAN COUNTRIES. (SOURCE ILAFA).



- After a maximum there is a depression, then a maximum lesser than the previous one, then follows a depression and lastly another maximum.

Said maxima are to be calculated by means of the specific consumption of steel per inhabitant. (See table 2.17).

In 1969 (first maximum studied), consumption was 7.7 kg of BRLP per inhabitant. Eight years later, in 1977,(following maximum of the period studied), consumption was 7.17 kg of BRLP per inhabitant. Since today there is an almost absolute minimum and that recovery can not be very rapid we must consider that the next maximum will appear at the end of 10 years after the previous one, that is, in 1987, with an BRLP consumption of 20.200 t, calculated supposing that:

- The vegetative growth of the population is kept (2,668% annual cumulative).

- Consumption per capita of BRLP in that year will be 3 kg/inhabitant.

It has been supposed that the recovery of the same specific consumption level of steel of 1969 (absolute maximum with 7.7 kg/inhabitant) will be in the next maximum of the cylce, toward 1995.

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TABLE 2.17

Per Capita Steel Consumption in Bolivia (Kg/person)

Year	Persons x 10^3 Population	Total yearly Steel Consumption (Source: Metal Bulletin) Mt	Annual Consumption of BRPL (Source: INE) Mt	Total steel consumption kg/person	BRLP consumption kg/person	% BRLP* over Total
1969	4,212.1	-	32,500	-	7.7	-
1970	4,324.6	-	18,000	-	4.2	-
1972	4,541.2	-	25,000	-	5.5	-
1973	4,662.7	-	13,000	-	2.8	-
1974	4,772.2	-	17,818.2	-	3.7	-
1975	4,894.4	-	17,632.6	-	3.6	-
1976	5,026.9	-	24,957.4	-	4.96	-
1977	5,163.3	-	37,047.1	-	7.17	-
1978	5,303.8	-	32,233.8	-	6.1	-
1979	5,449.3	82,200	31,119.5	15.08	5.7	38
1980	5,599.6	50,100	17,962.6	8.94	3.2	35.7
1981	5,755.1	113,300	31,806.7	19.68	5.52	28.06
1982	5,915.8	54,800	19,070.8	9.26	3.22	34.6
1983	6,115.0	28,000	10,733.6	4.6	1.76	38.3
1984	6,252 7	29,000	7,335.0	4.64	1.17	25.3

* BRLP: Bars, Rods and Light Profiles

On the other hand, the Banco Interamericano de Desarrollo, in its annual report for 1985 on the economical and social pregress in Latin America, in some of its paragraphs says: "under the best circumstances the productive capacity will grow rather slowly, as the investment coefficient recovers from its minimum level of 1983-84"... "Thus, an important aspect of the 1985-90 period will be the attempt to recover the lost ground of the last few years as regards imports and investment; the growth, by all means would permit only a modest growth". "Since it is expected that global production increases only slightly over the growth rates of the population and the labor force, the levels of actual income per capita for 1980 might be recovered before the end of the decade".

For all the above and as has been said, it has been supposed that Bolivia will recover in the following cycle maximum, toward 1995, the per capita consumption of 7.7 kg/inhabitant. According to these forecasts, Bolivia will have on that year an approximate BRLP consumption of 65,000 t which besides taking into account that in Bolivia the BRLP represents 35% of the steel total, would represent a total steel consumption on that year of about 20 kg/inhabitant, present figure of countries like Uruguay or Peru, steel producers for many years and that Bolivia can and must reach in said period (See table 2.18).

Considering that the following consumption maximum would come toward 2005, that practically coincides with the useful life period of the plant, it is more economical not taking it into account for effects of dimensioning production, as coinciding with the substitution or renewal of equipment and in view of the market evolution one could then think of an enlargement in case it were necessary. This way the market is always supplied, the equipment is not underused and the initial investment is very much lower.

TABLE 2.18

Per-Capita Steel Consumption (kg/inhabitant) in Latin America Countries

Country	1979		1980		1981		1982		1983		1984	
	Total	BRLP*	Total	BRLP*	Total	BRLP*	Total	BRLP*	Total	BRLP*	Total	BRLP*
Argentina	103.8	40.5	99.0	37.8	82.1	26.7	79.3	28.6	79.70	28.4	77.5	27.1
Brasil	91.9	36.3	101.3	38.2	80.3	29.3	73.9	28.6	58.7	33	74.5	33.2
Chile	48.6	22.5	53.3	25.2	49	21.7	23.3	11.5	31	22	41.2	23
Paraguay	13.2	12.8	7.5	7.2	8	7.2	11.2	7.9	10.6	8.5	9 8	8.6
Perú	19	11.9	23	12.7	34.3	19.8	21.5	11.9	14.4	13.6	16.8	13.6
Uruguay	38.4	21.8	45.8	25.6	34.7	18.4	24.3	14.8	20.2	11.3	20.4	11.6

Notes:

* BRLP = Bars, rods and light profiles.

The total consumption of steel has been taken from the Metal Bulletin
The BRLP consumption is according to the ILAFA data

If of the figure of consumption of 65,000 t of BRLP in 1995 we deduct 10,000 tons, estimated to be then the production of private rolled products, there remains a market for about 55,000 t of BRLP which will be the figure to be considered in future as design capacity of the rolling mill.

No market is considered for export, since as has already been said and is now emphasized one can not take into account occasional quantities for the design of a plant.

2.4 AVAILABLE RESOURCES IN BOLIVIA IN RELATION WITH THE SIDERURGICAL PROJECT

2.4.1 Introduction

This chapter analyzes the Bolivian availabilities of raw materials (iron ore, manganese ore and limestone), reducers (charcoal and natural gas), electric energy, water, transport means and human resources, all in relation with the siderurgical project.

Basically, the practical total of these resources is available only in the Department of Santa Cruz, reason for which all the studies made to date have foreseen the location of the various project analyzed in said Department.

Following are analyzed the availabilities of the different resources in the two locations foreseen in the existing studies, that is, the city of Santa Cruz and the Mutun zone.

2.4.2 Iron Ore

1) Ore deposits and types

In Bolivia there are two known deposits of iron.

- Changolla
- Mutún

a) Changolla.

This deposit is located in the department of Cochabamba. The ore reserves and chemical characteristics of the ore are:

	Tons	Fe%	SiO_2	P	Al_2O_3%
Measured ore	2.990.000	43.4	29.3	0.037	1.7
Indicated and inferred ore	3.011.000	44.2	-	-	-
Total	6.001.000	43.8	-	-	-

(Source: "Estrategia Nacional para el Hierro y el acero" (National Strategy for Iron and Steel) author-Fernando Baptista Gumucio. This book uses data from a report by Kaiser Engineering).

According to this same source, to obtain a production of 140,000 tons per annum it would be necessary to use 25% open mining and 75% underground mining.

As can be seen, the ore in question has a high silica content and a low grade in Fe. Considering these circumstances and the fact that it would have to be extracted with underground mining (75%), its exploitation would not be economically profitable. Additionally, this deposit has a very small reserve. In view of the above, this study will only consider the ore at Mutún.

b) Mutún.

This deposit is in the department of Santa Cruz, (see figure 2.16).

Types of ores. Three different classes of iron ores have been fundamentally identified: primary, eluvial and coluvial.

Primary ore. This is the originary ore of the deposit and it is fundamentally formed of iron oxide, silica and carbonates. Within the iron ore three types may be distinguished.

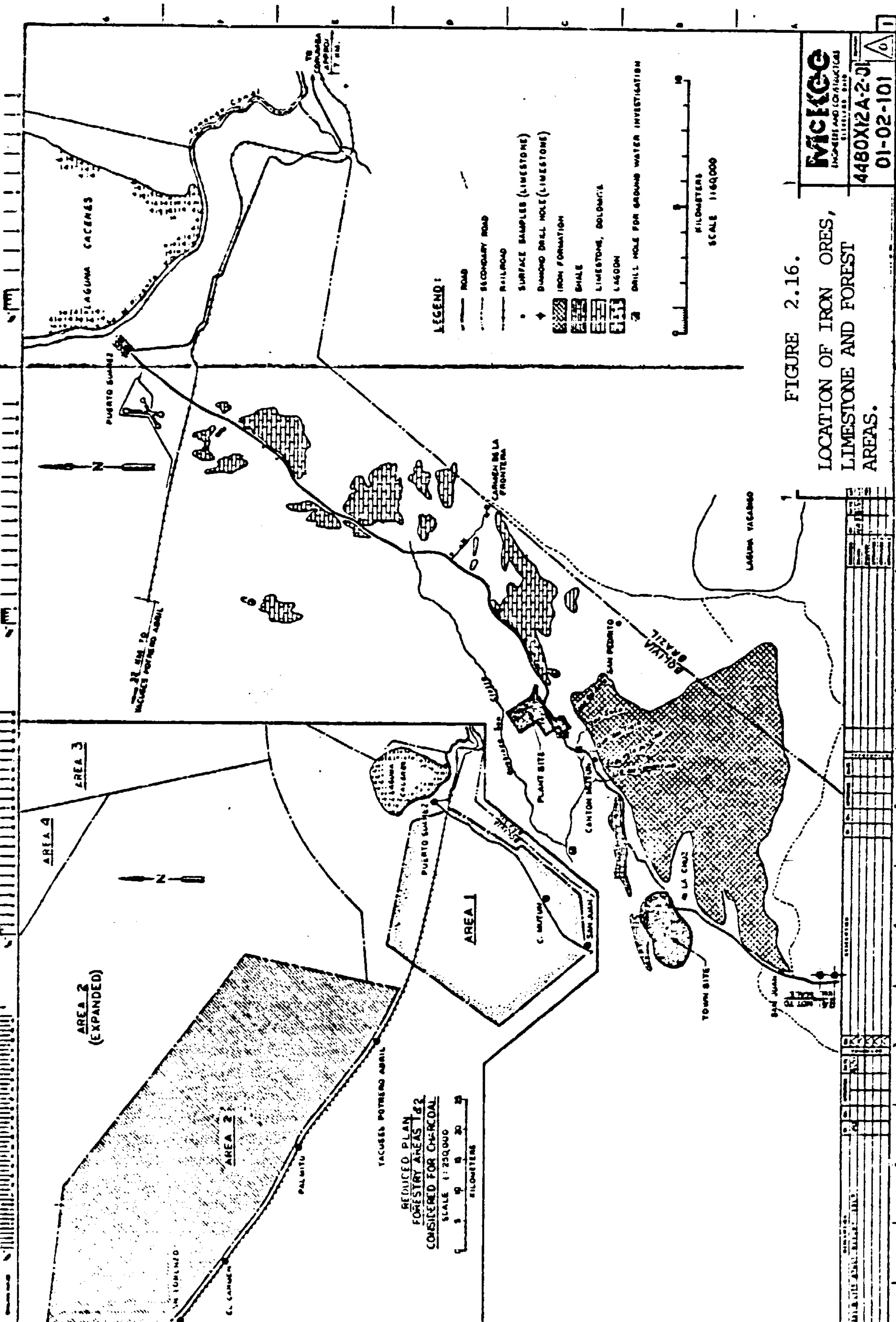

FIGURE 2.16.
LOCATION OF IRON ORES, LIMESTONE AND FOREST AREAS.

Type 1. Fine grain laminate hematite in combination with silica and siderite.

Type 2. Fine grain magnetite and medium, distributed in bands and combined with silica and carbonates.

Type 3. Sedimentary breaches.

Secondary Ores. These minerals originate from the meteorization of the primary ore and are of three types:

Eluvial ore. Located above the primary ore, from which it proceeds due to meteorization and lixiviation. Mineralogically the eluvial ore is composed of:

Hematites	65%
Goetite	14%
Magnetite	5%

The eluvial ore is covered by a layer of ground of about 30 cm. Two horizons may be distinguished in this ore:

- Horizon A, the upper one, with a thickness of 0.5 to 1.5 m. It is composed of broken ore blocks of iron loose within the argillaceous ore and with no degree of cementation.

- Horizon B, the lower one, is the result of the reduction of meteoric action in depth, producing a very fractured layer of ore with macroscopic characteristics between those of eluvial ore A and the primary ore. Normally there is a slight degree of cementation between the fragments and the argillaceous ore.

- Coluvial ore: It forms a band of variable width and thickness which surrounds the Mutun mountain range. This ore is derived from the primary ore as a result of meteorization and driftage.

- Canga: Breached conglomerate made of pieces of hematites and other rocks in lower proportion, cemented with limonites. It has little economic interest in comparison with the two other types of secondary minerals.

2) Ore reserves and grades

The ore reserves and grades of Changolla are indicated in section 2.4.2 1). As has been said, this deposit lacks economic interest due to its reserves and its cnaracteristics.

In the following paragraphs the stocks and chemical and physical analyses of the Mutún ores will be indicated based on existing studies.

a) United Nations Report.

From a geological and research point of view, the oldest study (as to date of performance) that we have received, concerning the Mutún deposit and the characteristics of its minerals, is that of the United Nations, titled "Research of the Iron and Manganese Deposits of the Mutún", dated 1974. This report includes:

- Historical background of research carried out in Mutún since its discovery in 1845.

- Areas investigated and procedures used. The areas investigated by the United Nations (see figure 2.17) were:

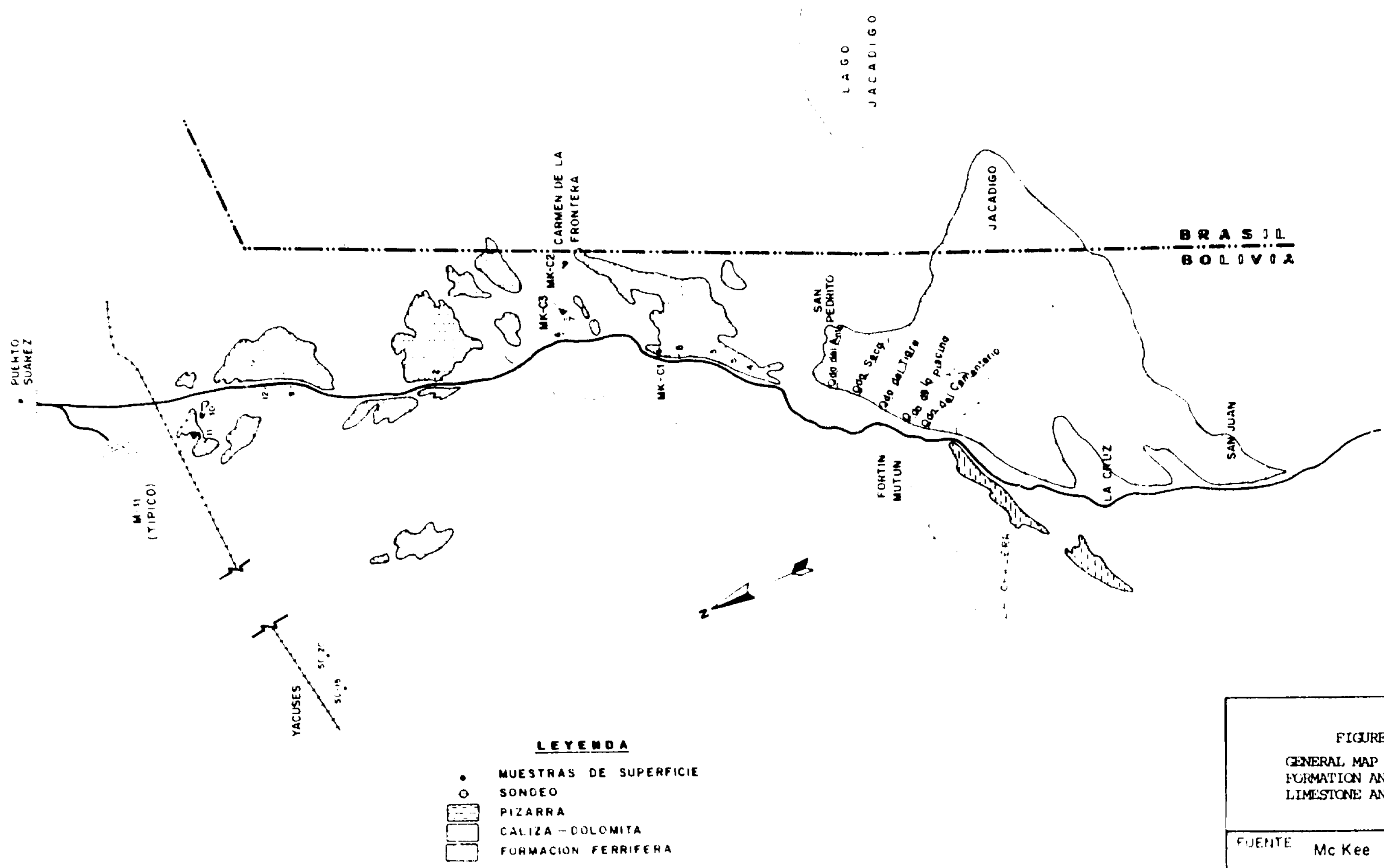

FIGURE 2.17.

GENERAL MAP OF THE FERRITIC FORMATION AND OUTCROP OF LIMESTONE AND DOLOMITE.

FUENTE Mc Kee

Area of 10 km^2, between La Cruz and San Juan, in the coluvial ore by means of 204 exploratory shafts forming a network of 200 m.

Area of 4 km^2, between Fortin Mutun and San Pedrito, in the coluvial ore, by means of 68 exploratory shafts forming a network of 200 x 200 m.

An area of 1 km^2 on the top of Mutun Hill, in the center of the deposit, also evaluated by 35 exploratory shafts forming a network of 200 x 200 m mesh, in the eluvial ore.

An area of 500 m^2 within the aforementioned zone in which the primary ore was investigated using drills.

As a result of this campaign, the following positive reserves were obtained for the investigated zone, which represents only part of the Mutun deposit, the total surface of which is 50 to 60 km^2.

Coluvial ore	21,128,000 t
Eluvial ore	4,077,000 t
Primary ore	77,361,000 t

To this, one must add the following:

Eluvial ore discovered by COMIBOL	14,829,000 t
Probable primary ore	330,176,000 t

The origin and analysis of these minerals is shown in table nº 2.19 in which it may be observed that neither silica nor phosphorus analyses were carried out for the coluvial minerals of La Chalera.

Another fact of great importance which appears in said report and which is contained in the same table is the notable improvement in quality, and increase in Fe grade, which is obtained from the coluvial as well as the eluvial by extracting only the portion -1 1/4 to 1/4". This improvement in the grade of the coluvial and eluvial ore by means of a simple elimination of the fine sizes (-1/4") has been the basis for the processes of enrichment of said minerals up to the present and will continue being so for future plans.

With respect to the primary ore, its Fe content is low and its SiO_2 grade is high and therefore its direct use in iron and steel plant is not recommendable.

b) McKee Study.

McKee directed an investigation campaign of the minerals of Mutun, the results of which are included in table 2.20. The coluvial ore was investigated by means of 51 exploratory shafts made in a zone located to the N.E. of Fortin Mutún, parallel to the course of the road to Puerto Suárez. This area of about 2 km^2 covers part of that investigated in this same zone by the United Nations.

McKee measured a total of 9.6 Mt (million tons) of crude ore, from which about 6.9 corresponded to an ore calibrated between 150 and 9 mm with an average Fe grade of 51.19. These stocks of calibrated ore descend to 4.7 Mt if a cut-off grade of 50% Fe is established for all fractions superior to 9 mm. Analyses were not made for silica nor for phosphorus.

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TABLE 2.19

Reserves and Grades of Mutun Iron Ores according to the United Nations Report (1974)

Ore	Location of the studied area	Run of mine ore					Lump ore: 1 1/4" + 1/4"				
		Kind of reserves	Mt	Fe%	SiO_2%	P%	Weight%	Mt	Fe%	SiO_2%	P%
Coluvial	La Cruz-San Juan (10 km^2)	Positive	14,166,000	39.83	-	-	34.90	4,944,000	48.05	13.56	0.042
	Fortín Mutún-S.Pedito (4 km^2)	Positive	6,962,000	48.17	-	-	32.70	2,277,000	57.08	7.83	0.061
	Total	Positive	21,128,000	42.58	-	-	34.21	7,221,000	50.90	11.75	0.048
	La Chalera *		14,829,000	** 52.14	-	-	** 44.08	** 6,536,000	62.66	-	-
	Total		35,957,000	46.52	-	-	38.30	13,757,000	56.49	-	-
Eluvial	Cerro Mutún (1 km^2)	Positive	4,077,000	58.62	-	-	51.16	2,086,000	64.70	3.73	0.038
Primary	Cerro Mutún	Positive	77,361,000	51.00	12.38	0.094	-	-	-	-	-
	Cerro Mutún	Probable	330,176,000	52.69	-	-	-	-	-	-	-

* Investigation performed by COMIBOL

** Calculated values

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TABLE 2.20

Reserves and Grades of the Mutun Iron Ores according to the McKee Study

Ore	Studied Surface Location	Run of mine ore					Lump ore: + 9 mm - 150 mm				
		Kind of reserves	Mt	Fe%	SiO_2%	P%	Weight%	Mt	Fe%	SiO_2%	P%
Coluvial	N.E Portín Mutún (area: 2 km^2)	Positive	9,630,000	45.77	-	-	71.54	6,889,000	51.19	-	-
		Positive "cut off" + 50% Fe for all the fractions ± 9 mm	6,749,000	48.86	-	-	69.80	4,709,000	53.91	-	-
Eluvial	Cerro Mutún (area: 6 km^2)	Positive "cut off" + 50 % Fe for the frac tions + 9 mm	29,833,000	53.2	-	-	57.0	17,016,000	61.8	-	-
Primary	Cerro Mutún (area: 15 %)	Positive	175,000,000	50.1	-	-	-	-	-	-	-

The eluvial ore was investigated in an area of 6 km^2 located on Mutun Hill (Mutun Chico), 29.8 Mt of crude ore having been measured. From this amount 17 Mt of calibrated (-150 mm + 9 mm) of grade 61.8% could be obtained. Neither silica nor phosphorus were examined in the crude or in the calibrated ore. This research was carried out in two campaigns:

The first of 30 ditches (nº 1 to 42, of which nº 26, 27 and 29 are missing) in an area of 4.1 km^2, having screened at 6", 1 ½", 3/8" and analysed the corresponding granulometric fractions and the -3/8".

The second exploratory campaign of 24 ditches (nº I to XXIV) in zones outlying the aforementioned one. The same type of screening was used.

The primary ore was investigated via a drill campaign (29) with a total of 3,400 m. From this campaign 175 Mt were measured with an average grade of 50.1% Fe, with no analysis for silica nor phosphorus.

c) Cobrapi Study I

Cobrapi did not investigate as to the measurement reserves, but rather using samples of the eluvial ore extracted from the trenches previously prepared by McKee, it obtained an average grade maintaining McKee's reserves, which has been rounded off to 30 Mt. The average grade obtained by Cobrapi, 65% Fe, is considerably higher than McKee's. Fe appears in all the 101 samples of the 63 trenches (39 + 24), but there is no analysis of SiO_2 and P was only analyzed in 15 of the 101 samples.

These data are included in table 2.21.

TABLE 2.21

Reserves and Grades of the Mutun Iron Ores according to COBRAPI and Unidad Promotora Studies

Study	Ore	Location	Run of Mine Ore					Lump Ore: -1 1/4 + 3/8"				
			Kind of reserves	Mt	Fe%	P%	SiO_2%	Weight%	Mt	Fe%	P%	SiO_2%
Cobrapi I	Eluvial	Cerro Mutún	Positive	30,000,000	55%			53.33	16,000,000 * "cut off" to 59% Fe	65	0.08	
Unidad Promotora	Eluvial	Cerro Mutún 6 Km^2	Positive	31,801,380				52.67	16,750,641		64.4	

* If the lump ore had the size -1 1/4" to 1/4", the reserves should be 19 million tonnes

Cobrapi proposed a complementary plan of investigation with 36 trenches and 25 detail trenches in an array of 25 blocks selected from the 58. This array of 25 blocks will permit extraction of the ore for thirty years with an average Fe grade of 65.2. This complementary investigatory plan has not been carried out.

d) Unidad Promotora Study.

This is nearly a transcription of the Cobrapi study in which the stock obtained exceeds that calculated by Cobrapi by 1.801.000 t and with a grade of 64.4% Fe. The reason for the greater tonnage obtained by the Unidad Promotora is that some blocks were measured that did not appear in the Cobrapi study.

This data are included in table 2.21.

e) SIDERSA Data.

SIDERSA has defined three areas of calibrated coluvial ore in La Chalera zone. The grades and reserves of these areas are:

Area	Fe Grade	Brute tons
Area 1	63.64%	2,069,427
Area 3	61.50%	7,482,148
Area 4	61.99%	1,225,793
Total	61.97%	10,777,368

These figures differ from those of the United Nations Study ascribed to COMIBOL in that the reserves are greater; 10.77 Mt vs. 6.5 Mt, and the Fe grade is lower; 61.97 vs. 62.66%.

This same reserves figure >10 Mt and 61% Fe grade were provided verbally by SIDERSA in the visit made to Mutún (29/9/85).

On the other hand, SIDERSA responded to point 14 of the questionnaire by Tecniberia (3/10/85) with reference to the present reserves of coluvial ore that allow the attainment of a 63% Fe in dry form with the following:

The coluvial ore stocks in the La Chalera zone are:

Area evaluated by Comibol 2,438,980 m^2

The total iron reserves in the sector were estimated to be 12,975,3/3 t.

Mean iron grade: 52.14

In the -1 ½" to 1/4" fraction corresponding to 44.08%. Reserves of the -1 ½" to -1/4" fraction: 5,719,545 t.

Iron grade: 62.66%

These last figures are practically the same as those appearing in the 1974 United Nations study. There is therefore a discrepancy between the data concerning grades and reserves provided by SIDERSA.

Summary and Comments concerning Iron Ore Reserves at Mutún

In table 2.22 the maximum possible reserves gauged for each of the three types of minerals of Mutún have been included, in accordance with the report and studies carried out up to the present.

The run of mine (crude) ore reserves are:

Coluvial	38.6 million t
Eluvial	31.8 million t
Primary	175 million t

The reserves of calibrated ore, the grade of which is notably higher than that of the crude ore, are:

Coluvial	22.6 million t
Eluvial	16.7 million t

From the reserves of calibrated coluvial ore only those of La Chalera (6.5 million t) have a grade which permits their direct commercialization without complementary treatment.

In summary, the ore reserves which are saleable with a mere washing and calibrating are:

Coluvial	10.7 million t
Eluvial	16.7 million t

The information concerning P content is scarce and that concerning SiO_2 is virtually non-existent.

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TABLE 2.22

Maximum Positive Measured Reserves in Mutun. Grades

Source	Ore	Location	Run of Mine Ore				Lump Ore				
			Mt	Fe%	SiO_2%	P%	Granulometry	Mt	Fe%	SiO_2%	P%
United Nations	Coluvial	La Cruz-S.Juan	14,166,000	39.83	-	-	-1 1/4" + 1/4"	4,944,000	48.05	13.56	0.042
McKee	Coluvial	Fortin Mutún	9,630,000	48.86	-	-	-150mm + 9mm	6,889,000	51.19	-	-
Comibol-Sidersa	Coluvial	La Chalera	+14,829,000	52.14	-	-	-1 1/4 + 1/4"	**10,777,368	61.97	-	-
Total			38,625,000	46.81				22,610,368	55.64		
Unidad Promotora	Eluvial	Cerro Mutún 6 km^2	31,801,300		-	-	-1 1/4 + 3/8"	16,750,641	64.4	-	-
McKee	Primary	Cerro Mutún	175,000,000	50.01	-	-					

* Data from Comibol
** Data from Sidersa

Since the McKee study practically no investigations have been carried out in the Mutún deposit. A notable difference can be seen between the average Fe grade of the eluvial ore calculated by McKee, 61.8% and that obtained by Cobrapi, 64.4%. There are also considerable differences between the efficiencies or weight recuperation of the calibrated ore referring to crude ore. McKee's figure, 57% is the highest and Unidad Promotora's is the lowest. This seems to justify the difference in the average Fe grade.

3) Exploitation, Beneficiation, and Commercialization of the Iron Minerals of the Mutún

Introduction

Up to the present some 300,000 t of coluvial ore have been extracted, and 133,000 t of calibrated ore have been exported. No mining of either the eluvial ore or the primary ore has been done.

Consequently the beneficiation or concentration of the ore have only been achieved at an industrial scale with the coluvial ore. The tests performed on the eluvial and primary minerals have been limited to laboratory or pilot plant.

The tests carried out by the United Nations, McKee and Cobrapi have made it clear that for the coluvial and eluvial minerals it is possible to improve the Fe grade by screening at 1/4" or 3/8" and discarding the smaller fraction of this mesh. The coarse ore (calibrated or lumps) obtained in this fashion has a Fe grade that surpasses that of the run of mine or crude ore by 10 units. Consenquently its content in SiO_2, Al_2O_3 and K_2O decreases. The P grade of the calibrate is lightly lower than that of the crude and the Na_2O grade is fairly the same for both.

It should be pointed out that although there is abundant data available concerning the Fe grade, for the crude ore as well as for the calibrates, little data exists concerning the P grade. Data is also scarce as to SiO_2, Al_2O_3, K_2O and Na_2O. This situation is explainable in that complete analyses were only made, when concentration tests were made or in samples of exported minerals. however these determinations have not been made in the samples taken for reserves measurements, where in general only the total Fe content has been analysed.

Below we will examine in more detail the information available concerning the working, beneficiation, commercialization and possible use of the Mutún minerals in the bolivian siderurgical project. This information, derived from the studies by McKee and Cobrapi and SIDERSA's data has been analysed by Tecniberia to draw the pertinent conclusions.

Coluvial ore

As has been previously explained, of all the known reserves of this type of ore, the only ones which would be usable for their commercialization or for use for the national siderurgical project would be those corresponding to the "La Chalera" zone, which represent 5.7 or 10.7 million to of calibrate, according to Sidersa's figures, with a Fe grade of 62.66 and 61.97 respectively.

McKee made a concentration test for dense liquids (bromoform) with the 3/8" fractions (calibrated minerals), which gave no result.

Apart from this, no tests have been made, except screening, with the crude ore to try to improve its quality, especially to reduce its phosphorus content, but the conclusions can be similar to those reached for the eluvial ore, which will be shown subsequently.

The coluvial ore is exploited in the La Chalera zone, where in addition to having a better grade, its covering is less and the ore mass has a higher concentration.

The calibrated ore is obtained from the crude ore in a rudimentary installation which SIDERSA calls "experimental plant" and which consists simply of a grate wich eliminates the +1 1/4" sizes and a screening with water spraying, which discards the -1/4" fraction, obtaining the sellable product: -1 1/4" to +1/4". According to SIDERSA, this plant has a capacity for 8,000 t/month in two shifts and 20 work days per month.

Previously there was a plant designed by Comibol, from which some machines are left. This plant had: two stages of grinding; screening with water spray; separation by means of a helix screw of the slimes from the fines. It is not known why SIDERSA stopped this plant and started the "experimental plant" when the former is technologically much better than the latter.

Tests have not been performed to determine the possibility of improving the quality of the calibrate ore or of the fines (-1/4") via gravimetric concentration.

Presently no quality control of the minerals is carried out at the mine since, although a good laboratory is available, albeit very poorly maintained, there is no chemist or analyst.

The fine discarded ore is stored mixed with sludge (slimes), there being a stock of some 100,000 t according to a SIDERSA estimate.

The calibrated ore is transported in a brazilian contractor's trucks to Corumba (Brazil) where it is stored and loaded on barges to be exported to Argentina. The port installation belongs to PORTOBRAS and consists of an open stock of 3,600 m^2 (maximum 5,000 m^2), from where the ore is loaded into a hopper lifted by a mobile shovel loader. The hopper pours the ore onto a fixed conveyor belt which unloads onto the barge. The capacity of the barge loading installation is 1,000 to 1,200 t in eight hours, as SIDERSA informed.

The loading installation is very primitive and could be improved without large investment by, for example, a cemented-in hopper and shiftable conveyor belt, which would allow an increase in loading capacity.

In Bolivia the construction of a port is projected, as has already been mentioned, in Puerto Quijarro, through which some 60,000 t/year of calibrate would be embarked for export to Argentina.

The ore exports, whose sole destination was the Argentinian siderurgical plants, began in 1973. In that year 50,000 t were sent from Puerto Busch to SOMISA. It seems that this ore had a very poor performance in the blast furnaces because of its tendency to decrepitate.

According to data provided by SIDERSA, the exports were renewed in 1977 but bound for the Altos Hornos de Zapla. From that date until 1984, 82,902 t were exported in 8 years, the annual tonnage being very variable (see table 2.23), since it oscillated from a maximum of 38,109 t in 1978 to a minimum of 2,256 t in 1977. In 1985, in spite of having a contract for 60,000 t, nothing was exported, there being a stock of 10,000 t ready for loading in Corumbá.

09402(106)/86

TECNIBERIA

TABLE 2.23

Exported Coluvial Ore - Tonnages, Prices and Destinations

Year	Metric Tonnes	FOB Price US$/Mt*	Destination
1972	50,000	?	Somisa
1977	2,256	7.13	Altos Hornos de Zapla
1978	38,109	7.13	"
1979	2,543	7.13	"
1980	10,651	7.13	"
1981	4,113	7.60	"
1982	7,705	7.60	"
1983	11,025	12.50	"
1984	6,500	14.00	"
1985	-	14.00	"
Total			

* Basic price for Fe = 63% of dry ore.

It has not been possible to obtain an exact reason from Sidersa for these variances in exportation and for the fact that nothing has been embarked in 1985. Technicians at SIDERSA have given various opinions:

- SIDERSA has not fulfilled its previous obligations with respect to tonnage available for embarking.
- The ore has decrepitation problems. These problems are less in Altos Hornos de Zapla since they are smaller than the SOMISA ones.
- The ore is degraded due to all of the handling it undergoes until it reaches the Zapla blast furnaces.
- The ore has a high phosphorus content.
- The commercial procedures have not been proper.
- Argentina has problems in obtaining US dollars for use.

SIDERSA was requested to give the results of the shipping analyses in order to try to investigate the phosphorus content and its heterogenity, since these could be possible causes for the difficulty in exporting the ore.

SIDERSA only provided analyses for some of the shipments done in 1980, 1981 and 1983. According to SIDERSA they did not have the analyses results on file and could not obtain them from SOMCO (which is the company which arranges the sale of the ore).

Based on the analyses provided by SIDERSA, table 2.24 has been prepared, which contains: grades; the maximum, minimum and average granulometry of said shipments; the Altos Hornos de Zapla specifications (Dirección General de Fabricaciones Militares). These specifications are explicit as far as the grades of Fe, SiO_2, P, S and Mn equally in that referring to typical values as well as concerning penalizations and rejection (because of phosphorus or sulphur), but there are no granulometric conditions, since it is only indicated to be -1 1/8" to +1/4". The base price is established for a 63% Fe ore in dry form.

There are no granulometric analyses available at the destination point, which would be the most interesting in order to demonstrate the possible degradation of the ore due to handling.

From the results of table 2.24 it can be concluded that the embarked ore is within the specifications fixed for the "thypical ore" for the Altos Hornos de Zapla. It should be pointed out that the shipments for where data was available only represent a small portion, 17,571 t out of a total of 82,902 t.

The Fe grades of the embarked minerals exceed the average calculated grades for the calibrated reserves of La Chalera, from whence they originate. This seems to indicate that the parts richest in Fe are being exploited in this zone.

Consequently, based on the information that SIDERSA has made available to Techniberia, it cannot be concluded that the cause of the anomalies and exportation difficulties in the granulometric or chemical characteristics of the ore since these are within the specifications. However, the calibrated coluvial ore is of inferior quality compared to the other calibrates handled on the international market, especially in its phosphorus content, which is high.

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TABLE 2.24

Ore Grades and Sizes of Samples for Shipment and of Sales Specifications

			Grades of Dry Ore %																		Sizes %					
Date	Metric Tonnes	Nº sam-ples	Fe			SiO_2			Al_2O_3			P			S			H_2O			1 1/4"			1/4"		
			Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
20/23-10-80	2,889	3	63.2	62.8	63.0	6.59	6.13	6.34	1.25	1.18	1.21	0.13	0.12	0.12	0.005	0.004	0.004	2.57	2.20	2.40	3.81	3.00	3.29	6.53	3.29	4.90
10&11-2-81	2,657	2	64.8	64.3	64.5	5.30	4.88	5.09	1.04	0.78	0.91	0.10	0.96	0.98	0.006	0.006	0.006	2.60	2.55	2.57	3.51	2.93	3.22	3.51	2.53	3.01
23/26-3-83	11,025	7	64.2	62.6	63.7	6.59	5.10	5.87	1.32	0.98	1.13	0.10	0.09	0.10	0.01	0.007	0.008	3.1	2,9	3.0	5.40	1.10	3.10	3.8	1.7	3.0
Specifications of Altos Hornos of Zapla			M. x. -	Min. 57	Typ. 63	Max. 8.0	Min. -	Typ. 6.0	Max. -	Min. -	Typ. -	Max. 0.15	Min. -	Typ. 0.10	Max. -	Min. 0.0	Typ. 0.05	Max. -	Min. -	Typ. -	- 1 1/8"			+ 1/4"		

A calibrate usually has the following grades:

Fe:	65 to 67.5%
SiO_2:	2.5 to 1.2%
P:	0.04 to 0.01%

Nor has information been received from Altos Hornos de Zapla as to the performance of the minerals in blast furnaces.

In summary, according to the information received, scarce as it may be, the calibrated ore is of acceptable characteristics (except for phosphorus content) for its commercialization and even for its eventual use in the bolivian siderurgical project, although the eluvial is better. However, SIDERSA must carry out quality controls in the mine as well as in the plant and gather data concerning granulometry and the performance of the ore in the Zapla blast furnaces.

Nor does it seem that the argument can be used that Argentina lacks currency, since this country imports about 1.8 million t/year of pellets and iron ores.

Finally, with regard to the possible behavior of this ore in the blast furnace, McKee explains in his study that metallurgic tests indicate that reductibility and stability are essentially the same as for the eluvial minerals under the same circumstances. That is, it is an ore apt for direct loading into blast furnaces, especially into small ones in, which the material is submitted to lower forces during its reduction.

Eluvial Ore

This ore has not been worked and the tonnage extracted has been for reserves measurements samples or for pilot plant tests.

The eluvial ore has a better quality than the coluvial, according to the average reserves analyses on the crude as well as on the calibrate.

The Cobrapi study is that which contains the greatest information concerning this mineral. Part of this information is derived from the McKee study and the rest was obtained by COBRAPI from samples and tests done. Therefore, the Cobrapi study will be used for the eluvial ore.

Cobrapi took a sample of eluvial ore from the trenches previously prepared by McKee to carry out analyses and tests.

The average grade of the crude eluvial ore for COBRAPI's sample gave the following grades:

Fe:	55.72%
SiO_2:	8.10%
P:	0.094%
Al_2O_3:	3.8´%

This Fe grade is practically the same as that appearing in Table 2.28 as the average reserves of the crude eluvial.

Cobrapi has studied in detail the iron content in the crude as well as in the calibrate. However, little attention has been paid to phosphorus. This is surpising since this element is one of the greatest problems which the Mutún minerals present in general.

Cobrapi has grouped the reserves of 16.75 Mt of calibrated eluvial ore as to their Fe content (see table 2.25). There is a range of a minimum grade of 47.5% to a maximum of 68.5% the average grade obtained being 64.4 Fe.

To achieve this grade it would be necessary to have several points of the deposit in exploitation and to mix the minerals. With this in mind, Cobrapi has marked out a zone of 25 blocks (out of a total of 63) with a stock of 6.18 Mt and an average grade of 65.2% Fe, the minimum being 59.2% Fe.

Exploitation will begin in this zone and Cobrapi recommends that "the short range geological investigations be widened not only in the reserves aspect, but also to mark out areas with distributions of iron, phosphorus and limonite. The intention is to proportion and homogenize the material to be used in the blast furnace, so as to obtain a product with the average quality of the reserves and to avoid as far as possible the exploitation of the ore of a high decrepitation degree". Nothing has been done up to the present to follow up on the Cobrapi recommendation.

Cobrapi has not done a similar task for phosphorus as was performed for iron. For this reason, the existing data concerning this element will be considered below.

In table 2.26 the available data for phosphorus analyses are shown from 15 calibrate samples for 6 trenches. The sample corresponds to a total of 2,027,321 t with an average grade of 0.095 P%. This tonnage is only 12% of the total calibrate stocks and therefore it is not a very representative sample of the total.

TABLE 2.25

Distribution of the Recoverable Reserves of Iron Ore Clods per Fe Content (Eluvial Ore)

Range of Content % Fe	Content % Fe	Recoverable Reserve (Mt)	%	Accumulated %	Accumulated % Fe
47.0 - 47.9	47.5	69,810	0.4	100.0	64.4
50.0 - 50.9	50.5	141,392	0.8	99.6	64.4
51.0 - 51.9	51.5	204,062	1.2	98.8	64.5
52.0 - 51.9	52.5	153,922	0.9	97.6	64.7
56.0 - 56.9	56.5	94,396	0.6	96.7	64.8
57.0 - 57.9	57.5	144.278	0.9	96.1	64.8
58.0 - 58.9	58.5	216,230	1.3	95.2	64.9
59.0 - 59.9	59.5	904,652	5.4	93.9	65.0
60.0 - 60.9	60.5	1,026,900	6.1	88.5	65.1
61.0 - 61.9	61.5	869,415	5.2	82.4	65.5
62.0 - 62.9	62.5	507,574	3.0	77.2	65.8
63.0 - 63.9	63.5	1,170,279	7.0	74.2	65.9
64.0 - 64.9	64.5	1,857,845	11.1	67.2	66.2
65.0 - 65.9	65.5	2,662,380	15.9	56.1	66.5
66.0 - 66.9	66.5	4,070,007	24.3	40.2	66.9
67.0 - 67.9	67.5	2,529,704	15.1	15.9	67.5
68.0 - 68.9	68.5	126,795	0.8	0.8	68.5
Total	-	16,750,641	100.0	-	-

Source: Cobrapi

TABLE 2.26

Eluvial Ore - Samples with Phosphorus content analysis
(Cobrapi I Study)

Trench N.	Horizon	Lump Ore Reserve (Mt)	Grades	
			Fe%	P%
1	A	81,900	67.3	0.060
	B	285,831	61.2	0.158
6	A	68,262	66.3	0.076
	B	65,234	62.1	0.060
12*	A	275,269	67.2	0.083
	B	375,898	63.9	0.078
18	A	60,642	63.8	0.066
24*	A	120,087	66.4	0.059
	B	170,427	67.5	0.059
30*	A	55,904	66.8	0.070
32*	B	32,105	57.4	0.083
36	A	62,201	66.6	0.116
	B	40,681	65.1	0.158
42	A	95,160	66.5	0.139
	B	237,900	66.0	0.109
Total	-	2,027,321	65.03	0.095

* Samples corresponding to the mining blocks forecast for 20 years exploitation.

Source: Cobrapi I Study

In table 2.27 the tonnages have been distributed according to their P content. The corresponding histogram is represented in figure 2.18.

If one had to discard the ore with a P content surpassing 0.150%, which is the limit established by Altos Hornos de Zapla for the coluvial ore, it would be necessary to discount 16% of the reserves weight. That is to say, phosphorus may constitute an important problem in the evaluation of reserves and the exploiting of the ore. With the samples which Cobrapi gathered, tests have been performed concerning ore characterization, concentration and pelletization. Some of these tests were done on a laboratory scale and others on pilot plant scale.

Cobrapi tried to improve the ore quality by grinding it so as to free the gangue and subsequently concentrating it by means of flotation or magnetic separation. The tests were done for the -3/8" fractions as well as for the -3/8" ones.

Cobrapi also made cuts at various granulometries of the crude ore, analysing the different fractions and submitting them to a concentration for dense liquids (bromoform).

The conclusions which Cobrapi reached are:

a) In general the tests showed that we are dealing with a ore that is easily processable for the attainment of a granulometry of a natural granulate of 1 1/4" to 3/8".

b) Any other concentration except trituration and screening presents serious difficulties such as the following:

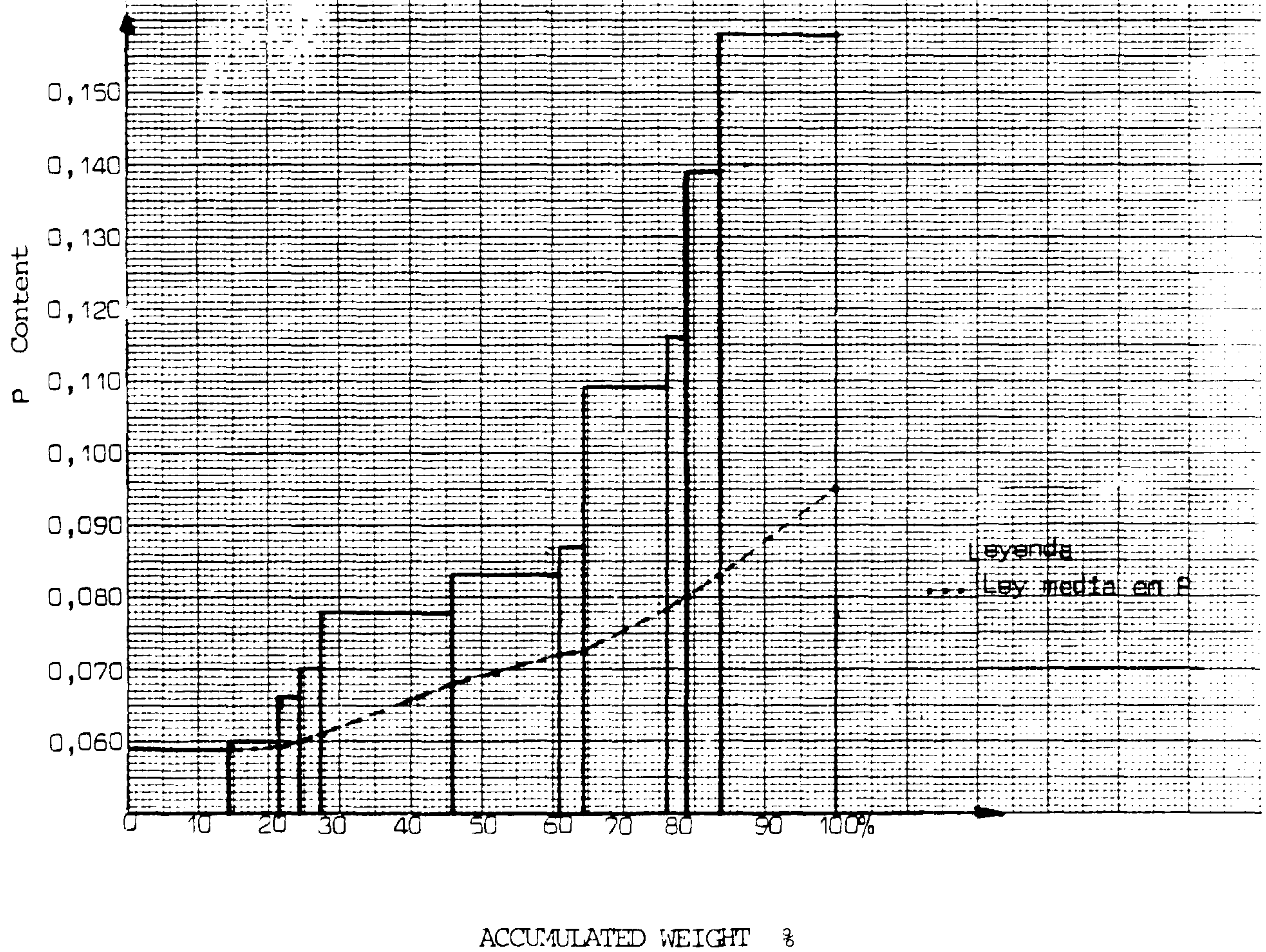
TABLE 2.27

Lump Ore Tonnage Distribution per Phosphorus Content (Eluvial Ore)

P%	Mt	Weight%	Cummulative Weight%	Cummulative P%
0.059	290,514	14.33	14.33	0.059
0.060	147,134	7.26	21.59	0.059
0.066	60,642	2.99	24.58	0.060
0.070	55,904	2.76	27.34	0.061
0.078	375,898	18.54	45.88	0.068
0.083	307,374	15.15	61.04	0.072
0.087	68,262	3.37	64.41	0.072
0.109	237,900	11.73	76.14	0.078
0.116	62,021	3.06	79.20	0.080
0.139	95,160	4.69	83.89	0.083
0.158	326,512	16.11	100.00	0.095
0.095	2,027,321	-	-	-

FIGURE 2.18.

HISTOGRAM OF THE P CONTENT OF THE CALIBRATED ELUVIAL ORE RESERVES.



- Given its structure, the ore needs an ultra-fine grinding to liberate its gangues (5 to 10 microns).
- High generation of ultrafines in grinding.
- Low efficiency of the concentration processes for fine granulometries.
- Problems in th: decanting of slimes.

Following the results of the Cobrapi tests, one must discard the possibility of improving the ore grade by liberating the gangues. Consequentlv, the best procedure would be crushing and screening to obtain a calibrate. The concentration of this -3/8" calibrate via gravimetry lacks interest since there is scarcely any improvement in quality, but it might be of interest for the -3/8" fraction as stated below. However a market would have to be found for this product as sinterfeed.

The data from the granulometric tests that Cobrapi performed on the crude ore crushed at 1 1/4" are shown on table 2.28. From this data the weights and grades of the accumulated fractions have been calculated. This allows us to know the efficiency and the quality of the calibrate which would be obtained by varying the sifting mesh for discard (fine fraction). The discards have also been calculated for the 7,937 mm and 6.35 mm mesh. The latter would correspond to 1/4" (present coluvial specification) and the larger mesh to a safety sifting to avoid -1/4" fractions in the sift due to imperfection in the procedure or degradation of the calibrate due to handling.

Calibrate 1 1/4" at 7,937 mm would have the following grades:

Fe:	64.52%
P:	0.086%

Weight efficiency would be 57.46%, which confirms that the easiest concentration is a trituration and subsequent sifting at 1/4" if it is only desired to recuperate the calibrates. Also, if one whishes to improve the metallurgical efficiency of the operation a sinterfeed may be obtained by eliminating the slimes (-0.149 mm).

In order to check the usefulness of a gravimetric concentration of the calibrate of the fines, Table 2.30 has been prepared based on the Cobrapi test data. Comparing with Tables 2.28 and 2.29 it can be seen that the gravimetric concentration is of no interest for the thick fraction (calibrate), given that the concentrate only shows an improvement of 0.66 Fe units. On the other hand there is a significant improvement for the fine fraction of 6,49 Fe units, fine concentrates of the following grades being obtained:

Fe:	59.34
P:	0.016

This quality may be improved by cutting at a size greater than 0.149 mm.

The decrease in Fe grade in the fine fractions and the good results brought about by gravimetric concentration demostrate that gangue is liberated in these granulometries. It would also be of great interest to study this subject in more detail and look for a market for this sinter-feed. SOMISA might be a market, since it does import great quantities of sinter feed from Brazil.

TECNIBERIA

TABLE 2.28

Weight and Fe Content of the Coarse Size Fraction of the Run of Mine Eluvial Ore Samples

	Run of Mine	Lump Ore Partial and Cummulative Weights and Analyses						Weights & Analyses of the discarded ore	
		+ 25.40 mm	+ 19.05 mm	+ 12.70 mm	+ 9.525 mm	+ 7.937 mm	+ 6.35 mm	0 - 7.937mm	0 - 6.35 mm
Weight %	100	9.06	15.12	18.74	9.00	5.54	3.34	42.54	39.20
Cummulative Weight %	100	9.06	24.18	42.92	51.92	57.46	60.80	42.54	39.20
Fe %	55.72	65.65	65.66	64.38	63.47	61.78	60.46	43.83	42.38
Cummulative Fe %	55.72	65.65	65.66	65.01	64.82	64.52	64.32	43.83	42.38
P %	0.094	0.090	0.073	0.089	0.088	0.099	0.097	0.105	0.106
Cummulative P %	0.094	0.090	0.079	0.084	0.084	0.086	0.086	0.105	0.106
SiO_2 %	8.10	2.91	2.88	3.44	3.76	4.92	5.47	14.45	15.20
Cummulated SiO_2 %	8.10	2.91	2.89	3.13	3.21	3.40	3.52	14.45	15.20
Al_2O_3 %	3.83	-	-	-	-	-	-	-	-
FL (Fireloss)	3.87	-	-	-	-	-	-	-	-

Source: Cobrapi I and Tecniberia.

TECNIBERIA

TABLE 2.29

Weight and Fe Content of the Fine Size Fraction of the Run of Mine Eluvial Ore Sample

Mesh size in mm		+ 0.149	+ 0.250	+ 0.500	+ 1.00	+ 2.00	+ 4.00	+ 6.35
Weight %	Partial	1.28	1.65	2.27	3.71	8.87	9.89	3.34
	Cummulative	1.28	2.93	5.2	8.91	17.78	27.67	31.01
Fe %	Partial	29.24	31.03	43.99	48.12	54.26	59.36	60.46
	Average	29.24	30.81	36.56	41.38	47.80	51.93	52.85
P %	Partial	0.105	0.108	0.118	0.116	0.118	0.105	0.077
	Average	0.105	0.107	0.112	0.113	0.116	0.112	0.108

Source: Cobrapi I and Tecniberia

TECNIBERIA

TABLE 2.30

Weight and Grades of the Concentrates Obtained Through Dense Liquid (Eluvial Ore)

I. Lump Ore

Mesh size in mm		25.4	19.05	12.7	9.525	7.937
Weight %	Partial	9.06	14.94	18.27	8.54	5.13
	Cummulative	9.06	24.00	42.27	50.81	55.94
Fe %	Partial	65.65	65.99	65.02	64.54	63.62
	Cummulative	65.65	65.86	65.50	65.34	65.18
P %	Partial	0.090	0.071	0.087	0.080	0.091
	Cummulative	0.090	0.078	0.082	0.082	0.083

II. Sinter Feed

Mesh size in mm		0.149	0.250	0.500	1.00	2.00	4.00	6.35
Weight %	Partial	0.53	0.86	1.71	2.97	7.40	8.55	3.02
	Cummulative	0.53	1.39	3.10	6.07	13.47	22.02	25.04
Fe %	Partial	47.83	49.77	53.66	55.38	58.76	62.75	62.98
	Cummulative	47.83	49.03	51.58	53.44	56.36	58.84	59.34
P %	Partial	0.140	0.140	0.130	0.120	0.110	0.095	0.088
	Cummulative	0.140	0.140	0.134	0.127	0.118	0.109	0.106

With regard to tests to determine the possible behavior of the calibrated ore in siderurgical processes, several have been carried out by McKee and Cobrapi.

McKee says "due to its high Fe grade and its acceptable stability during reduction, at high and low temperatures, the ore is considered adequate for direct loading into blast furnaces, especially in small furnaces in which the material is subject to lower forces during reduction".

Cobrapi ordered the COISRMJ (Committee for Overseas Iron and Steel Making Raw Materials of Japan) tests to be made on three samples with the following results:

Block 1:	4.79%
Block 2:	8.80%
Block 3:	2.27%

According to this test, minerals with an index of less than 4% are considered to have a low decrepitancy tendency.

The results indicate a good deal of differences with respect to the behavior of the eluvial calibrated ore.

Primary ore

Information concerning this ore is basically fround in the McKee study.

McKee prepared a brief preliminary scheme concerning the surface mining of the deposit.

McKee performed concentration tests, submitting the ore to a very fine grinding (80% - 0.043 mm), followed by a low intensity magnetic concentration. With the concentrate pelletization tests were made.

The ore proportion extracted from the concentrate was 4.67 : 1.

The analyses of the primary ore, both grinded (80% - 0.043 mm) followed by a magnetic concentration at low intensity and pelletizing, appear in table 2.31, in which it can be observed that the grades are very favorable. This was the case for the concentrated (pellets feed) as well as for the pellets, except for phosphorus grades, which were very high in both products. This circumstance would make their commercialization very difficult on the international iron market.

In conclusion, given the present technological state, the primary ore would require a very fine grinding for its concentration. This would necessitate the production of pellets whose phosphorus contents are absolutely beyond the international market specifications. In addition, pellet production would demand high operation costs, for the grinding as well as for pelletization and a very substantial investment. Therefore, the primary ore should be discarded as a raw material under present conditions, both in the case of the national siderurgical project and for its commercialization.

2.4.3 Manganese Ore

According to the United Nations report there is manganese material in the ...in in the lower part of the Banda Alta ("High Band"). The ore ...lomelane (MnO_2) with a rating of 1.30 m and a Mn grade of 46.29% and 11.40% in Fe.

TABLE 2.31

Analysis of the Primary Ore Concentrate
(80% - 0,043 mm) and Pellets

%	Primary Ore	Magnetic Concentrated	Pellets
Fe	53.2	67.8	65.11
Fe ++	1.85	--	--
SiO_2	19.9	2.17	3.0
CaO	0.28	0.08	2.70
MgO	0.01	0.01	0.8
Al_2O_3	0.68	0.18	0.49
Mn	0.01	0.01	0.025
S	0.004	0.002	0.001
P	0.43	0.190	0.178
F.L. (Firelosses)	1.49	0.66	0.06

Source: McKEE

This ore was worked in the San Pedrito zone and sold to Brazil. Presently the work is stopped because of the lack of market caused by the fact that its quality is lower than that of the brazilian minerals.

There is a stock of about 6,500 t which Sidersa acquired from the former owners of the mine and has not been able to sell. According to verbal information from Sidersa the stock's grade is 42% Mn and 12% Fe.

According to the grades appearing in the United Nations report, the ore would be usable in the bolivian siderurgical project, since the usual minerals have 40 to 50% Mn; 6-10% SiO_2; -0.2% P and -0.1% As.

It is necessary to carry out an investigation to find out the stocks and qualities of the manganese ore at Mutún, since the information available is insufficient.

2.4.4 Limestone

As can be seen in the studies by McKee and Cobrapi, there is no problem as to limestone stocks, since there are surface outcroping between Puerto Suárez and Mutún.

McKee did three drills, MK-C1, MK-C2 and MK-C3 and 12 samples of surface outcroping were also taken (M1 to M-12).

Samples M1, M2, M8, M9, M10 and M12 correspond to good quality limestone, as well as drill MK-C2. However the MgO contents are low compared with an ideal dolomitic limestone for use in siderurgy, the ideal composition of which would be:

CaO minimum	41.2%
MgO max.	11.3%
CaO + MgO min.	52.5%
SiO_2 max.	1.4%
Al_2O_3 max.	0.9%

On the other hand, drill MK-C1 passed through a dolomite of excellent quality.

A mixture of limestone and dolomite in proper doses would allow the attainment of a material whose characteristics approach those of the ideal dolomitic rock for siderurgy.

The zones where the outcrops of limestone and dolomite are located as well as the drills and surface samples appear on the enclosed drawing by McKee (see figure 2.17).

2.4.5 Possibility of manufacture of charcoal

1) Introduction

No known reserves of coal exist in Bolivia. According to table 2.32 charcoal is now produced, used fundamentally in the Vinto tin casting mill of the Empresa Nacional de Fundiciones ENAF. According to said table, the total 1984 production was 22,660 t representing 80% of the installed capacity.

The main problem for supply of charcoal to Vinto is the great distance between the charcoal production centers and the casting plant, between 500 and 1,200 km, which means a total price of the charcoal placed at Vinto of double the price at the maker, as indicated in table 2.33, with a mean cost of transport of US$ 0.1087/t km for charcoal with 70% of fixed carbon and 7% humidity.

TABLE 2.32

Production Capacity and Actual Production of Charcoal in Bolivia

Department	Productive Centre	Distance to Vinto (Km)	Capacity Mt/year	Production Mt/year
Santa Cruz	Cabezas, Pararenda, Charagua, Pipi	800-900	9,000	7,350
Tarija	Palmar, Caigua, Sun-chal, Caiza	1,156-1,220	10,500	8,720
Chuquisaca	Olopa, Tomina	490-517	4,000	2,780
	Independent Producers		5,000	3,800
Total			28,500	22,660

Source: ANICARVE 1.981

(Taken from Volume VI of the U. Promotora Study).

TABLE 2.33

Charcoal Prices in Bolivia (US $/Mt)

Year	In Charcoal Plant	In Vinto
1.975	39	79
1.976	44	89
1.977	45	90
1.978	44	89
1.979	49	99
1.980	51	102
1.981	80	160
1.982	44	90
1.983	123	210
1.984	57	131
Average price of the period	57,60	113,90

Source: ENAF, ANICARVE 1.984

(Taken from Volume VI of the Unidad Promotora Study)

Unfortunately there is no sufficient information about the forest zones worked, as the studies made by McKee, Cobrapi and the Promoting Unit are reduced to the Mutun area.

2) Forest possibilities of the Mutun zone

In the Mutun zone there is experience in the fabrication of charcoal, as in the neighbor Brazilian territory there are worked 2 batteries of 10 kilns each, supplied with Bolivian lumber and operated by Bolivian workers also.

The most important forest study available is the one made by HUNT, LEUCHARS and HEPBURN (H.L.H.) for McKee, which identified the two zones shown in drawing 2.16, determining a surface of natural forest with potential for the production of charcoal of 2.2 million hectares.

Zone 1, located near Mutun with an area of 80,000 ha of productive forest, in which restocking is not possible due to the nature of the soil.

Zone 2, located about 75 km to the N.W. of Mutun covered an area of 204,000 ha of which 182,000 ha would be productive forest. Restocking would be possible in this zone, that could be enlarged toward Roboré about 250 km from Mutun.

Said study identified many species of trees. The lumber production taking in consideration trees over 20 cm in diameter was estimated at 74.5 m^3/h with an annual wood increment by natural growth of 2.75 m^3/ha. According to H.L.H. tests and estimates there was considered a wood to charcoal ratio of 7:1 with a wood density of 1.444 t/m^3. The quality of the charcoal obtained in H.L.H. tests was equal or higher than that obtained in Brazil with eucalyptus.

For a charcoal production of 220,000 t/year the four systems indicated in table 2.34 were compared. However, by solution adopted by McKee was foreseeing an own production of 170,000 t/year in Missouri kilns and 85,000 t/year purchased from private suppliers. For this production there were worked annually 15,000 ha, 7,200 ha in zone 1 and 7,800 in zone 2, with a total of 1,700 workers, 1,150 in forest operations and 550 in charcoal production.

The Cobrapi II variant with charcoal foresaw a production capacity of charcoal of 111,100 t/year in 25 batteries with a total of 980 half-orange kilns, working 9,740 ha/year of native forests.

Lastly, in the Promoting Unit study is foreseen a charcoal production capacity of 67,900 t/year in 19 batteries of 20 half-orange kilns each. As forest area there is considered the Yacuses-Puerto Suárez-San Juan triangle, that is, practically zone 1 of the McKee study, with a surface of 100,000 ha. It is foreseen to work in 20 years a surface of 44,550 ha of natural forest, of which 22,500 ha would be reforested with eucalyptus. The charcoal production would have the following origin: the first 8 years with wood coming from native forest and the following years eucalyptus planted forests.

To date only a few experiments have been made with small lots of "Eucaliptus calmadurensis" in Campamento La Cruz.

Carrying out experiments of reforestation in a large scale is deemed very important, as the yield foreseen by the Unidad Promotora for eucalyptus plantations, estimated at 20-25 m^3 of wood/ha and year, according to Brazilian experiments (6) may be increased to 46 m^3/ha/year making the planting of reforested eucalyptus in what is called "energetic forestry", spacing them 1t 1 x 1.5 m in place of the classic 2 x 3 meters.

TABLE 2.34

Carbonization Alternatives Analyzed in the Mckee Study

System	Type	Nº of Jobs	Investment US$ x 10^3
1	Partially mechanized timber collection. Carbonization in retort	1,460	20.506
2	Partially mechanized timber collection. Missouri Kilns	2,165	15,715
3	Partially mechanized timber collection. Half-orange Kilns	2,597	16,120
4	Hand collecting. Half-orange Kilns	4,881	1,669

3) Conclusions of the possibilitv of charcoal manufacturing

In view of the data presented above, the potential possibilities of the Mutun zone from the point of view of wood for the production of charcoal are very large.

The production based onlv on natural forests would carry with it a deforestation of the zone, for which it is considered that reforestation is indispensable. In this regard verv little has been done to date, as there is a lack of the necessary experience on the species to acclimate, possible yields, etc.

The Unidad Promotora tacitly admits this lack of information as in its volume VI devoted to "Electric energy, Forest Ordination and production of charcoal", it indicates that with the approval of its project by the Nationanal Government, the first operations to carry out in this field are:

- Nursery plan
- Determination of plantation areas

2.4.6 Natural Gas

1) Reserves

The proven recoverable reserves of natural gas of Bolivia remaining as of July 1, 1983 according to the classification adopted by Yacimientos Petrolíferos Fiscales Bolivianos (7) are 4,730 thousand millions cubic feet, with the breakdown indicated in table 2.35. Said reserves remaining are given by difference between the original reserves proven recoverable, less the cumulative production to 1/7/83.

TABLE 2.35

Proved and Recoverable Reserves of Natural Gas
Remanent on 1st July 1.983 (x 10^9 CU FEET)

	Proved recoverable reserves	Cummulative Production (1/7/83)	Remanent reserves 1/7/83
Class I	4,530.7	1,180.8	3,349.9
Class II	372.2	--	372.2
Class III	1,007.9	--	1,007.9
Total x 10^9 feet^3	5,910.8	1,180.8	4,730.0
Total %	100.0	20.0	80.0

Source: YPFB, reference 7

The class I proven reserves are those recoverable from existing wells, ready for production. Class II are also recoverable additionally from existing wells not yet ready for production. Lastly, class III require the drilling of new wells in the proven area.

The reserve breakdown by productive fields is taken in table 2.36. The location of these fields is shown in the drawing of figure 2.19 locating all of them in the Llanura Chaco-Beniana and the Subandean Strip, Departments of Santa Cruz, Chuquisaca and Tarija.

2) Present and foreseen productions

Natural gas production in Bolivia is about 300 million cubic feed a day, of which 220 million/day are exported by gas-ducts to the Argentine Republic the sales contract of which ends in 1992. The price is revised every six months being the one effective for 1985 of US$ 4.70/thousand cubic feet.

The internal consumption located in Santa Cruz and Sucre fundamentally for producing electric energy is only about 20 million cubic feet a day, with a price that is today at cost level in US$ 1.5/1000 cubic feet. The difference between the production less the sales to Argentina and the internal consumption is reinjected to the fields.

TECNIBERIA

TABLE 2.36

Sheet 1

Remanent Reserve at 1st July 1.983

Producing fields	Crude Oil MBbl.	Gas in solution 10^9 CF	Condensed MBbl.	Free Gas 10^9	Crude Oil + Condensed MBbl	Natural Gas 10^9 CF
Caranda	14,080.00	49.40	789.00	142.10	14,869.00	191.50
Colpa	1,453.00	4.20	3,095.00	278.50	4,548.00	282.70
Rio Grande	--	--	18,891.00	1,085.40	18,891.00	1,085.40
Palmar	434.30	4.28	1,029.40	9.89	1,463.70	14.17
Santa Cruz	--	--	22.40	10.43	22.40	10.43
Naranjillos	--	--	816.40	73.80	816.40	73.80
Yapacani	--	--	4,538.20	4,538.20	4,538.20	485.61
Enconada	--	--	540.80	33.27	540.80	33.27
Palometas	--	--	356.10	112.97	356.12	112.97
Santa Rosa	--	--	302.10	119.82	302.10	119.82
Palacios	--	--	957.40	103.60	957.40	103.60
Monte Cristo	--	--	1,839.20	62.35	1,839.20	62.35
Espejos	15.60	--	--	--	15.60	--
Rio Seco	--	--	58.90	9.42	58.90	9.42
Humberto Suárez	761.90	0.17	--	6.33	761.90	6.50
La Peña	1,829.00	2.20	345.00	26.20	2,174.00	28.40
Bulo Bulo	--	--	53.00	3.51	53.00	3.51
Guairuy	86.10	--	--	--	86.10	--

Sheet 2

TABLE 2.36

Remanent Reserve at 1st July 1.983

Producing fields	Crude Oil MBbl.	Gas in solution 10^9 CF	Condensed MBbl.	Free Gas 10^9	Crude Oil + Condensed MBbl	Natural Gas 10^9 CF
Buena Vista	0.80	--	--	--	0.80	--
Camatindi	13.20	--	--	--	13.20	--
Caigua	513.70	0.59	71.30	28.52	585.00	29.11
Los Monos	5.70	0.01	--	9.29	5.70	9.30
San Alberto	66.00	--	--	--	66.00	--
Area Bermejo	218.50	--	--	--	218.50	--
Sanandita	69.40	--	--	0.15	69.40	0.15
Cambeiti	1,174.30	1.38	--	3.82	1,174.30	5.20
Vuelta Grande	--	--	51,642.30	838.03	51,642.30	838.03
Ñupucu	--	--	2.50	0.24	2.50	0.24
El Espino	--	--	1,394.60	36.07	1,394.60	36.07
San Roque	--	--	1,769.70	106.15	1,769.70	106.15
Camiri	9,850.80	4.30	--	--	9,850.80	4.30
Tatarenda	192.30	--	--	--	192.30	--
Monteaguado	15,797.30	20.22	33.80	35.27	15,831.10	55.49
Huayco	--	--	66.70	17.78	66.70	17.78
Porvenir	--	--	9,160.90	105.57	9,160.90	105.57
Tita	--	--	649.30	9.49	649.30	9.49

TECNIBERIA

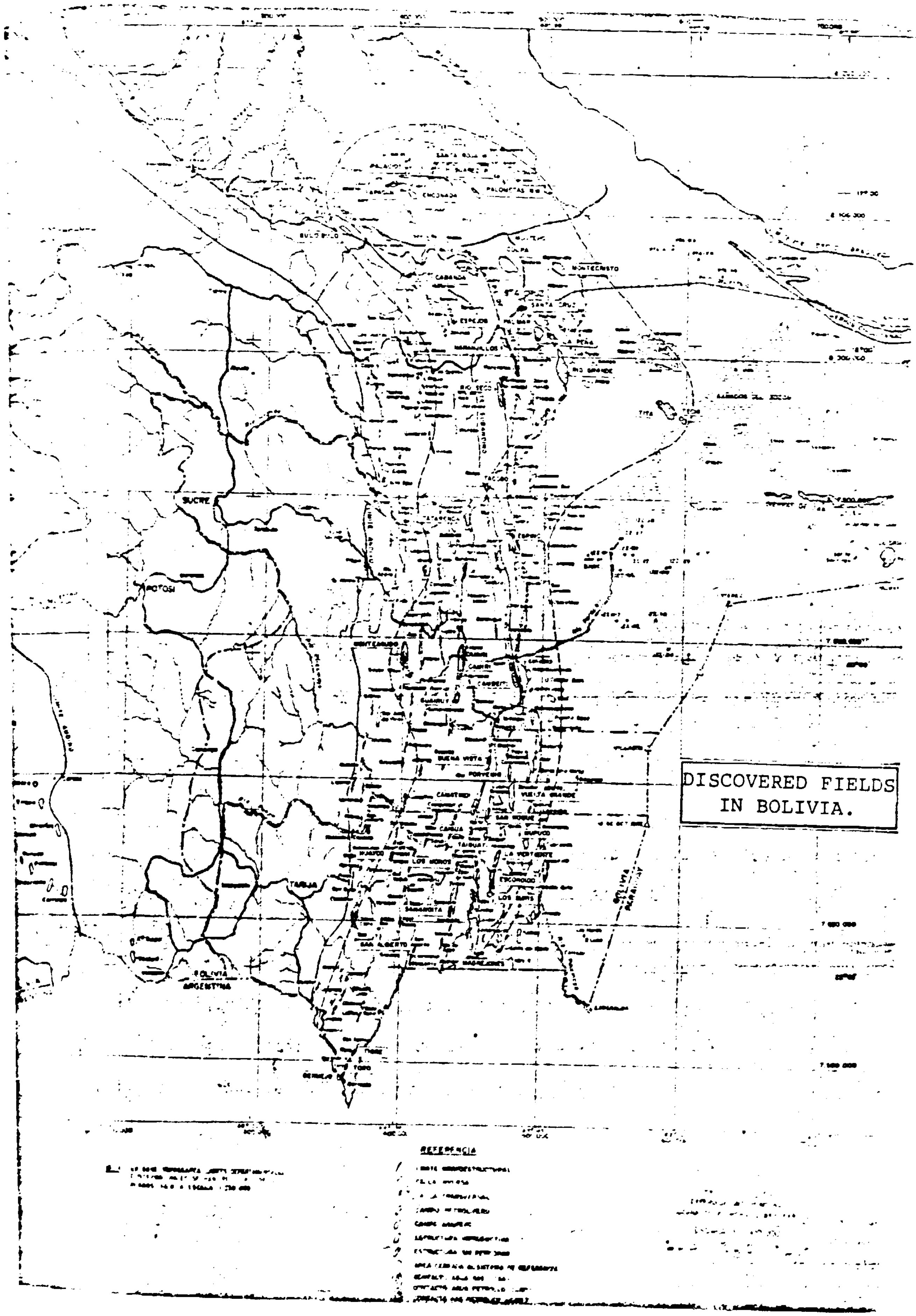
TABLE 2.36 Sheet 3

Remanent Reserve at 1st July 1.983

Producing fields	Crude Oil MBbl.	Gas in solution 10^9 CF	Condensed MBbl.	Free Gas 10^9	Crude Oil + Condensed MBbl	Natural Gas 10^9 CF
Techi	44.30	--	--	--	44.30	--
La Vertiente	--	--	2,104.50	159.88	2,104.50	159.88
Los Suris	--	--	2,004.00	260.49	2,004.00	260.49
Taiguati	--	--	2,046.60	88.24	2,046.60	88.24
Escondido	--	--	10,015.70	381.08	10,015.70	381.08
National Total	46,606.20	86.75	114,640.80	4,643.27	161,247.00	4,730.02

Source: YPFB

FIGURE 2.19.



DISCOVERED FIELDS IN BOLIVIA.

The short term forecast is duplicating internal consumption for which there is being rehabilitated as a gas-duct an old oil-duct from Camiri to Cochabamba, as well as another old line from Cochabamba to Oruro, to later joining with La Paz. With all this, the present fuel consumption will be replaced by natural gas, as well as diesel and kerosene in cement, glass and brewery factories. Likewise to the substituted by natural gas will be the use of other fuels in the Southern zone of the Department of Tarija in cement and sugar mill factories.

The old project (from 1974) to supply Brazil with about 400 million cubic feet/day, a figure later reduced to 240 million, through a new Santa Cruz-San Pablo gas pipeline is today postponed. The cost of the 600 km of the Bolivian section of the gas pipeline from Santa Cruz to Puerto Suárez was US$ 1,000-1,200 million, figure also including the activation of the fields. The completion time was about 3 years.

One of the most difficult problems to resolve about this project in the opinion of those responsible in YPFB is the payment system for the gas, as Brazil is not willing to pay in foreign exchange, wishing in turn to pay in products. There are also opinion sectors in Bolivia against this gas export to Brazil.

3) Characteristics of the natural gas

The estimated average of molarity composition of all the fields, as a function of the chromatographic analyses and the reserves of remaining recoverable gas per field is as follows:

Component	Mol.%
Nitrogen	1.44
Carbon dioxide	1.15
Methane	86.85
Ethane	6.45
Propane	2.49
Isobutane	0.29
Normal-Butane	0.64
Iso-Pentane	0.12
Normal-Pentane	0.17
Hexane	0.19
Heptane	0.22

The density is 0.659. The lower calorific measured at 60ºF and 14 lbs/in^2 is 1,045 BTU/cubic foot.

The internal price of US$ 1.5/1000 cubic feet is equivalent to US$ 5.70/million Kcal, that is, about 3 times less than the international reference price (US$ 18.30/m Kcal), that in turn coincides sensitively with the present price of the Bolivian gas supply to Argentina (US$ 4.70/1000 cubic feet, equivalent to US$ 17.85/M Kcal).

4) Conclusions on natural gas

From the point of view of consumption there is no problem at this time, since production exceeds the sum of national consumption plus exports to Argentina in a figure of about 40 million cubic feet per day. In the future, when national consumption is doubled, the surpluses at the present production rate will be 20 million cubic feet/day.

The project foreseen in the Cobrapi I studv would have natural gas requirements of 101,035,000 m^3/year, equivalent to 10.81 million cubic feet per day of operation (supposing 330 opeation days a year) or 9.78 million cubic feet per calendary day.

The problem is located in that gas is available in the zone of the city of Santa Cruz near which there are manv productive fields, but not so in the Mutun zone.

2.4.7 Electric energy

1) Installed power and distribution networks

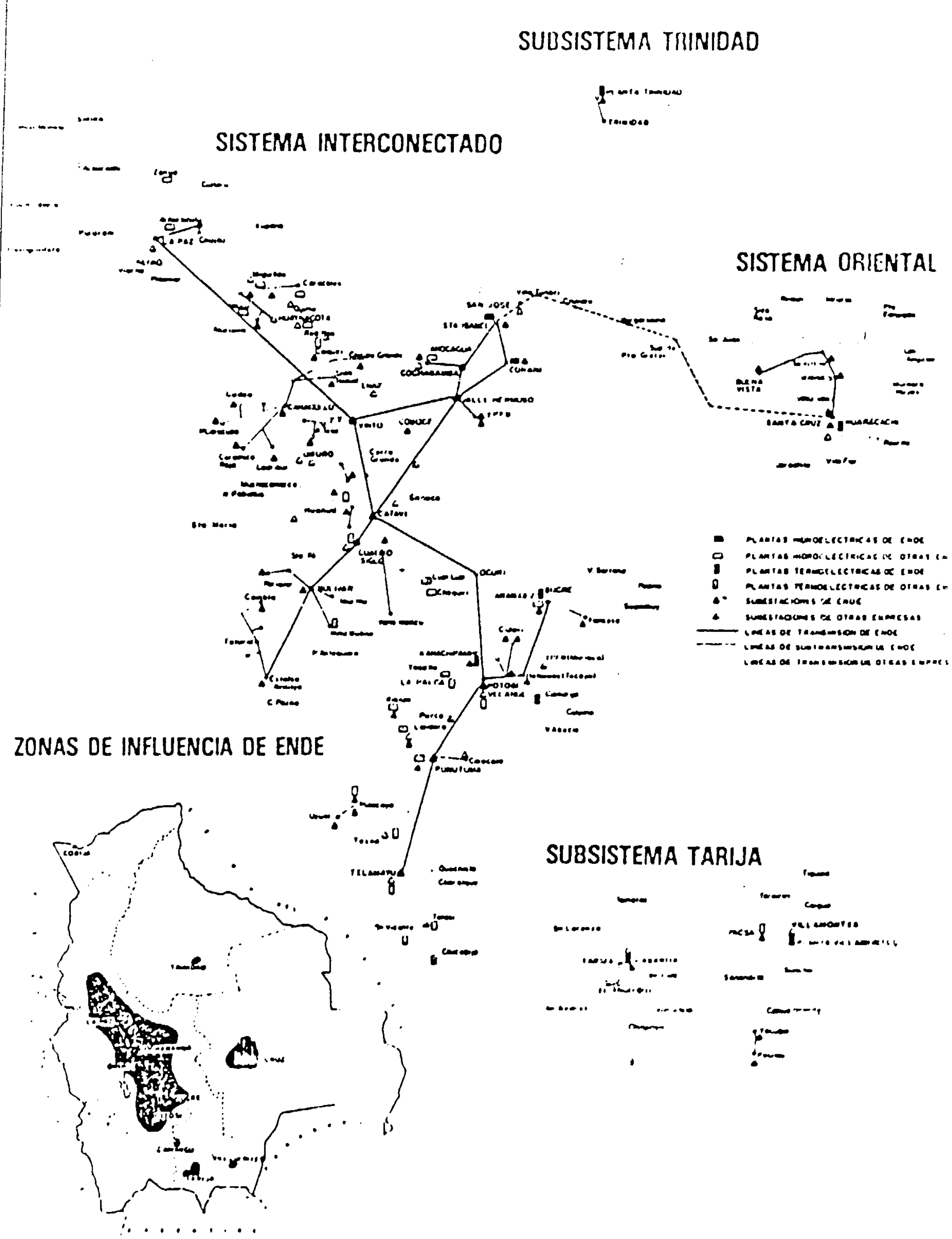
ENDE (Empresa Nacional de Electricidad, S.A.) organized in 1962, started its operations in 1967. Now, with 294,000 kW of installed power, it is the main electric service companv in Bolivia. In its 18 years of activity, ENDE has developed an interconnected national system and has taken charge of the main isolated systems in the countrv. In high voltage 115 and 69 kV are employed. In low voltage, 380, 220 and 110 V. The frequency is 50 H.

Figure 2.20 takes the influence zones of ENDE which cover basically two electric distribution system and two independent sub-systems, that is, not interconnected between each other.

a) Interconnected (central) system.

This is the most important system and it covers a part of the Western departments of the countrv (La Paz, Oruro, Cochabamba, Potosí and Chuquisaca). The total installed power is 164,700 kW, of which 77% is of hydraulic origin and 23% thermal. It has two hydraulic plants, the largest in the country:

FIGURE 2.20. ELECTRIC NETS OF E.N.D.E.



-	Corani	54,000 kW
-	Santa Isabel	72,000 kW
	Total hydraulic	126,000 kW

b) Eastern system.

It is located in the zone around the city of Santa Cruz in the same name Department. The electric energy production takes place in the Huarachí thermal plant, of 117,000 kW equipped with 5 turbines driven by natural gas.

c) Trinidad system.

It covers the zone around Trinidad, capital of the Department of Beni. It only has a Diesel plant with an effective power of 2,500 kW.

d) Tarija subsystem.

In the same name Department, they have a small hydraulic plant and another Diesel one, with a total effective power of 4,665 kW.

To summarize, of the 294,000 kW installed, 282,300 kW, that is, 96% belongs to 5 plants with the following distribution:

Hydraulic type

Interconnected system:

Corani	54,000 kW
Santa Isabel	72,000 kW
Total	126,000 kW

Thermal type

Interconnected system:

Aranjuez-Potosí	38,700 kW

Eastern system:

Huaracachí	117,600 kW
Total	156,300 kW

As the most important project one must mention the San José hydraulic plant on the Paracti river, downstream of the Santa Isabel plant, belonging to the integrated system, with an installable power of 126,900 kW and the commissioning of which is foreseen for 1992.

Likewise, it has been foreseen to interconnect the Eastern and the central systems from the new San José plant to the city of Santa Cruz, as is taken in figure 2.20.

2) Considerations on the supply of electric power to the Department of Santa Cruz

As seen in figure 2.20, the Mutun zone lacks ENDE supply, being supplied from Corumbá (Brazil). The problem is that the Brazilian frequency is 60 Hz, that requires a frequency converter. The present price of electric energy from Brazil is US$ 0.036 kWh.

In the zone of the city of Santa Cruz, according to 1984 data the maximum power demand was 61,200 kW (52% of the installed power), increasing the production to 274.6 million kWh. This production was given to the Cooperativa Rural de Electrificación in the

Substations of Santa Cruz, Parque Industrial, Warnes, Montera, Buena Vista and Viru-Viru.

In the substation of the Huaracachí plant, according to data from the Cobrapi I study, for 1987 there were foreseen the following short circuit powers:

Minimum	556 mVA
Maximum	641 mVA

According to said Cobrapi I study, the installation of a steel mill, continuous casting mill and rolling mill in Santa Cruz for 100,000 t/year of rolled products, would require a power of 28.8 mVA with a consumption of more than 109 million kWh/year, which would make necessary the interconnection of the Eastern and central systems, as well as continuous operation of 4 turbines at Huaracachí.

3) Price of electric energy

In respect to the new electric rates, Supreme Decree 21060 of 29/8/85 sets forth that the rates for industrial consumption for mining activities, casting mills and industry supplying the generating companies, will be formed by a rate of consumption of energy and another charge rate for demand.

These rates will be set in direct negotiation for each operation, between energy suppliers and the consumers as a function of the location, class of facility and factors of load specific of each consumer.

The combined rate for these concepts will not exceed US$ 0.045 (four and a half cents of a US dollar) for kilowatt-hour consumed.

2.4.8 Water

From the point of view of water supply for a possible siderurgical plant to be installed near the city of Santa Cruz, there is no problem at all, as near it flows the Grande river and its tributary throught the city itself, the Piray.

Regarding the Mutun, the United Nations report gave the following hydraulic resources in the zone:

San Juan river	60 liters/sec.
Piscina and Tigre streams	20/30 liters/sec.

The McKee study also gives the San Juan river in low water a flow of 60 l/sec., the dry season being in June, July and August with a maximum rainfall of 300 mm.

The San Juan river has a concrete dam with 500 m^3 storage capacity. It has a Diesel pump with a flow of 110 m^3/h driving the water to an elevated tank at 70 m, with capacity for 300 m^3, at a distance of 1,570 m. Pipe diameter is 6".

In 1972 drilling was made with the idea of determining the aquifer capacity, the location of which is taken in the drawing of figure 2.21, taken from the Unidad Promotora, that in turn comes from a McKee source. The capacity of this aquifer was estimated from 2 to 3 l/sec.

For a large scale water consumption it would have to be pumped from the Tamengo Canal, between Puerto Suárez and Corumbá, 30 km from Mutun, or from the swampy zones located 20-30 km to the South, where the phreatic level is permanently on the surface.

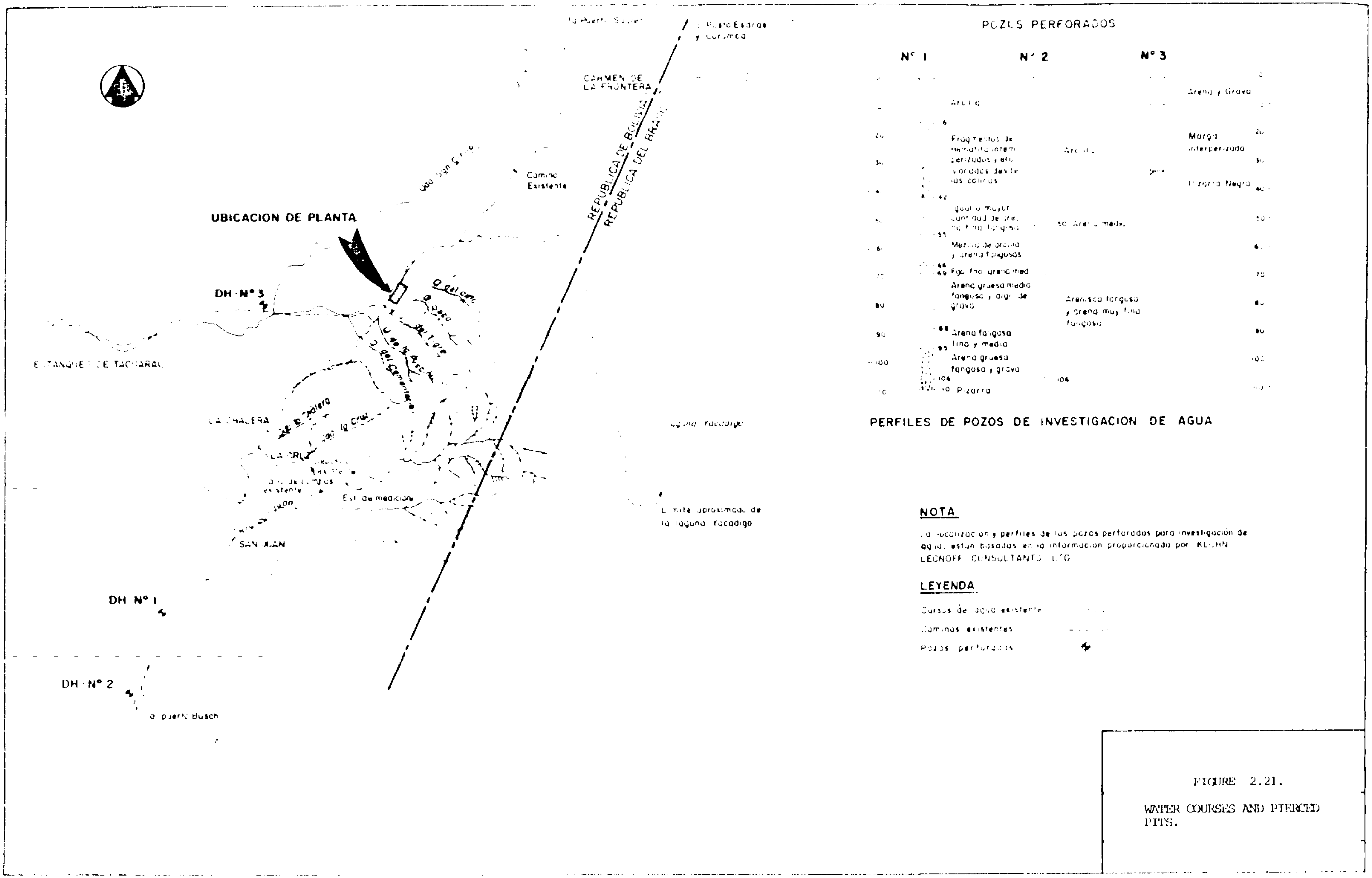


FIGURE 2.21.

WATER COURSES AND PIERCED PITS.

In both locations there is supposed a cost of the water of renewal of US$ 0.09/m^3, taken from the Unidad Promotora.

2.4.9 Transport means

1) Road network

The road network existing in Bolivia has the following extent:

Paved	1,396 km
Riprap	7,975 km
Earth	30,278 km
Total	39,629 km

Only the Departments of la Paz, Cochabamba, Santa Cruz and Oruro are connected by paved roads. The connection of Santa Cruz with Tarija, Chuquisaca (Sucre) and Potosí is by riprap roads.

There is neither connection between Santa Cruz and Trinidad (Beni) nor with Cobija (Pando), which are inaccessible by road during the rainy season.

The paved road between Santa Cruz and Cochabamba, fundamental for connection with La Paz and Oruro, has a need of repairs in almost all its course.

There is a project of a road construction between Santa Cruz and Puerto Suárez, which will have a course parallel to the present railroad. Likewise there is another project between Santa Cruz and Cochabamba avoiding passing the Central Mountain Range. In this case the section between Chimoré and Yapacani in the Department of Cochabamba is still to be finished.

2) Railroad network

There are two networks, the Andean and the Eastern, not connected between each other.

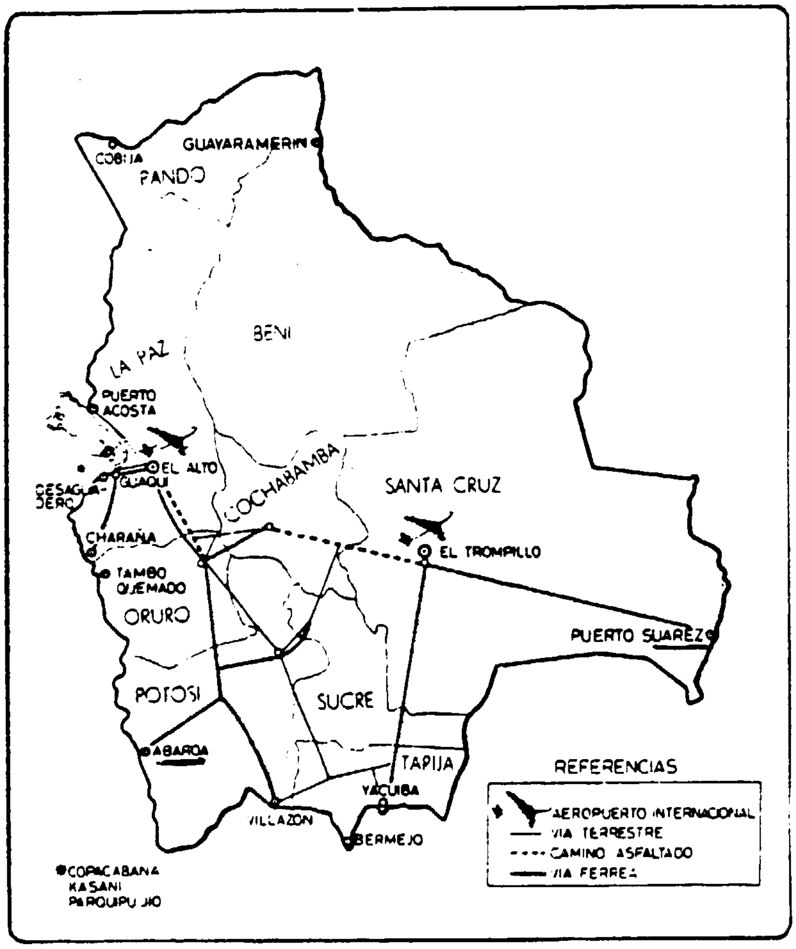
The Andean network connects the Departments of La Paz, Oruro, Cochabamba, Potosí and Chuquisaca (Sucre), joining the Argentine network on Villazón and that of Chile on Charaña and Abaroa. It has an extension of 2,257 km.

The Eastern network with 1,426 km extension, connects the Departments of Santa Cruz, Chuquisaca and Tarija, where it connects with the Argentina network at Yacuiba. In Santa Cruz the network extends to the East up to Puerto Suárez, at the border with Brazil, connecting with the Brazilian network Corumbá-San Pablo.

There are various alternatives of interconnection of the Andean and the Eastern networks (see figs. 2.22 and 2.23).

a) Cochabamba-Vallegrande-Mataral-Santa Cruz: Its construction is being negotiated, having made the feasibility study.
b) Sucre-Vallegrande-Florida: There is a section of 78 km built.
c) Sucre-Baynibe: With an extension of 365 km, there is a built section of 40 km between Baynibe and Cuerto.
d) Balcarce-Tarija-El Palmar: Distance of 470 km. The Balcarce-Tarija section is under study.

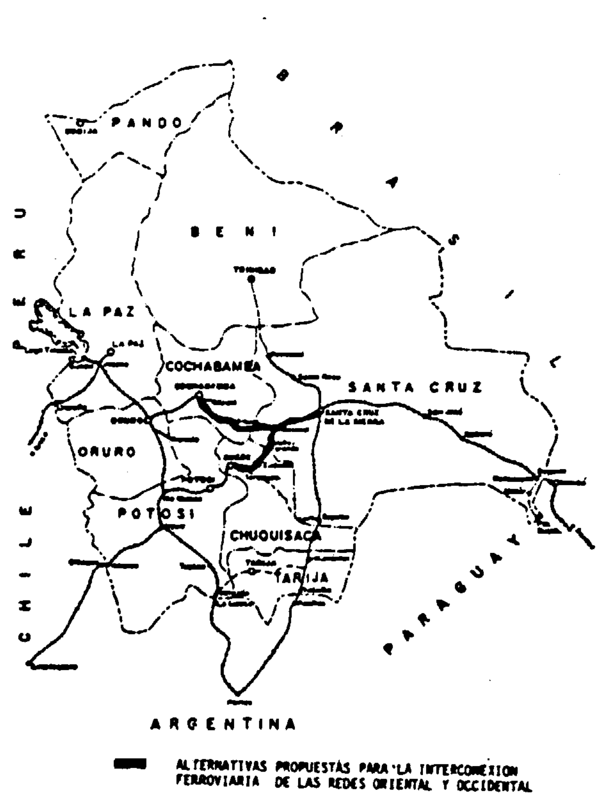
FIGURE 2.22



ROADS AND RAILWAY NETS IN BOLIVIA.

FIGURE 2. 23.

RAILWAY MAP.



3) Airports

International airports exist in La Paz (El Alto), Santa Cruz (Viru Viru) and Puerto Suárez.

National airports exist in Cochabamba, Potosí, Oruro, Sucre, Tarija and Trinidad.

4) Waterways

On the East of the Department of Santa Cruz, the navigable waterway par excellence is the Paraguay river. Today there is no Bolivian port that is usable, using for exports of iron ore from Mutun the close Brazilian port of Corumbá.

There is a project for building a river port in Puerto Quijarro, location very close to Puerto Suárez, which requires dredging the Tamengo canal, that communicates Laguna Cáceres with Paraguay river. This port will have a minimum draft of 6 feet (1.8 m) in low water, with a docking line of 160 m long by 30 m wide. It is foreseen to transport complete trains of 6 barges with 700 t each.

The maximum movement of this port will be 400,000 t/year, corresponding to 295,000 t of exports and 105,000 t imports.

The investment is estimated at US$ 10 million and the construction time 10 years. Bidding for the engineering project was foreseen to be in November 1985. For its financing it is counted with a CACEX credit from the Banco do Brasil to be paid in 12 years with a deficiency period of 1 year and 7% interest.

5) Transport costs

Table 2.37 gives the distances in km, transport means, estimated time in hours and rates in US$/t deduced from the studies for different sections. It is noted that the Mutun-Santa Cruz railroad had an annual increment in its rates of 23% for the period 1977 to February 1985, while truck transport between 1977 and 1982 had an annual increment in its rates of 12% a year, remaining in November 1982 in US$ 0.12056 t/km. This road transport price in 1982 is about 11% highter than the US$ 0.1087 t/km mentioned in section 2.4.5 1) for charcoal transport.

The present situation is as follows:

a) Railroad transport.

The new rates given by ENFE (9), including the reductions indicated on September 30, 1985, applicable as of October 2, 1985, are those taken in table 2.38.

There are discriminated rates for type of product (this table takes those applicable to iron ore, wood, charcoal, and siderurgical products, being wood the lowest rate and also by network (Eastern or Western). For the same product the cost in US$ t/km is practically the same within each network. It is also noted that the rates in the Western network are higher than in the Eastern one.

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TABLE 2.37

Transport Prices According to the Studies (US$/t)

Way	Distance Km	Transport Mean	Estimated Time (hours)	McKee 1,977	Cobrapi Nov 1,982	U. Promotora 13/2/85
Mutún - Santa Cruz	651	Railway	48	8.30	31.33	40.38
Santa Cruz - Cochabamba	497	Truck	72	23.80	59.92 (1)	--
Cochabamba - Oruro	200	Railway	30	--	14.28	--
Cochabamba - La Paz	430	Railway	73	13.05	23.15	--
Santa Cruz - Trinidad	558	Truck	96	--	67.27 (1)	--
Santa Cruz - Tarija	723	Truck	120	--	87.17 (1)	--
Santa Cruz - Sucre	610	Truck	96	--	73.55 (1)	--

(1) Applying 0.12055 US$/Mt/km calculated by COBRAPI

TABLE 2.38

Railway Fares

Network	Way	Iron Ores (1)		Timber (2)		Charcoal		Iron and Steel Products (2)	
		US $/t	US $/t/km	US $/t	US $/t/km	US $/t	US $/t/km	US $/t	US $/t/km
Eastern	Puerto Suárez - Santa Cruz (651 km)	72.45	0.111	49.85	0.077	70.44	0.108	74.00	0.114
Western	Cochabamba - La Paz (498 km)	69.91	0.140	44.77	0.090	63.26	0.127	64.84	0.130
Eastern	Yacuiba - Santa Cruz (539 km)	60.82	0.113	41.84	0.078	59.12	0.110	62.	0.115

(1) Given in US$/t by ENFE
(2) Given in $b/t by FNFE. Applied rate of exchange: 1 US$ = 1 M $ b

Source: ENFE (Considering the fares reduction communicated on September the 30 th 1.985)

b) Truck transport.

According to Supreme Decree 21,060 the rates for cargo transport will be set by agreement between users and transporters. A price of US$ 0.15 t/km is estimated, taking into account that today US$ 3.5 t are charged for the transport of iron ore between Mutun and Corumba, a distance of about 23 km, so that railroad transport will be always cheaper than truck transport, a situation observed also in 1977 and 1992 in the McKee and Cobrapi studies respectively.

2.4.10 Human resources

a) Resources

The Bolivian active population is today around 2 million persons (1.97 million in 1983), with the following distribution:

Agriculture and cattle	50%
Industry and mining	24%
Services	26%
Total	100%

In metallic mining according to data of the Asociación Nacional de Mineros Medianos (10) there were employed in the joint Bolivian mining 65,000 persons in 1983, with an employment loss in 1982 of 5 7%. Mining data are included as the country lacking a siderurgical industry and having a transforming industry of siderurgical products that is very scarce and very atomized, the professional mining categories will be taken as orientation at the salary level.

The city of Santa Cruz has a present population of about 400,000 persons, estimating that only about 300 are employed in activities related to siderurgical products.

On its part, Puerto Suárez and its influence zone has a population of about 1,500 persons, being 120 employed in the SIDERSA mining works.

In mining and metallurgy there are the following professional categories:

Doctors in Metallurgy
Masters
Engineers
Hight Technicians
Medium Technicians
Qualified labor
Semiqualified labor
Non-qualified labor

The training centers excepting the Doctorate and master levels are the following:

a) Universities.

La Paz
Oruro
Potosí

b) Industrial school.

La Paz

c) Labor training centers (FOMO).

In each Department

2) Personnel costs

Both in the Cobrapi and the Unidad Promotora studies, the 8 mining and metallurgy professional categories were rearranged into 6, with the following monthly basic salaries as of February 1985:

Category	Basic salary US$/month
High	325.-
Technician	155.-
Master	135.-
Qualified worker	135.-
Semiqualified worker	120.-
Non-qualified worker	100.-

The social benefits are estimated in 73% of the basic monthly salary, so the annual personnel costs will be as follows:

Category	Annual cost US$/year
High	6,747.-
Technician	3,217.8
Master	3,217.8
Qualified	2,802.6
Semiqualified	2,491.2
Non-qualified	2,076.-

For foreign technical assistance costs are foreseen per expert in US$ 4,000/month, equivalent to US$ 48,000/year.

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ONUDI - 4177

III. SELECTION OF ALTERNATIVES

3.1 INTRODUCTION

In this chapter the different possible alternatives for the obtention of liquid steel are studied. The units of continuous casting for obtaining the billets and their rolling are considered common to all alternatives.

Previous to the analysis and selection of the alternatives, is studied the ores concentration in Mutun, to obtain a calibrated ore suitable for its use either in the blast furnace or in direct reduction. The Fe contant is 64.5%.

The possible alternatives for the liquid steel production are the two following ones:

Alternative I

Blast furnace with charcoal and pig iron refining into steel in LD converter.

Alternative II

Production of sponge iron with natural gas (N.G) with subsequent melting and refining in electric arc furnace.

Concerning the iron ore, it has only been considered calibrated because can be used directly in any of the analyzed processes. It is not necessary to pelletize. Another aspect is the fines generation because of the decrepitation of the ores appointed by H y L and CVRD. Neverthelees this problem could be solved with a briqueting machine at the product outlet of the direct reduction plant.

Alternative III

For this third alternative, the production of rolled material out of imported billets, is the only case studied.

3.2 MINING AND PREPARATION OF IRON LIMESTONE AND LIME

3.2.1 Iron Ore

1) Process Description

As already expressed in section 2.4.2 3), the iron ore to be used for the national siderurgical project will be the Mutun eluvial calibrate. Eventually coluvial material from some selected zones could be used, providing that similar quality to that of the former is garanted (Fe = 64%, P = 0,9). The primary ore is to be discarded. According to the test and the report performed by Cobrapi, the preparation of the ore would consist simply of crushing and water spraying the crude ore in order to obtain a calibrate of 1 1/4" to 1/4".

Given that according to the Cobrapi and Mckee studies of the coluvial, it is not possible to concentrate the calibrate ore, and keeping in mind that its Fe grade may range in the zone selected for working from 59.2 to 67.8%, and that there will also be very notable variations in phosphorus content (0.059 to 0.158% according to table 2.27), in order to obtain the foreseen average quality it will be necessary to:

a) Have a detailed knowledge of the qualities of each of the blocks into which the stocks have been divided.

b) Carry out the mining so as to allow mixing ores of various qualities.

c) Have sufficient stocks of the different calibrate qualities in case it were necessary to correct the grades.

Therefore, it is necessary to carry out a detailed investigation on the zone selected for mining (25 blocks) in accordance with the recommendations of the Cobrapi studies. The Fe and P contents are to be analyzed and the presence of goetite to be identified, since the latter is the iron ore which may cause decrepitation in the blast furnace.

Once this research has been done, a mining plan for a minimum of 5 years should be prepared.

Once the deposit has been examined in detail and the longterm exploration plan has been prepared, the exploitation will present no difficulties except that of having several open cuts so as to be able to extrac different qualities and mix them. The opening to be moved is very small (0.3 m) and the height of the banks is also limited to 1 to 3 m by the thickness of the covering and the ore mass. The mining exploitation will be a cheap operation.

In the case that these recommendations are not followed, there could be unpleasant surprises in the functioning of the blast furnace and in the quality of the crude iron obtained as weel as in the sales of the ore intended for export.

With respect to the concentration of the ore, although from the tests made with dense media it does seem that no possibility exists of improving the calibrate quality, it will be recommendable to confirm this point by performing tests with low grade ores. For example it would suffice to make a simple manual selection to see if there are wastes liberated and if these are found in the thickest fractions (1 1/4"), as seems to have been SIDER A's experience with the coluvial. That is, several tonnes of eluvial would have to be passed through the present "experimental plant".

Concerning the treatment process proposed by Cobrapi seems to be reasonable and it is practically the same as that of Unidad Promotora, which is enclosed as graph 3.1. It consist of:

Pimary Crushing
Second crushing with closed circuit
Sifting with water spray
By pas to eliminate the thick types
Lump hopper
Washing with helical screw to separate fines and loams
Storage of fines
Loam decanting
Sludge basin
Recirculation of clarified waters

The following observations must be made to this process:

a) Gravitmetric concentration tests should be made on the fines by means of jigs, since the test perfomed by Cobrapi with dense liquid had satisfactory results.

b) Laboratory sintering tests should be carried out on these fines.

c) The possibility of selling the fines (sinter-feed) to SOMISA should be investigated, since they import great quantites of this product from Brazil. The sale of sinter feed from Mutun, the grade of which can be 59-60% Fe and 0.100 % P, would considerably improve the metallurgical efficiency of the plant and would represent a supplementary currency income, and would avoid manipulation and storage problems at the mine.

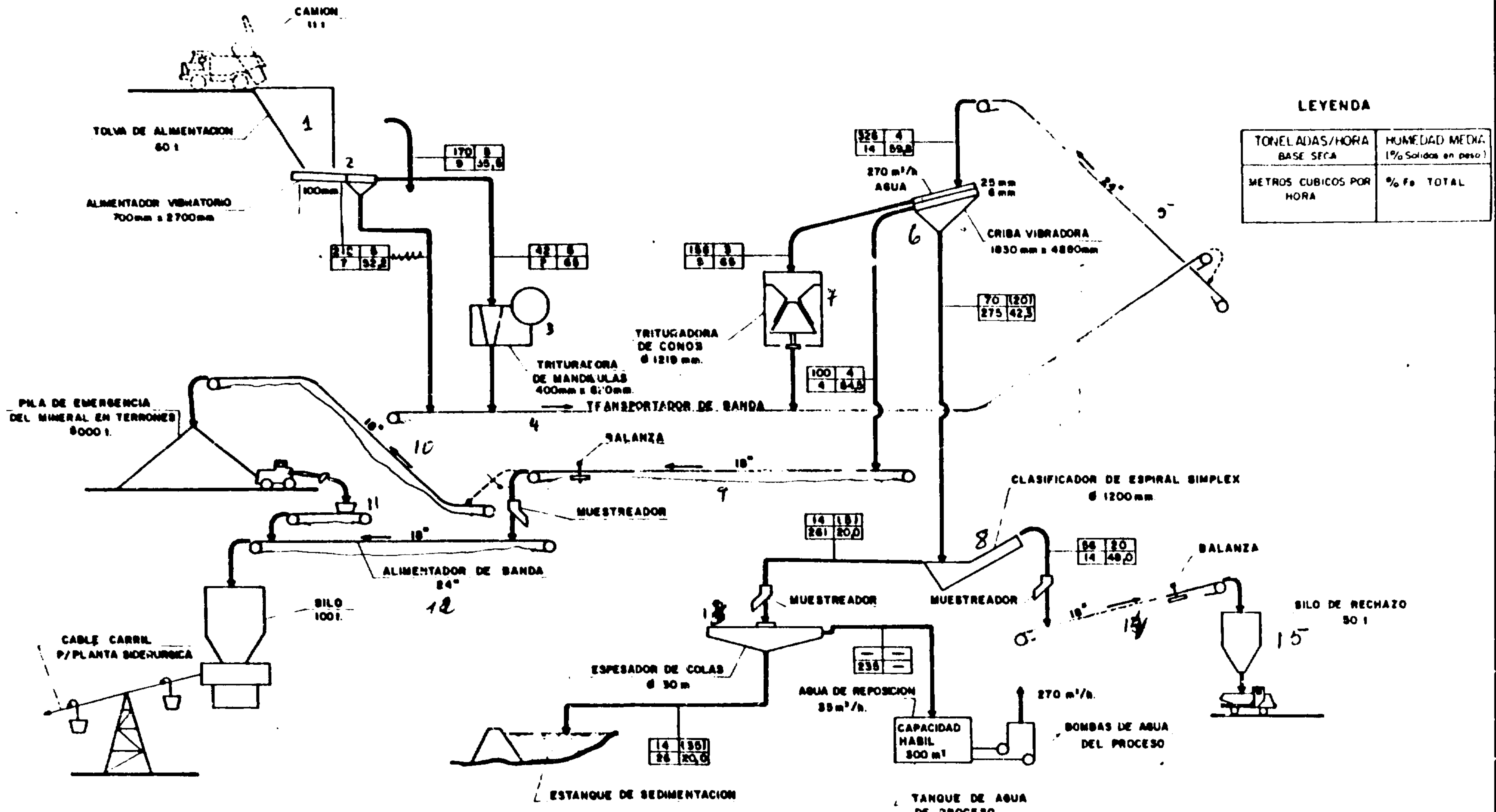

FIGURE 3.1.

SCHEME OF THE IRON ORE PREPARATION PLANT. IRON ORE AND WATER FLOW DIAGRAM.

FUENTE COBRAPI

d) A zone should be foressen for the storage of fines (which represent 31% of the crude ore) with sufficient capacity and cheap handling so as to allow these fines to be utilized once they have been concentrated.

e) Decanting tests should be performed on the loams, studying the water classification and the loam thickening, so as to size the thickener and find out the reactive consumption. This last point is possibily of considerable economic consequence.

f) The location of the sludge should be studied (geotechnical studies), as weel as the behavoir of the loams and the type of sealing dam. It should be kept in mind that the loam represents 17 to 19% of the crude ore.

With regards to the weight efficiency of the calibrate with respect to the crude ore, the former will be approximately 50%, which is shown in figure 3.1, prepared by Unidad Promotora. Even though according to Cobrapi tests, the efficiency would be 57.4% for a sifting of 8 mm and of 31,9 mm 3/8" (see figure 2.28), nevertheless in industrial production there will be greater production of fines. Thus the 50% figure seems prudent.

Another important point is that the calibrate ore be well desludged, because the loams contain a great deal of silica and alkalines, and the latter cause serious problems in the working and duration of the blast furnace.

2) Machinery List and Characteristics

a) Capacity

We have used a tonnage production base of 150,000 t/yr of calibrate intented for:

National Siderurgy	86,200 t/yr.
Exportation to Argentina	63.800 t/yr.
Total	150,000 t/yr.

The tonnage necessary for the national siderurgy is explained in section 3.3.2 and that correponding to export to Argentina is based on point 5 of the minutes of the "Preparatory Meeting for the Bolivian-Argentina Joint Comission, Ferro-Siderurgical Sector", held on April 26 and 27, 1984. Argentina thereby expresses interest in participating in the siderurgical project, and in turn acquiring iron ore from Mutun in quantities ranging from 50 to 100 thousand tons per year without excluding the possibility of increasing these quantities in the future. In addition, in the Puerto Quijarro project the embarkment of 60,000 t/yr., has been foreseen.

b) Mine Machinery

Based on this calibrate ore figure and keeping in mind the weight efficiency, it would be necessary to extract 300,000 t/yr.. of crude eluvial ore. Based on 40 hours a week and 50 weeks, we arrive at 2,000 hrs/yr, which are affected by an utilization coefficient of 0.75. Thus the hourly capacity should be 200 t of ore, which is practically the same as that indicated in figure 3.1.

The machinery anticipated by Cobrapi or Unidad Promotora seems reasonable. This machinery for one working shift only and already taking into consideration the necessary reserve equipment would be:

- 2 Front loaders on tires, shovel capacity 1.4 m^3 100 CV power. One working and another on reserve.
- 2 D-8 Caterpillar tractors or similar. 330 CV power.
- 1 Motorgrader 100/150 CV power.
- 5 12T dump trucks, 200÷220 CV power. Three working and two on reserve.
- 1 10,000 l. tanker truck
- 1 Light truck
- 1 Crane truck
- 2 All-terrain vehicles

c) Plant Machinery

The machinery for the crushing and sifting plant is basically the same as that foreseen by Cobrapi or Unidad Promotora, the following observations being made:

- The crusher with a 650 x 450 mm feed opening should not be fed blocks that surpass the maximum dimension of 360 mm, so as to avoid obstructions being produced. This makes it necessary to place a grate on the hopper or the unloading chute of the trucks. In any case, the granulometry of the crude ore would have to be examined to find out the maximum recoverable size and the % -100 mm.

- It has been supposed that the material is not very hard nor very abrasive, whereby a simple effect crusher could be installed. This would have to be checked and in the contrary case a double effect (Blake) machine of greater price and weight would have to be installed.

- Regulated crusher feeding is indispensable, with no below regulation (approx. 100 mm) sizes. This can be done with a plate feeder and a fixed grate (COBRAPI solution) or with a vibrating feeder with built-in presifting (Unidad Promotora solution). The selection of one or the other solution will depend on the characteristic and behavoir of the crude ore and especially on its clay content. humidity and adherence tendency. If it is necessary to spray into the feeding chute, the Unidad Promotora solution seems more recommendable.

- A good desludging of the lumpy ore 25 to 100 mm is important both to avoid difficulties in the fuctioning of the secondary crusher (Cono Symons or similar) as well as to improve the calibrate quantity. To this end it should be attempted to spray as efficiently as possible during sifting.

- For the sifting there are two alternatives: to use just one 1.8 x 4.9 m machine as proposes Cobrapi; or rather two sifters as suggests Unidad Promotora so as to be able to eliminate by means of by pass the lumpy pieces wheen they have a considerably high percentage of wastes. Tests have to be made to confirm in which sizes the liberated wastes are found in order to determine the sifting size and if the sifting should be done on the 1 1/4 to 8mm (or 3/8") fraction or rather on the +1 1/4" fraction, since this would affect the size and arrangement of the sifters.

Another solution could be to place only one sifter with 3 screens, which would allow greater flexibility, although it would offer as disadvantage more difficult maintenance and spraying systems.

In the investment evaluation a 2-level sifter has been supposed, since this point is not well defined.

- For investment evaluation purposes it has been admitted that the loam thickening and water classification can be done in a 30 m. diameter thickener. As has been expressed, this is a point which must be checked by tests.

- It has not been possible to evaluate the investments necessary for the sludge basin, since there are no more data.

- It has been admitted that the transport of the calibrate from the crushing plant to the siderurgical plant be done by cable carrier, but this is a point which should be studied in more detail, for a conveyor belt might a more economical solution both in regards to investment and maintenance.

This list of machinery and characteristics are:

1 Hopper or feeding chute
1 Feeder and presifter
1 Simple effect jaw crusher with 650 x 450 mm catchbasin inlet, 50 CV motor power
1 Cono Symons standard, 4', 125 CV motor
1 Two-level sifter with $9m^2$ serviceable area. 20 CV motor

1	Double helical screw classifier, 600 mm diameter and 6,000 mm lenght. 12 CV motor
1	Thickener with 30 m diameter. 5 CV motor
1	Band feeder
1	Set of conveyor belts
1	Pump/250m^3/hr for 40 w.c.m.
1	Cable carrier for transport distance of 2,900 m and 500 m off-level. Regenerative actioning power 150 CV
2	Scales installed on conveyor belts
3	Samplers, 2 for lumps and 1 for pulp

The installation will work one shift per day.

3) Manpower

The supervisory and administrative personnel will be the same for iron and limestone mineworks and plant. This personnel will be the following:

Title	Qualification	Number
Chief of iron and limestone mineworks	Superior	1
Topographer	Technician	1

The iron mineworks, which will work one only shift, will have the following foreseen personnel

Exploitation technician	Techinician	1
Designer	Qualified	1

Title	Qualification	Number
Machine operators (shovel, tractor and motorgrader)	Semi-Qualified	3
Drivers (1 truck, 1 light truck, 1 jeep and crane truck)	Semi-Qualified	6
Topographer's helper	Non-Qualified	1
Total		12

For the crushing and sifting plant, which will work only one sift, the personnel will be:

Title	Qualification	Number
Control room operator	Master	1
Plant operator	Semi-Qualified	2
Cable carrier operators	Semi-Qualified	2
Helpers	Non-Qualified	4
Driver (fines and waste removal)	Semi-Qualified	1
Total		10

For the maintenace of the machinery and installation both for the iron and limestone ores, the foreseen personnel will be:

Title	Qualification	Number
Mechanical technician	Technician	1
Electrical technician	Technician	1

Title	Qualification	Number
Mechanical foreman	Master	1
Machanics	Qualified	2

Title	Qualification	Number
Welder	Qualified	1
Electrician	Qualified	1
Helpers	Semi-Qualified	3
Total		10

For cost purposes, the personnel with a maximum category of "Master" have been considered direct monpower. Technicians and superior technicians have been included in the general costs. Following this criteria, the direct cost personnel of the iron mineworks are:

Exploitation:		
	Qualified	1
	Semi-Qualified	9
	Non-Qualified	1
Plant:		
	Master	1
	Semi-Qualified	5
	Non-Qualified	4
Maintenance:		
	Master	1
	Qualified	4
	Semi-Qualified	3
Total		29

In accordance with this, the efficiency of calibrate/tons/man will be:

$$\frac{150,000}{29} = 5170 \text{ t/man/yr}$$

This efficiency is considered acceptable since for these massive ores the range is 6,000 to 12,000 t/man/yr.

4) Equipment investment

a) Mine Machinery

	Amount 10^3 US$
2 Frontal loaders on tires, capacity 1,4 m^3	120
2 D-8 Caterpillar tractors or similar	530
1 motorgrader	95
5 dump trucks 10/12 t	200
1 tanker truck, 12,000 l.	25
1 light truck	15
1 crane truck	20
2 all-terrain vehicles	40
	1045

b) Plant Machinery

1 feeder and grate	23
1 simple effect jaw crusher	25
1 sifter, 9 m^2, 2 screens	20
1 cone, 4 ft	85
1 helical classifier	15

	Amount 10^3 US$
1 thickener	100
1 band feeder	10
1 pump, 250 m^3/hr 40 w.c.m.	6
1 set of conveyor belts	140
1 cable carrier	1275
2 scales and 3 samplers	21
	1720

c) Other Items

On table 3.1 the investments in other items for mine working and the plant are shown.

The mine working has a very particular treatment since the investment working for determined items have not been foreseen or are very low, for example, for installation, set-up, starting up, personnel and engineering.

The items which appear in the table are the following:

- Studies, research and prior tests, which affect equally the mine working as well as the plant and which refer to: detailed investigation of the zone to be worked; Fe and P chemical analyses; identification of zones containing goetite; gravimetric tests with lumps and fines from furnace; sedimentation test; geotechnic studies of the sludge basin, etc.
- Equipment: These are the values calculated in section 3.2.1 4).

- Cranes: In view of the slight importance of this equipment (they are merely manual hoisting blocks), it is considered in the following point.
- Halls: a 1,000 m^2 hall has been foreseen for mine equipment maintenance. For the plant the equipment frames, sheds and foundations are included, this amount being 20% of that corresponding to that equipment.
- Spare parts: 5% of the cost of the equipment.
- Installations: These are: motors electrical installation, water network, control, etc. They have been evaluated as 30% of the equipment amount.
- Transport, insurance and fees: represent 15% of items (2+5+6).
- Subtotal is sum (1+2+3+4+5+6+7).
- Assembly and start-up is 7% to the subtotal, excluding item 1.
- Personnel training is 1% of the equipment value.
- Engineering is 7% of the subtotal.
- Unforeseen are 10% of the subtotal.

The total sum of the investements amounts to:

	1,726	10^3US$	For mine exploitation
	3,859.5	10^3US$	For the plant
Total	5,585.5	10^3US$	For iron minework

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TABLE 3.1

Summary of investments in mining and iron preparation plant

Investments in 10^3 US$

Item	Mining exploitation	Crushing and sieving	Total
1. Studies, researchs and previous analyses	150	100	250
2. Equipment	1,045	1,720	2,765
3. Bays, structures civil are works	125	344	469
4. Cranes (included in 3.)	--	--	--
5. Spares	52	86	138
6. Utilities	20	516	536
7. Transportation, insurances and taxes	168	349	517
8. Subtotal	1,560	3,115	4,675
9. Erection and start-up	--	211	211
10. Personnel training	--	17	17
11. Engineering	10	205	215
12. Contingencies	156	311.5	467.5
13. Total	1,726	3,859.5	5,585.5

5) Production Costs

a) Manpower

Qualification	Number	Yrly Cost man US$	Annual Total Cost US$
Qualified	2	3,217.8	6,436
Masters	5	2,802.6	14,013
Semi-Qualified	17	2,491.2	42,350
Non-Qualified	5	2,076.0	10,380
	29		73,179

Amount per ton of calibrate:

$$\frac{73,179}{160,000} = 0.488 \text{ US\$}$$

b) Diesel

Power of vehicles working 1,600 CV
Consumption: 0.1 L/CV
Number of hours: 2,000
Coefficient: 0.8
Consumption per ton.

$$\frac{1,600 \times 0.1 \times 2,000 \times 0.8}{150,000} = 1.71 \text{ L/t}$$

Amount: 1.71 L/t x 0.38 = 0.646 US$/t

c) Electric Power

Power installed 530 CV = 390 kW

Utilization factor 0,8; 390 x 0.8 = 312 kW

Lighting and various 10% = 31 kW

Total 343 kW

Total consumption per ton of calibrate

$$\frac{343\ kW}{100\ t/h} = 3.43\ kWh/t$$

Amount 3.43 x 0.036 = 0.123 US$/t

d) Water

0.5 m^3/t

Amount: 0.5 x 0.09 0.045 US$

e) Tires

0.13 US$

f) Maintenance

4% of the specific investment (US$/t calibrate) in equipment and installations:

$$\frac{0.04 \times (2,765 + 536 + 517)}{150,000} = 1.018\ US\$/t$$

g) Summary

Total expenses:

Manpower	0.488
Diesel	0,646

Energy	0,123
Water	0.045
Tires	0.130
Maintenance	1.018
Total	2,450 = 2.5 US$/t

3.2.2 Limestone and Quicklime

1) Process Description

No data is available to be able to judge the equipment foreseen by Cobrapi for the mine exploitation, nor for its operating costs, although both items do seem reasonable in principle.

With regard to crushing and limestone classification, the installation is very simple. For calcination Cobrapi propose shaft furnaces. It seems that the possibility of using a rotating furnace ought to be considered, as this type allows for greater working flexibility and lower investment than others.

2) Machinery Listing and Characteristics

a) Capacity

The national siderurgical consumption neccessities are:

Limestone	2.800 t
Quick lime	6.500 t

Admitting that the limestone has the typical specifications for siderurgy which were shown in section 2.4.4., that is,

CaO	41.5%
MgO	11 %
CaO + MgO	52.5%

The obtain 1 ton of CaO + MgO, 2 tons of dolomitic limestone are needed thus the 6,500 t of quicklime will require 13,000 t of dolomitic limestone.

In agreement with this and the granulometry foreseen by Cobrapi, the distribution of useful products will be:

120 - 40 mm	2,800 t/yr
40 - 12	13,000 t/yr

This distribution cannot be obtained with an open circuit jaw crusher. Therefore it will be necessary to install a secondary crusher or to modify the granulometric ranges to:

100 - 70 mm for the limestone
70 - 10 mm for the product to be calcinated
10 - 0 mm for the discard fines

Following this granulometric distribution the following weight percentages are obtained:

100 - 70mm	14%	2,800 t/yr
70 - 10mm	69%	13,800 t/yr
- 10mm	22%	4,400 t/yr
		21,000 t/yr

One would have to discard 4,400 t/yr, of fines -10mm which would have no use.

The most flexible solution would be to install a secondary closed circuit jaw crusher with a sifter, in order to crush the excess of the 40-120 mm fraction. The quarry and crushing installation would work 1 shift per day and 5 days a week. The calcination operation would work 3 shift a day and 7 days a week.

b) Mine Explotation Machinery

One should make sure that this machinery has the same characteristics as that for the iron ore work so that they are interchangeable and spares can be reduced.

The machines would be:
1 front loader on tires, 1,4 m^3
2 dump trucks, 12t
1 light truck
1 moveable compressor
3 manual perforators

c) Limestone Crushing Installation

1 plate feeder
1 simple effect jaw crusher
1 two-level sifter, 2.5 m^2
1 simple effect secondary jaw crusher
1 set of bands

d) Quincklime Obtainment Installation

1 feeding silo
1 feeder
1 calcination oven
1 silo for quicklime

3) Manpower

In the mine working the following personnel is foreseen:

Title	Qualitication	Number
Shovel operator	Semi-Qualified	1
Perforators	Semi-Qualified	2
Driver/tractor driver	Semi Qualified	2
Total		5

In the crushing and calcination plants the proposed personnel is:

Crushing operator	Semi-Qualified	1
Calcinator operator	Semi-Qualified	4
Helpers	Non-Qualified	8
Total		13

4) Investments

a) Machinery for Mine Working

	Amount 10^3 US$
1 frontal loader on tires	70
2 dump trucks 10/12t	80
1 light truck	15
1 moveable compressor	22
3 manual perforators (hammer drills)	3
Total	190

b) Machinery for Limestone Crushing and Sifting

	Amount 10^3 US$
1 plate feeder	28
1 jaw crusher	23
1 sifter, 2 screens, 2.5 m^2	10
1 secondary crusher	16
1 set of bands	38
Total	115

c) Calcination Machinery

The rest of the items have been calculated with criteria similar to those used for the iron ore. The summary is included on table 3.2.

5) Operating Costs

a) Limestone

Since the type and the quantity of the sheet to be moved per t of limestone are unknown, it is difficult to calculated the limestone cost. In view of this, the figure of 2.24 US$ used by Cobrapi and Unidad Promotora is considered valid for the lumpy limestone. This figure is within the normal values this type of material.

b) Quick Lime

To obtain 1 t, of lime, 2 tons of limestone are needed.

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TABLE 3.2

Summary of investments in limestone mining, preparation and calcining plants

Investments in 10^3 US$

Item	Mining exploitation	Crushing and sieving	Calcining	Total
1. Studies, research & previous analyses	25	--	--	25
2. Equipment	190	115	240	545
3. Bays, structures and civil works	--	23	48	71
4. Cranes (included in 3)	--	--	--	--
5. Spares	10	6	12	28
6. Utilities	--	22	72	94
7. Transportation, insurance and taxes	30	21	49	100
8. Subtotal	255	187	421	863
9. Erection and start-up	--	13	29	42
10. Personnel training	--	1	3	4
11. Engineering	--	12.5	35	47.5
12. Contingencies	25.5	19	42.5	86.5
13. Total	280.5	232.5	530.5	1,043

The electrical energy consumption is 40 kW h/t.

Fuel consumption is obtained assuming that for each kg of limestone 900 Kcal., are needed. The consumption per ton of quicklime will be 90,000 kcal., equivalent to 90 kg., of fuel, which in turn means 100 liters of fuel.

The fuel consumption per ton would amount to:

100 x 0.38 = 38.00 US$/ton

The energy consumption is 40 kW, which represent:

40 x 0.036 = 1.44 US$/t

In addition 2 tons of limestone are needed to obtain 1 ton of quicklime, the repercussion of this item will be:

2 x 2.24 = 4.48 US$/t

Finally, manpower consists of 4 semi-qualified and 8 qualified, the annual amount of which is:

4 x 2,491.2 = 9,964.8
8 x 2,076 = 16,608.0
Total 26,572.8 US$/year

The incidence per t of limestone will be:

$$\frac{26,572.8}{6,500} = 4.08 \text{ US\$/t}$$

In summary the cost would amount to:

Fuel	38.00 US$/t
Electricity	1.44 "
Raw materials	4.48 "
Manpower	4.08 "
Spare parts and various	2.50 "
Total	50.50 US$/t

3.3 POSSIBLE ALTERNATIVES

3.3.1 Introduction

The following yields are considered:

- 90% in rolled products
- 95% in continuous casting

According to these yields, for a fore seen rolled products capacity of 55,000 t/year, the following productions will be obtained with the fundamental facilities:

- Rolled products 55,000 t/year
- Continuous casting billets $\frac{55,000}{0.9} \cong 61,000$ t/year

Liquid steel: $\frac{61,000}{0.95} = 64,210$ t/year

With independence of the alternative used for obtaining the liquid steel, (blast furnace + LD converter or else sponge iron and melting in electric arc furnace), it is considered that the steps of continuous casting and rolling are identical.

Under these circumstances two alternatives will be considered for obtaining liquid steel (Alternatives I and II):

Alternative I: Charcoal blast furnace and pig iron refining in LD Converter

Alternative II: Obtaining sponge iron (DRC) in a direct reduction process and melting and refining in an electric arc furnace.

Alternative III: Obtaining rolled products from imported bittets. In this case the rolling facilities will be identical to the ones described for the other two alternatives.

3.3.2 Alternative I

For determining the consumption of ferric raw material (scrap and iron ore) we start with the following considerations:

- Fe in the liquid steel	98%
- Metallic yield of the converter	96%
- Fe in the scrap	96%
- Fe in pig iron	94%
- Metallic yield of the blast furnace	96%
- Fe in Fe-Mn	25%
- Consumption of Fe-Mn	7 kg/t steel
- Fe in Fe-Si	50%
- Consumption of Fe-Si	9 kg/t steel
- Fe in the classified ore	64.5%
- Ore consumption in the converter	40 kg/t steel

The Fe in the metallic load will be:

$$\frac{980}{0.96} = 1,020.83 \text{ kg Fe/t steel}$$

The Fe contributed by ferroalloys and the ore is:

$$7 \times 0.25 + 9 \times 0.5 + 40 \times 0.645 = 32.05 \text{ kg Fe/t steel}$$

The Fe to be contributed by pig iron and scrap will then be:

$$1{,}020.83 - 32.05 = 988.78 \text{ kg/t steel}$$

There is considered a mean distribution in the load of 83% pig iron and 17% scrap, so that the consumption per ton of steel will be:

Pig iron: $988.78 \dfrac{0.83}{0.94} = 873.07$ kg/t steel,

which is equivalent to 56,060 t/year

Scrap: $988.78 \dfrac{0.17}{0.96} = 175.10$ kg/t steel,

which is equivalent to 11,243 t/year

To determine the consumption of classified ore in the blast furnace, there is considered a scrap consumption of 34 kg/t of pig iron (that is, 1,904 t/year). The Fe in pig iron is 940 kg/t, so that the Fe constributed by the ore will be:

$$940 - 34 \times 0.96 = 907.4 \text{ kg/t}$$

With 5% loss of ore per sifting, the ore consumption will be:

$$\frac{907.4}{0{,}645} \times \frac{1.05}{0.96} = 1{,}538.64 \text{ kg/t of pig iron,}$$

equivalent to 86,256 t/year

The needs of gross ore with 50% losses by fines will be:

1,538.64 x 2 = 3,077.28 kg/t of pig iron, equivalent to 172,500 t/year

As a whole there is a scrap consumption of:

11,243 + 1,904 = 13,147 t/year

As in the steel shop, continuous casting and rolling mill 6,320 t/year are recovered, the needs of outside scrap will be:

13,147 - 6,320 = 6,827 t/year

3.3.3 Alternative II

The operation is similar to the above, considering the same Fe in the liquid steel and metallic yield and besides:

- Fe in the sponge iron	91%
- Consumption of Fe-Mn	7.5 kg/t steel
- Fe-Si consumption	7 kg/t steel
- Iron ore consumption	12 kg/t steel

The Fe contributed by ferroalloys and the ore is:

7.5 x 0.25 + 9 x 0.50 + 12 x 0.645 = 14.12 kg Fe/t steel

The Fe to be contributed by scrap and sponge iron will then be:

1,020.83 - 14.12 = 1,006.71 kg/t steel

The load as is usual in these cases to have a first melting of scrap to feed continuously the sponge iron, is supposed to be integrated by a maximum of 20% scrap and 80% sponge iron, so that the consumption per t of steel will be:

Scrap: $1,006.71 \frac{0.20}{0.96} = 209.73$ kg/t steel,

which is equivalent to 13,470 t/year

Sponge iron: $1.006.71 \frac{0.80}{0.91} = 885.02$ kg/t steel,

the equivalent of 56,827 t/year

The needs of classified ore are determined supposing losses by fines of 5%. It is known from tests conducted in H Y L that these losses may reach values of 25%, but it is foreseen to briquet said fines hot. Under these conditions the consumption of classified ore will be:

$$885.02 \frac{0.91}{0.645} 1.05 = 1,311.06 \text{ kg/t steel}$$

(1,481 kg/t sponge iron), the equivalent of 84,183 t/year

The gross ore operating as in section 3.3.2, will be:

84,183 x 2 = 168,400 t/year

Considering the generation of scrap in steel shop, continuous casting and rolled products of 6,320 t/year, the needs of outside scrap in this alternative will be:

13,470 - 6,320 = 7,150 t/year

3.3.4 Alternative III

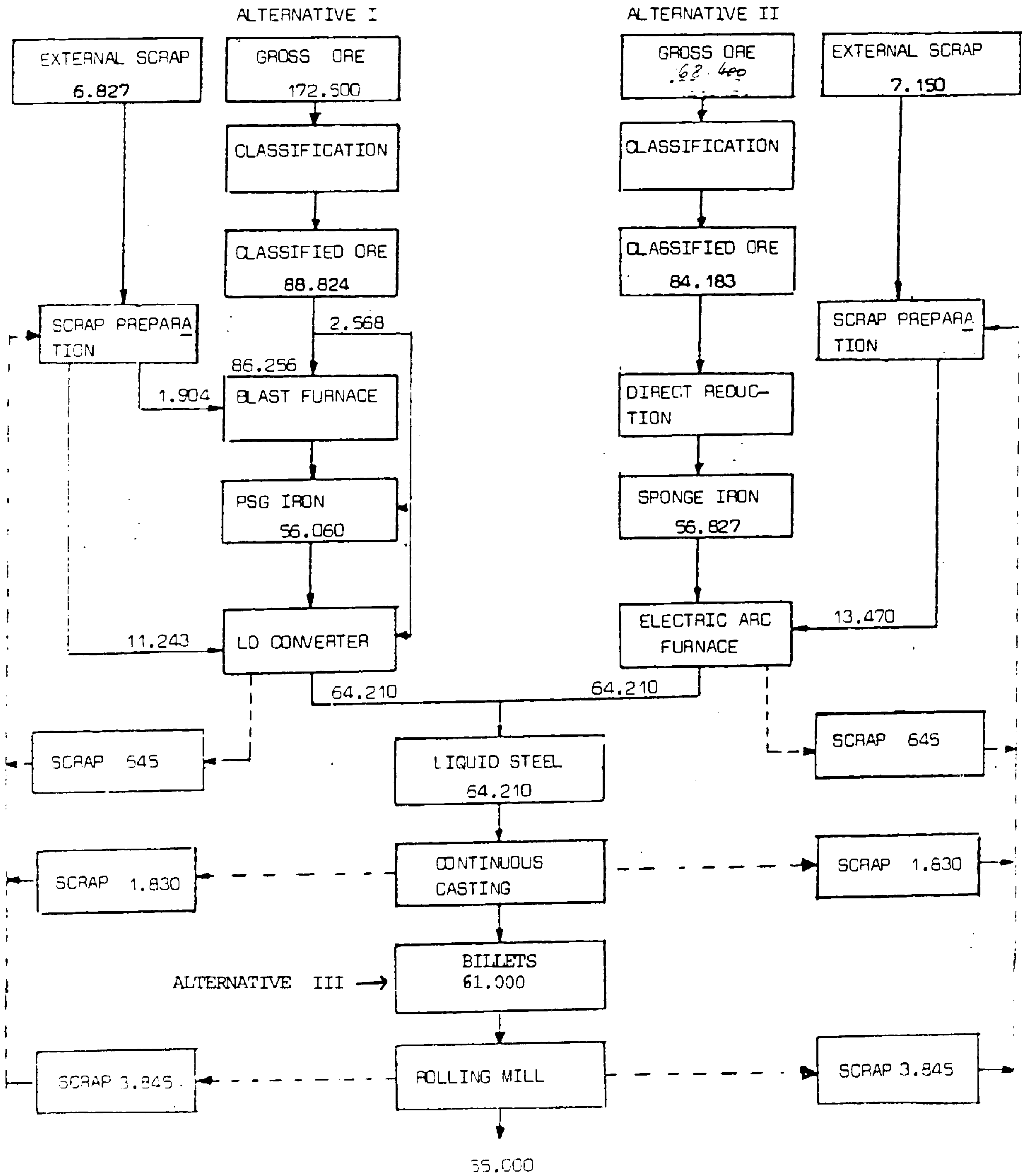
This alternative requires only a supply of 61,000 Tm/year of imported billets.

3.3.5 Total consumption of ferric matter

Figure 3.2 takes the sketch of flows of the three alternatives analyzed, which indicates that II consumes less gross ore at the expense of a larger utilization of outside scrap, although this a differences are not significant.

FERRIC MATERIALS FLOW DIAGRAM

(Figures in Tonnes/year)



3.4 ALTERNATIVE I

3.4.1 Charcoal requirements and cost

Previous experience has given, in case of blast furnaces, a requirement of net charcoal consumption (excluding fines, after accurate sieving) of 705 kg/tm of pig iron. Assuming an average fines percentage of 25 % when sieving the raw charcoal, then raw charcoal consumption would be 882 kg/tm pig iron. Then for a yearly pig iron production of 56,000 Tm the charcoal requirements would be 49,300 Tm/year.

For cost calculation, Unidad Promotora Study's data have been used after recalculation of required number of furnaces, equipments and manpower for the revised needs, and, after having increased the Unidad Promotora's prices for lubricating greases and fuels.

Charcoal cost price is a function of the size of the charcoal warehouse (bunker) as it is shown on table 3.3 where figures (production costs) for four different charcoal bunker capacities are given. The 67,900 Tm/year capacity ties in well with the charcoal bunker capacity forecast by Unidad Promotora, but due to above indicated changes, the new cost will be US $ 78.96/Tm which is US $ 10. Higher than the one given by Unidad Promotora (main increases in fuels and lubricants).

Using the correlation that can be stablished from table 3.3 data:

$$y = 1,291.04\ x^{-0.253}$$

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TABLE 3.3

Estimate of the Production Cost of Cha coal for Different Charcoal Plant Sizes

Production (ton/year)	Fixed Investment	Specific production cost (US $/t Charcoal)			
		Manpower	Equipment	Administration over-head and Depreciation	Total
10,000	1,036,796	42.90	57.12	27.12	127.87
26,000	2,195,620	35.14	48.64	10.43	94.21
50,000	3,843,552	34.02	43.92	5.88	83.82
56,000	4,420,604	32.86	43.51	4.94	81.31
67,900	5,524,720	31.66	43.06	4.24	78.96

The charcoal plant capacity is related to the price of the produced charcoal by the following equation:

$$Y = 1.291,045 \times X^{-0,253}$$

where X is the plant capacity in t/year and Y the resulting price in US $/t charcoal. The correlation relationship being $R^2 = 0,981$

where: y = the price in US $/ton of charcoal
x = charcoal bunker capacity in Tm/year of raw charcoal.

For the 49,300 Tm/year now forecast, a cost price of US $ 83.82/ton is obtained.

3.4.2 Charcoal Blast Furnace

We are not to insist here on this process, since it has been sufficiently described in the previous studies.

In very general lines, it consists in loading through the top part of the blast furnace: iron ore, fuel (charcoal in this case) and flux (limestone and/or dolomite) and, through the bottom part of the furnace hot air is blown that burns a part of the fuel producing the heat necessary for developing the chemical reactions of reduction and melting of the iron, while another part of the fuel together with the combustion gases, act as reducers combining with the metal oxygen.

The fluxes have a double function: on the one part, furnish a fluid slag with the charcoal ashes, the ore gangue and other impurities loaded in the furnace and on the other, produce a slag of a chemical composition permitting a degree of control of the sulfur contained in the iron.

It is to be noted that the charcoal blast furnace is a process used today mainly in Brazil, that continued perfecting this technology, when most countries substituted it for coke.

Brazil has charcoal blast furnaces considered the largest in the world, as furnaces nº 1 and nº 2 of Acesita, nº 5 of Belgomineira and nº 1 of Mannesmann.

The profile of charcoal blast furnaces is generally "trunk" aspect, that is, non-slender and a smaller ratio between the cross section and the height as in coke blast furnaces.

The parameter that best defines the efficiency of a blast furnace is the carboindex or quantity of charcoal spent for producing a ton of pig iron, which has gone from 13,000 kg in 1813, to the present of about 700 kg, and even less when part of the ore load to the blast furnace is sinter.

1) Blast furnace dimensions

According to the standards for charcoal blast furnaces, the main dimensions for the blast furnace of the Iron and Steel Project with a production of 160 t/day of pig iron would approximately be the following:

Throat diameter	2.5 m
Shaft diameter	4.0 m
Crucible diameter	2.9 m
Total height	15.3 m
Effective height	12.3 m
Effective volume	115.0 m^3
Productivity t/day/crucible m^2	23
Productivity t/day/effective vol.	1.3
Carboindex	0.7 t charcoal/t pig iron

2) Labor

The direct labor deemed necessary for a blast furnace operation is 80 persons (the same staff as in the Unidad Promotora), broken down as follows:

- Technician category:

  4 operation foremen (one per shift)
  4 raw material foremen (one per shift)

- Qualified category:

  4 blast furnace foremen (one per shift)
  4 raw material yard foremen (one per shift)
  8 people for replacing sick leaves

- Semiqualified category:

  16 blast furnace workers (four per shift)

- Non-qualified category:

  24 blast furnace assistants (six per shift)
  16 raw material yard assistants (four per shift)

3) Investments

Investment as considered in the study by Unidad Promotora, has been revised and practically doubled as indicated in the comments paragraph 2.3.3 5) of this study. Actual figures for similar investments of world level are in a range also double of phase considered by Unidad Promotora.

Total amount of investment for the blast furnace is US$ 8.4 million, i.e. a specific investment of US$ 150 t/year considering a year by yield of 56,056 t of pig iron.

The breakdown of above investment is as follows:

	USx10^3$
Civil Work	3,222

Cost of civil work and brick work for the self supporting type blast furnace, of carbon steel structure of foundation for: stores, fume dedusting equipment, automatic loading of raw materials, blowers, casting area, etc.

Equipment	2,366

Cost of nozzles, air and blast furnace gas piping, bustle pipe, blowers fume dedusting, belt conveyors, bins, etc.

Utilities	290

Water and compressed air circuits, electrical network, etc.

Spare Parts	126
Freight, insurance, taxes.	324
Sub-total	6,328
Erection, testing & start-up	568
Training	121
Engineering	758

Including procurement (purchasing, inspection & expediting) administration and management of the project

Contingencies	632
Total	8,407

4) Production cost of a ton of pig iron

The unit cost of pig iron production, without depreciation, i.e. considering the operating costs as well a 4% of said investment as maintenance cost of the facilities is US$ 100.12 t/pig iron.

Furthermore. this figure does not include neither the overhead sharing expenses nor the finaning costs.

The expenses have been broken down in table 3.4.

The unit prices for each concept have been taken from the information collected in Bolivia.

3.4.3 LD Converter

The basic process of LD oxygen blowing takes the name from the Linz & Donawitz steel plants in Austria, where it was first used in 1952.

It consists of a cylindrical furnace that may be concentric or excentric with a basic lining, that may rotate around a fixed horizontal axle. The furnace vertical axle has a tubular lance, water cooled and retractile, that remains in a vertical position in the center of the bath. On the top part of the lance are connected rubber flexible hose with steel reinforcement, through which the oxygen reaches at a controlled pressure as well as the cooling water.

TABLE 3.4

Estimation of the Pig Iron Production Cost in Blast Furnace with Charcoal (Depreciation overhead & financing costs excluded)

Item	Unit	Consumption Units/t Pig Iron	Unit Price US$	Production Cost US$/t Pig Iron
Charcoal	t/(gross charcoal)	0.882	83.82	73.92
Iron ore	t(classified ore)	1.538664	2.50	3.84
Manganese ore	t	0.025	75.22	1.9
Limestone	t	0.050	2.24	0.1
Quartzite	t	0.035	66.21	2.3
Water	m^3	6.470	0.09	0.6
Electric Power	kwh	103.0	0.036	3.7
Scrap	t	0.034	110.0	3.74
Refractories	kg	1	0.421	0.42
Manpower (1)	Man. hours	3.3	1.09	3.6
Maintenance (2)	--	--	--	6.0
TOTAL				100.12

(1) 80 men x 48 hours/week x 48 weeks/year = 184,320 man-hours/year

$$\frac{184.320\ (m.h/y)}{56.060\ (ton/y)} = 3{,}3\ m.h/t$$

(2) As maintenance cost it has been considered the 4 % of the specific investment (150 US$/t)

The mode of operation is as follows: Once the furnace is loaded with controlled quantitites of pig iron, scrap and ore, it is rotated to the vertical position, bringing down the oxygen lance to a predetermined position above the center of the bath. Then oxygen is insufflated through the lance, at a pressure between 9 and [illegible] bars.

The action of the oxygen jet is in part physical and in part chemical, as when hitting the bath surface iron oxide is formed that quickly disperses producing in turn carbon monoxide that provokes a strong boiling and accelerates the metallurgical reactions of refining (phosphorus removal, sulfur removal, decarburation, etc.).

1) Calculation of the converter capacity

330 working days a year are supposed, equivalent to seven working days a week and one month stop a year.

The total number of available hours will be:

330 x 24 = 7,920 hours

Considering an effective time of work of 80%, we have:

7,920 x 0.8 : 6,336 effective hours of the converter

The converter utilization time is 43 minutes/casting distributed as follows:

Load	7 min/casting
O_2 blowing	20 min/casting
Puffing	2 min/casting
Samples and temperature	6 min/casting

Deslagging	3 min/casting
Casting	5 min/casting
Total	43 min/casting

$$N^{o} \text{ of castings} = \frac{\text{effective time}}{\text{casting time}} = \frac{6,336}{0.7166} = 8,841.7 \text{ castings a year}$$

As the plant needs a production of 64,210 t/year:

$$\text{Furnace capacity} = \frac{64,210 \text{ t/year}}{8841.7 \text{ castings/year}} = 7.26 \text{ t/casting}$$

To have more operation safety and since 7 t for an LD converter is a very small capacity, there will be installed 2 LD converters of 9/10 t each, minimum commercial size, that will be one in operation and the other in stand by or repair of the refractory.

2) <u>Labor</u>

Regarding the labor of this productive unit, we have taken into account continuous work and considered the four shifts necessary. There is pointed out here, that in the Unidad Promotora study, the labor is undervalued as one work shift has been eliminated regarding the Cobrapi study and for continuous work this is not possible.

Working 3 shifts a dav seven days in the week, the result is:

24 x 7 = 168 hours a week

Since each worker works 40 hours/week/shift, with 3 shifts they would work 120 hours/week, therefore, the quotient 168 :

120 = 1.4 gives the number of workers necessary per work position to cover the weekly 168 hours. Consequently, a fourth shift is necessary.

Taking into account the necessary four shifts, the direct labor for the steel shop are 80 people distributed as follows:

Work position	Category	Nº of persons
Scrap yard foreman	Qualified	4 (1 per shift)
Scrap yard assistants	Non-qualified	12 (3 per shift)
Converter worker	Qualified	4 (1 per shift)
Foreman	Qualified	8 (2 per shift)
Craneman	Semiqualified	12 (3 per shift)
Assistants	Semiqualified	8 (2 per shift)
Assistants	Non-qualified	16 (6 per shift)
Electricians for rapid action	Qualified	4 (1 per shift)
Mechanics for rapid action	Qualified	4 (1 per shift)
People for replacing sick leaves	Non-qualified	8 (2 per shift)

3) Investments

The actual investment now considered for the steel and oxygen plants is of US$ 10,274,000 which is in line with that provided by Unidad Promotora, although with a marked difference in this respective breakdowns.

	US$x10^3
Bays	1,016

The Unidad Promotora layout has been accepted. Combining the loading and converter areas plus a portion of the casting area an amout of 2,946 m^2 is obtained for the steel plant, at a unit price of US$ 345/m^2

Equipment	3,648
Two converters for 9/10 Mt, oxygen lances, steel laddes, pig iron mixer, scales, ladle cars, bins, etc.	
Cranes	
Pig inon crane 25/10 Mt	465
Scrap crane 10 Mt	95
Other services 12/4 Mt	210
Utilities	
Water	50
Compressed air	8
Oxygen	2,500
Lighting & electrical cabling net	40
Spare parts	198
Freight, insurance, taxes	
Carbon steel structure (324 Mt)	113
Main equipment (520 Mt)	182
Auxiliary equipment (180 Mt)	63
Sub-total	8,589
Erection & startup	311
Training	172

Engineering	344
Contingencies	858
Total	10,274

The specific investment appears as US$ 160 t as a ratio between the above total of US$ 10,274,000 and the total estimated production of 64,210 t.

4) Production cost of a ton of steel

The production costs per ton of steel in an LD converter, with the inclusion of a 4 % of the specific investment as maintenance costs of the facilities, is US$ 137.84.

This figure does not include the expenses for depreciation, overhead and furnacing.

Table 3.5 breaks down the costs for the various concepts.

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TABLE 3.5

Estimate of the LD Converter Steel Production Cost (Depreciation, Overhead & Financing costs excluded)

Item	Units	Consumption Units/t of Steel	Price US$/Unit	Production Cost US$/T Steel
Iron ore	t	0.040	2.5	0.1
Water	m^3	1.5	0.09	0.14
Electric Power	kwh	40.3	0.036	1.5
Refractories	kg	5	0.31	1.6
Scrap	t	0.1751	110.0	19.3
Pig Iron	t	0.87307	100.12	87.41
Lime	t	0.10204	50.50	5.2
Fluorite	t	0.004008	202.40	0.83
Ferromanganese	kg	7	0.5	3.5
Ferrosilicium	kg	9	0.47	4.23
Fuel Oil	x 10^3 kcal	87	0.034	2.96
Oxygen	Nm^3	56	0.03	1.7
Manpower (1)	Man. hours	2.87	1.034	2.97
Maintenance (2)	--	--	--	6.4
TOTAL				137.84

(1) 80 men x 48 hours/week x 48 weeks/year = 184.320 hours/man/year

$\frac{184.320 \text{ (hours/man/year)}}{64.210 \text{ (steel/year)}}$ = 2,87 man. hours/t

(2) As maintenance cost is has been considered the 4 % of the specific investment (160 US$/t)

3.5 ALTERNATIVE II

3.5.1 Direct Reduction (D.R) Process Selection

D.R is defined as a process to obtain metal iron through a reduction of iron or at temperatures below the melting points of the different components, i.e. the product is obtained in solid condition.

The most impressive stonemarks in the development of the D.R process between 1930 and 1950 -including testing and progress work prior to, during and after world war nº 2 -, can be defined as follows:

a) Development in sweden during and after W.W. nº 1 of the coal reduction process in melting pots, initially in Höganäs, then in Oxelösund and later on in the U.S.A. (Riverton).

b) In a practically simultaneous timing, development of the gas reduction process, per Kliberg procedure utilising a special carburizer still in use nowadays in Sweden.

c) A first step of development of D.R, with coal in rotating furnaces (kilns) through several different processes.

d) Development of the first industrial process based on natural gas (N.G) by Hojalata y Lámina (H y L) in Monterrrey (Méjico). Their first D.R. unit started in 1.957.

Since this very moment, a very slow progress took place with more testing or pilot plants-semiindustrial scale - than actually industrial ones. A number of ideas and parts of proceses were left and in 1.970 a true industrial development started and progressed.

Tables 3.6 & 3.7 show yearly and cummulative increases of production capacities by main processes of D.R with iron ores with a clear advantage for Gas Reduction (G.R) process and inside it for H y L and Midrex.

These - Midrex and H y L - have in common the three followinmg items:

- to use a shaft furnace
- to use a gas based on CO + H_2
- to produce that gas through reforming natural gas (N.G)

We will additionally consider the ACCAR procces, completely different from the two other previously mentioned - using a rotating furnace for reduction with N.G. or fuel directly applied with no previous reforming -.

As indicated in paragraph 2.4.6, the Mutun area has no natural gas avaible as gas resources are only located in the neighbor hood of Santa Cruz. Because of this very reason, the adequate location for a D.R plant should be Santa Cruz, not Mutun.

For the above mentioned three D.R. processes - Midrex, H y L, ACCAR - the following aspects will be analyzed.

- Process description
- Existing Units
- Ore & reducer requirements
- Other required raw materials (inputs)
- Updated fabricating costs
- Summary and Conclusions

TABLE 3.6

Production Capacity Yearly Increase for Main Iron Ore Direct Reduction Processes (in millions of Mt/year)

Years	Natural Gas Std		Other Processes	Coal based Processes	
	H y L	Midrex	with natural gas	Rotating furnace (Kin)	Other
1957	0.095	-	-	-	-
1960	0.270	-	-	-	-
1967	0.235	-	-	-	
1969	0.315	0.300	-	-	-
1970	-	-	0.150	0.165	-
1971	-	0.800	-	-	-
1972	-	-	0.330	-	-
1973	-	0.400	-	0.250	0.010
1974	0.725	-	-	-	-
1975	-	-	-	0.350	-
1976	0.360	0.330	0.350	0.240	0.040
1977	0.625	0.955	0.830	-	-
1978	0.575	0.820	-	0.060	-
1979	0.485	1.275	-	-	-
1980	2.687	0.420	-	0.130	-
1981	-	1.980	-	-	-
1982	2.150	2.087	-	0.150	-
1983	2.000	0.800	-	0.075	0.020
1984	1.000	3.750	-	0.320	-
1985	-	-	-	-	-

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TABLE 3.7

Iron Ore Direct Reduction Capacity Cummulative Yearly Increase (in millions of Metric T/year)

Years	Processes					Total
	Natural Gas Std		Other Process	Coal based Processes		
	H y L	Midrex	with natural gas	Rotating furnace (Kiln)	Other	
1957	0.095	-	-	-	-	0.095
1960	0.365	-	-	-	-	0.365
1967	0.600	-	-	-		0.600
1969	0.915	0.300	-	-	-	1.215
1970	0.915	0.300	0.150	0.165	-	1.530
1971	0.915	1.100	0.150	0.165	-	2.330
1972	0.915	1.100	0.480	0.165	-	2.660
1973	0.915	1.500	0.480	0.415	0.010	3.320
1974	1.640	1.500	0.480	0.415	0.010	4.045
1975	1.640	1.500	0.480	0.765	0.010	4.395
1976	2.000	1.830	0.830	1.005	0.050	5.715
1977	2.625	2.785	1.660	1.005	0.050	8.125
1978	3.200	3.605	1.660	1.065	0.050	9.580
1979	3.685	4.880	1.660	1.065	0.050	11.340
1980	6.372	5.300	1.660	1.195	0.050	14.577
1981	6.372	7.280	1.660	1.195	0.050	16.557
1982	8.522	9.362	1.660	1.345	0.050	20.939
1983	10.522	10.167	1.660	1.420	0.070	23.839
1984	11.522	13.917	1.660	1.740	0.070	28.909
1985	-	-	-	-	-	-

General reviews on this subject, performed by J. Astier, C.G Davis, Battelle Memorial Institute (Frankfurt) and Carbon & Steel European Community (CECA) have been used as bibliographic sources. Additionally, specific studies or reports presented to significant technical Congresses, as the ones organized by ILAFA, or to technical magazines have been used. At the end of Chapter 3. a complete Bibliographic list is included.

3.5.2 Midrex Process

1) Description

As shown on figure 3.3 this process uses the following components: One shaft furnace, one gas reformer, one cooling system.

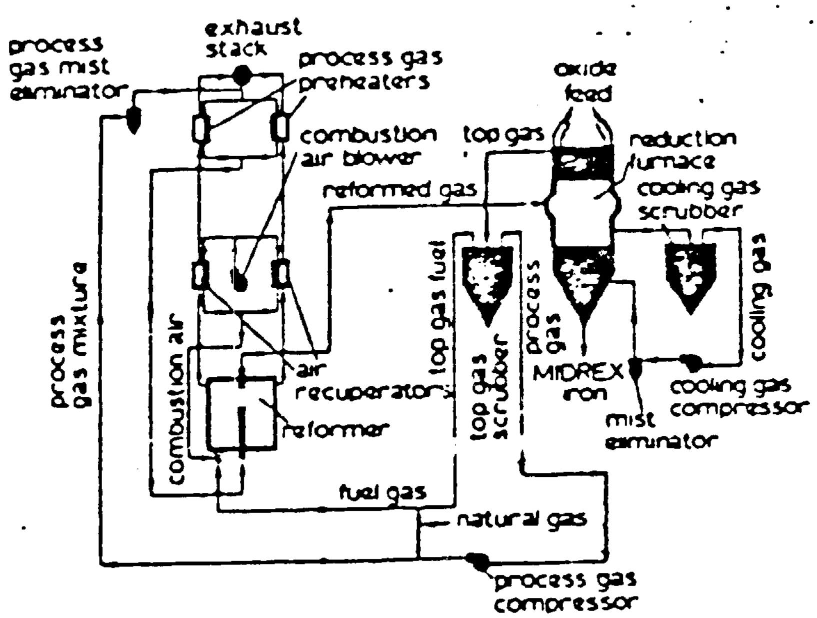
The shaft furnace is a c. steel vessel with internal refractory lining in the reducing zone. Ore is continously fed through the top of the furnace and the D.R product is discharged also in a continous way through the bottom. Both top and botton connections are Inert Gas (I.G) sealed in order to avoid gas leakages from the furnace.

Furnace design is so as to provide a uniform movement of the load by gravity through their three different zones: load preheating area (Top), Reducing area (central) and cooling area (bottom).

In order to avoid the ignition of the sponge iron, which is highly pyrophoric, it receives a passivation treatment, prior to longtime transportation or storage.

The reducing gas counter flows the way down of the load inside the furnace; the reducing process takes place at roughly 900º

FIGURE 3.3.



Midrex standard DR process flowsheet[4]

C. The reducing gas, partially used, is collected through a pipe at the top of the furnace, where, after cooling and filtering, most of it is compressed again and mixed with natural gas to start again the process through the reformer, and the balance is used as fuel gas for the reformer's burners.

The cooling gas counterflows also the way down of the load, from the bottom of the cooling area, reaching then the top portion of that area, where it is collected, filtered, cooled down through a scrubber and dried out to be compressed again to restart the cycle.

2) Existing Units

Table 3.8 shows the different Midrex Units erected through out the world since 1.969. 25 modules in 10 different countries totalizes that table, with a capacity of 10,370,000 tms all together. Total effective production in 1.984 was 4,940,000 Tms, which gives 48 % as utilization factor.

Module capacity ranges between 150,000 t/year-old, out of operation type-and 600,000 T/year as a maximum, with an average capacity of 412,000 t/year.

3) Ore & reducer requirements

Minimum ore iron content should be 64 - 65 % and its physical condition should be: pelletized or calibrated. A shaft furnace ore requires specific mechanical requirements - uts, reducibility and strength all through the reducing process, in order to avoid as much as possible fines production. Some units use a mixed - calibrated ore + pellets - load with 60 % pellets.

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TABLE 3.8

Midrex Direct Reduction Plants

Customer	Location	Capacity Mt/year	Start up year
Oregón Steel Mill	Oregón - USA	2 x 150,000	1969 *
Georgetown Steel Corp.	South Carolina - USA	400,000	1971
Hamburger Stahlwerke	Hamburg - G.F.R	400,00	1972
Sidbec I	Quebec - Canadá	400,000	1973
Dalmine	Campana - Argentina	330,000	1976
Sidbec II	Quebec - Canadá	600,000	1977
SIDOR I	Matanzas - Venezuela	400,000	1978
ACINDAR	V. Constitución - Argentina	420,000	1978
QASCO	Qatar	400,000	1978
SIDER II	Matanzas - Venezuela	3 x 420,000	1979
[illegible]T	Puntas Lisas - Trinidad	420,000	1980
[illegible]ERRO	Emden - G. F.R	2 x 400,000	1981
Delta Steel Mills	Warri - Nigeria	2 x 500,000	1982
SABIC	Jubail - Saudi Arabia	2 x 400,000	1982
OEMK	Kursk - SSRU	4 x 425,000	1983
Sabah Iron and Steel	Labuan Sabah - Malaysia	600,000	1984
Total		10,370,000	

* Not in operation

The N.G. requires to be practically sulphur free to do not damage the reforming catalyst which accelerates the reforming process. Fuel consumption can be estimated now around 2.5 G cal/tm of sponge iron (DRI).

4) Other required consumptions

Electrical power is also at a rate of 110 kwhr/Tm DRI because of the electric motors required for air & gas blowers, belt conveyors or elevators, bridge cranes, lighting etc,. Water consumption at a rate of 1,5 m^3/tm DRI is used at scrubbers for cooling and cleaning of gases.

Manpower for a 400,000 Tm/year capacity, is estimated at 0,22 man hours per Tm of DRI.

5) Operating costs

Required investment for a typical 400,000 Tm/year unit, including DRI passivation-to avoid oxydation and burn out-and briquetting of fines, is estimated now-adays as US $ 86 x 10^6, which gives a specific investment of US $ 215/Tm DRI/year of capacity of the new plant.

Table 3.9 gives an estimate of cost price of DRI under the hypothesis of a rawmaterial of 64.5. % Fe concentrates. Excluding depreciation, overhead and financing expenses a cost price of US $ 143,7/Tm DRI is obtained. The highest percentage of that cost is that of the ore beacause of the high cost of railway transportation Mutun - Santa Cruz.

TECNIBERIA

TABLE 3.9

Midrex Process Cost Estimate (Std. 400,000 Tm/year unit)

Item	Units	Consumption per D.R.T (sponge) Mt	Unit Price US$/Unit	Specific Cost US$/Mt year Sponge Iron (DRI)
Lump ore	Mt	1.481	74.95	111.00
Natural Gas	G Cal	2.57	5.70	14.25
Electric Power	kwh	100	0.045	4.95
Water	m^3	1.5	0.09	0.14
Manpower	Man Hours	0.22	1.13	0.25
Supervision	--	-	--	1.41
Other fabricating costs	--	--	--	3.10
Maintenance (1)	--	--	--	8.60
TOTAL				143.70

(1) 4 % of specific investment (US $ 215/Mt of year production)

6) Summary & Conclusions about Midrex Process

It is a process with a significant industrial development. Using 1,984 available figures, out of a total production of DRI (sponge) of 9.21 x 10^6 Tm, 54 % of them used Midrex Process, which clearly shows their world wide importance.

In the specific case of Bolivia it happens the gas and ore sources are very far apart (roughly 600 km) and only a rail way transportation is available with very high transportation tariffs. It is no possibility now of a gas transportation Santa Cruz - Mutun as it is no gas pipe line available; railways or truck cryogenic tanks with cryogenic reconversion stations at both ends would be extremely expensive.

3.5.3 H y L Process

1) Description

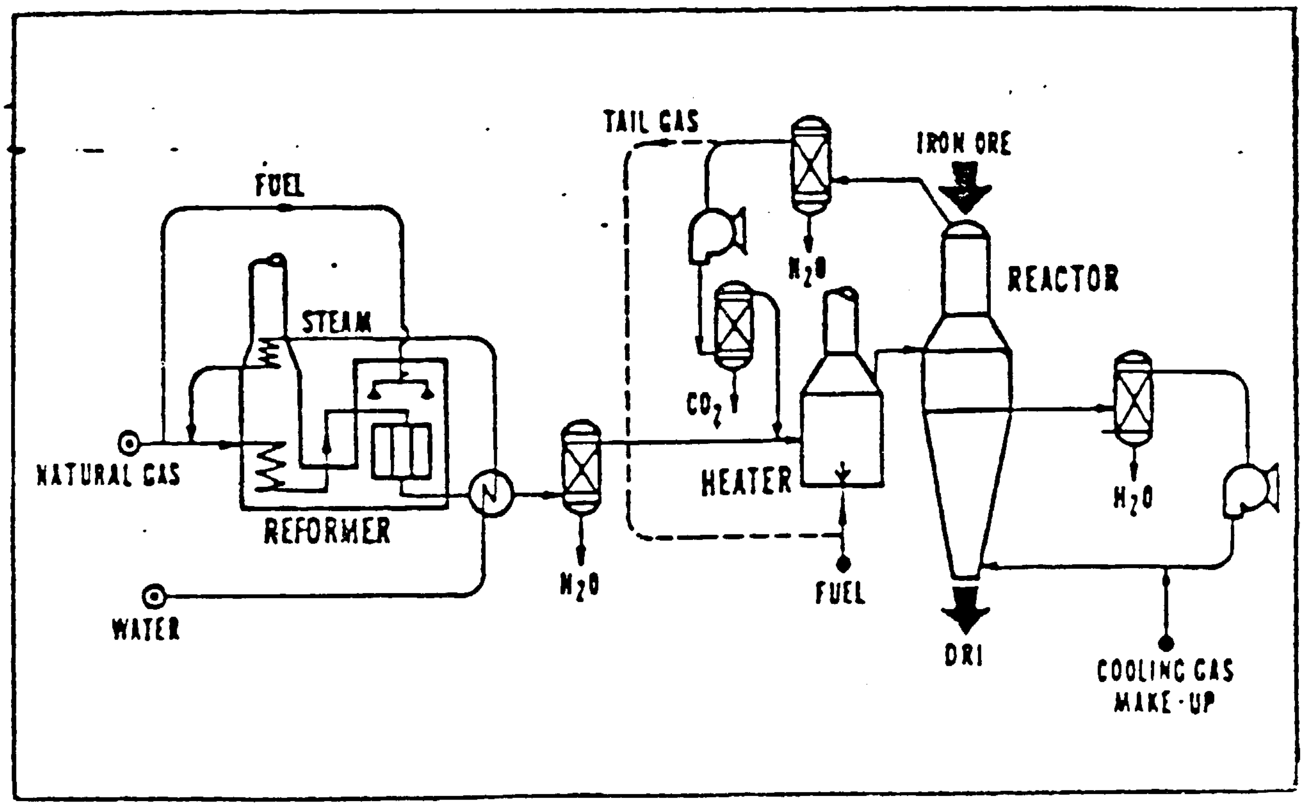
Originally the H y L consisted of 5 different reactors but later on only 4 were required. A mixture of N. G and steam is reformed in a catalyst reformer and goes one after the other through all the reactors. The iron ore contained in each reactor passes successively through phases of preheating, prereduction and cooling.

In semptember 1.980 after more than 13 years of research, laboratory tests, pilot plant and industrial production, H y L started their latest technological development called H v L III which is shown schematically in figure 3.4.

This new plant H y L III consists of two independent sections: the first one generates reducing gases, the second one performs the reduction operation.

FIGURE 3.4.

HyL III PROCESS FLOWSHEET



The first section-reducing gas generation - shows no change when compared with the previous models H y L I & H y L II, based upon fixed reactors, of conventional type to reform NG + steam in a similar way to that used for producing towngas or the one used in the Petrochemical Industry.

The second - reducing - section has differences indeed, as a special shaft furnace is now used, with two zones, through which different gases circulate, one zone for reduction, one for cooling.

The reducing gas is introduced at 900º - 960º C in the reducing zone and leaves the reactor through their load inlet head; then crosses a zone provided with dehumidifier and a CO_2 separator, and again recycled to the reactor through a gas heater.

The cooling circuit includes reactor's cooling zone, a direct contact gas scrubber and one recycling compressor. Cooling gas arrives to the reactor through the bottom of the cooling zone where process product cools down and is carburized. Exhaust gas is washed and cooled through a scrubber and is recycled again through the reactor.

2) Existing Units

Table 3.10 lists all the different H y L plants erected through the world since 1957 with a total of 21 modules, erected over 5 countries and out of which, 12 are located in Mexico. Total installed capacity is 10,026,000 Tm/year of DRI but their total 1.984 production was 3.25 x 10^6 Tm DRI giving a utilization factor of 32 % appreciably lower than that of Midrex.

Module capacity ranges between 105,000 and 700,000 Tm/year with an average capacity of 477,000 Tm/year of DRI.

TECNIBERIA

TABLE 3.10

H y L Direct Reduction Plants (units)

Customer	Location	Capacity Mt/year	Start up year
H y L, S.A (*)	Monterrey - Méjico	105,000	1957
H y L, S.A (*)	Monterrey - Méjico	190,000/250,000	1960/1980
TAMSA	Veracruz - Méjico	280,000	1967
H y L, S.A (**)	Puebla - Méjico	250,000	1969
H y L, S.A (**)	Monterrey - Méjicc	420,000/500,000	1974/1983
USIBA	Salvador - Brasil	225,000	1974
SIDER I	Matanzas - Venezuela	360,000	1976
H y L, S.A	Puebla - Méjico	630,000	1977
PTKS	Krakatau - Indonesia	4 x 560,000	1978
SOIDIC	Khar - Iraq	2 x 543,000	1980
SIDER II	Matanzas - Méjico	3 x 700,000	1981
SICARTSA (***)	Las Truchas - Méjico	4 x 500,000	1985
Total		10,026,000	

(*) Converted to H y L III in 1980, capacity 250,000 Mt/year
(**) Converted to H y L III in 1983, capacity 500,000 Mt/year
(***) Type H y L III

There are now six (6) modules operating with H y L III technology. Two of them are used in Monterrey in a converted existing plant through a modification keeping 2/3 of the previous units.

3) <u>Ore & Reducer requirements</u>

Paragraph 2.2.2 7) above already analized the possibility of using Mutun eluvial ore for H y L III, although fines appearance would increase.

In connection with fuel-gas consumption, H y L III figures, as given by H y L, are much lower than the ones for older units, and they range 2.4 - 2.9 Gcal/Tm DRI, with an average figure of 2.65 Gcal/Tm DRI.

4) <u>Other consumption requirements</u>

Electric Power consumption as given by H y L is 90 kwhr/Tm DRI maximum. Manpower requirements for a typical 400,000 Tm/year capacity plant (figure considered for comparison purposes with Midrex) stays at 0.25 Manhour/Tm DRI produced.

Water consumption for same conditions is estimated as 2.5 m^3/Tm DRI produced.

5) <u>Financing Costs</u>

Under same conditions of those given for Midrex Units, H y L III units investment cost is now estimated as US$ 213/Tm DRI/year capacity, to be compared with US $ 215/Tm DRI/year capacity for Midrex.

Table 3.11 gives estimates for cost price per Tm of DRI obtained from 64.5 % Fe content concentrates. Excluding again depreciation, overhead, and financing expenses a US $ 140.66/Tm DRI/year estimated cost price can be obtained which is US $ 3. lower than the same for Midrex Process. Difference lays mainly on a lower electrical consumption and item "other costs" which in the Midrex case covers also that of reformer catalyst.

6) Summary & Conclusions over H y L Process

Main unconvenience of old design H y L units was their high fuel gas consumption (3.5 - 4.0 Gcal/Tm) compared with 2.5 Gcal/Tm for the equivalent Midrex ones. This disadvantage has disappeared when H y L adopted also shaft furnaces, with a 35 % reduction in their fuel gas consumption as it has been verified in the modified Monterrey units.

H y L's experience, as in Midrex case, is highly remarkable, as they have reached by now a cummulative production of near 32 x 10^6 Tm DRI with an average contents of 89.4 % Fe and 1.9 % C.

3.5.4 ACCAR Process

1) Description

ACCAR means "ALLIS CHALMERS Controlled Atmosphere Reactor". It is a conseequence of all previous work performed by Allis Chalmers until reaching their grating (grilling) system - rotating furnace to consolidate green pellets -.

TECNIBERIA

TABLE 3.11

Cost Estimate for H y L Process (STD 400,000 Mt/year unit)

Item	Unit	Consumption Per Mt of DRI (Sponge Iron)	Unit Price US$/Unit	Specific Cost in US$/Mt year for DRI (sponge iron)
Lump ore	Mt	1.481	74.95	111.0
Natural Gas	G Cal	2.65	5.70	15.11
Electricity Power	kwh	90.0	0.045	4.05
Water	m^3	2.5	0.09	0.23
Manpower	Man hours	0.25	1.13	0.28
Supervising Staff	--	--	--	1.41
Other fabricating costs	--	--	--	0.06
Maintenance (1)	--	--	--	8.52
Total	--	--	--	140.66

(1) 4 % of the specific investment (US $/t 213)

It uses a rotating furnace (Kiln) provided with radially laid down nozzles as shown in fig. 3.5, and through which, alternating injections of air and fuel (Solid, liquid, gas, independently or mixed) are effected. Fuel is injected below the ore bed but air is injected above ore bed.

2) Existing Units

There are only two, one near Niagara Falls in operation since 1.973 with a 2,5 m Ø x 45 m high furnace provided with nozzles in a length of 25 m (figure 3.6) and a capacity of 35.000 Tm/year.

The other unit with a 240,000 Tm/year capacity is in operation in Sudbury (Canada) since 1976.

Finally Iron India Ltd has ordered a new 150,000 Tm/year unit from Allis-Chalmers at a cost of US $ 25 x 10^6, the startup of which is forecast for 1.986.

3) Ore and fuel requirements

In their demostration or exhibition unit calibrated ore or pellets are used as fuel, mainly 5-40 mm, 59 % Fe in natural condition goetite calibrated ore, with a 10 % fireloss and 5 % SIO_2 Most of bigger sizes are rejected when circulating through a magnetic separator.

In connection with fuels mention has already been made of the versatility of this process as it can use coal, fuel oil, NG one at a time or mixed without any requirement of a previous reforming as required by the other two processes.

FIGURE 3.5.

ACCAR PROCESS.

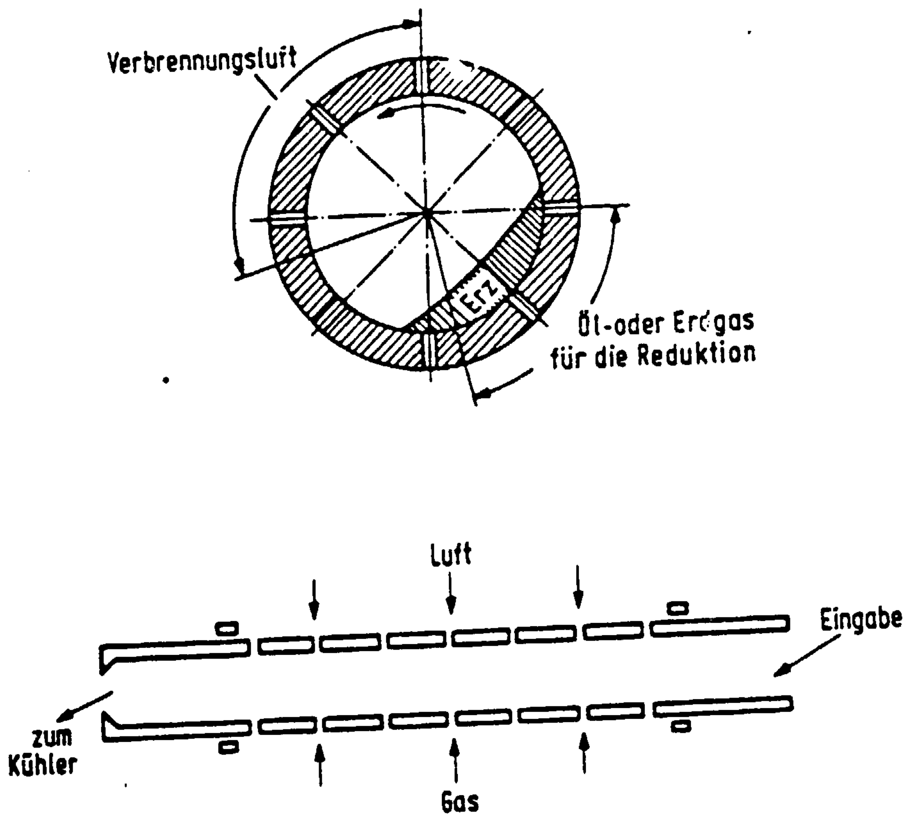
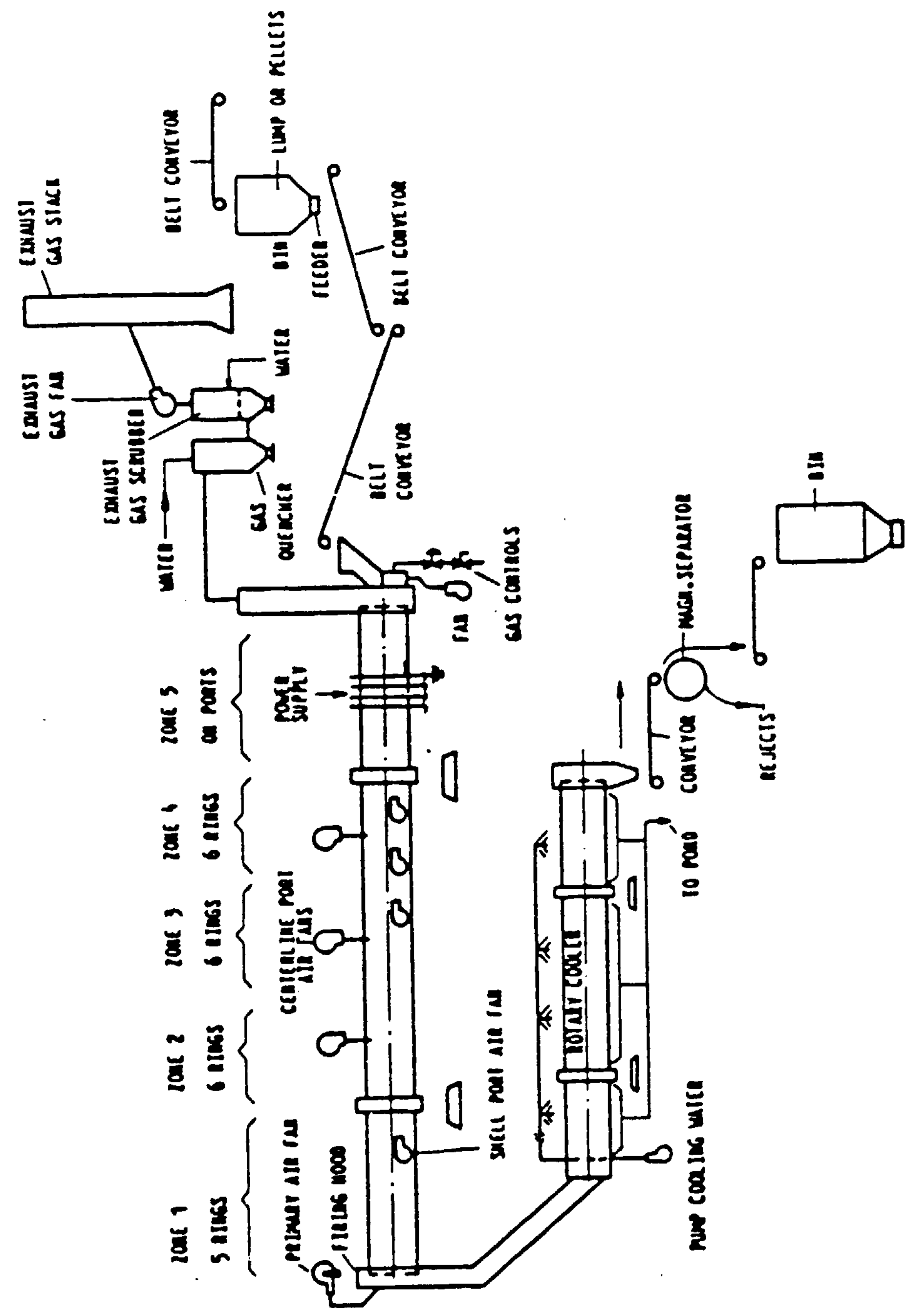


FIGURE 3.6.

ALLIS CHALMERS DEMONSTRATION PLANT SCHEME.



Total energy consumption-heating & reduction - is estimated as 4 Gcal/Tm DRI although that of electric power is roughly 75 kw hr/Tm.

4) Updated Costs

Investment for a 150,000 Tm/year DRI for India is estimated as US \$ 25 x 10^6 i.e US \$ 170/Tm DRI/year capacity.

Taking this figure of specific investment, table 3.12 obtains an estimate of the cost price per ton of sponge iron of US\$ 144.88 per ton.

5) Summary and Conclusions on ACCAR Process

This process differs from the other two provided with a rotating furnace using a shaft burner furnace for feeding heat for reduction, as it has not that. Oppositely it has a set of radial nozzles with alternative feeding of air or fuel, depending of the relative position load-nozzle.

When comparing with Midrex and H y L shows an important advantage of not requiring "reforming" of N.G with subsequent simplification and investment reduction. But it also has as unconvenience a 60 % excess of N.G consumption compared with the other two.

3.5.5 Summary of N.G Direct Reduction Processes

Considering D.R would take place in Santa Cruz area, as N.G is not available in Mutun, the production costs excluding depreciation, overhead and financing costs. (these will be estimated all together when fixing fabricating costs for billets) will be in the range of US \$ 140.6 - 144.9/Tm DRI.

TECNIBERIA

TABLE 3.12

Estimate of the Sponge Iron Production Costs Through the ACCAR Process (Plant size 150,000 t/y)

Item	Units	Unit price US$/unit	Consumption Units/t of sponge iron (DRI)	Production Cost US $/t of sponge iron (DRI)
64.5 % Fe iron ore	Mt	74.95	1.481	111.0
Natural Gas	Gcal	5.7	4	22.80
Electric Power	Kwh	0.045	75.00	3.38
Manpower	Man. Hours	1.13	0.8	0.90
Consumables and spare parts	-	-	-	1.90
Water	m^3	0.09	-	-
Maintenance (1)	-	-	-	6.80
Total	-	-	-	144.88

(1) 4 % of the specific investment (US$ 170/Mt)

Because of the close similitude with those of Midrex and H y L we will consider an average investment cost for any of these three processes as US $ 142/Tm DRI.

3.5.6 Electric Steel Mill

1) Capacity

For the choice of the electric arc furnace to be installed in this Alternative II we start from the following base data:

Needs of liquid steel	64,210 t/year
Raw materials	80% sponge iron and 20% scrap
Days of operation	288 per year (6 days for 48 weeks)
Total time	6,900 h/year

There is supposed a utilization coefficient in the furnace of 80%, with a distribution of the remaining 20% in : 5% for maintenance, 5% for breakdowns and 10% for limings.

The useful time would then be:

6,900 x 0.8 : 5,520 hours per year

The operation cycle, estimated, is as follows:

Preparation and setting of electrodes	10 min.
Load (1 bucket)	5 min.
Melting of scrap	35 min. (0.58 h)
Addition of sponge iron	65 min. (1.08 h)

Refining	30 min.
Preparation and casting	15 min.
Total	160 min. = 2.65 h

The number of castings per year will be:

$$\frac{5{,}520 \text{ h/year}}{2{,}65 \text{ h/cast}} = 2{,}083 \text{ castings a year}$$

The capacity of the furnace results then:

$$\frac{64{,}210 \text{ t/year}}{2{,}083 \text{ castings/year}} = 30.8 \text{ t/casting}$$

A choice is made of a furnace of 30 rated tons capacity per casting.

Dimensioning of the transformer for this cycle: It is done based on the following considerations:

- Electric energy for melting scrap at 1,550 degrees C = 365 kwh/t
- Electric energy for melting sponge iron at 1,550 degrees C = 425 kwh per ton
- Cos γ = 0.707
- Electric yield = 88%

a) Scrap melting:

$$P = \frac{0.365(\text{MWh/t} \times 0.[illegible]0(\text{t scrap/t steel}) \times 30(\text{t steel/cast})}{0.58 \text{ h}} = 3.96 \text{ MW}$$

$$P\ (\text{MVA}) = \frac{3.96}{0.707 \times 0.88} = 6.37 \text{ MVA}$$

b) Melting of sponge iron:

$$P = \frac{0.425\ (MWh/t) \times 0.83\ (t\ sp/t\ st) \times 3\ (t\ st/cast)}{1.08\ h} = 9.90\ MW$$

$$P\ (MVA) = \frac{9.90}{0.707 \times 0.88} = 15.92\ MVA$$

Adopting the larger power there results an electric arc furnace with a capacity of 30 t and a 16 MVA transformer.

2) Description of the facilities

Alternative II analyzed would cover the following aspects:

- Bays
- Production equipment
- Gas purification equipment
- Maintenance equipment
- Auxiliary equipment

2.1 Bays

a) Raw material storage yard.

The raw materials (sponge iron and scrap), would be located in a bay 60 m long, 15 m wide and 18 m high of the rail beam.

Storage of sponge iron

It has been calculated sufficiently to permit storing the consumption applicable to one month of sponge iron (density 2.4 t/m^3):

Annual consumption 56,827 t

Monthly consumption $\frac{56,827}{12} = 4,735$

Storage volume $\frac{4,735}{2.4} = 1,973\ m^3$

Three silos are foreseen with a unit volume of 650 m^3, belonging to dimensions per silo of 7.6 m diameter and a height of 14 m. These silos would be joined by a conveyor belt to the storage silos located in the furnace bay.

Scrap storage

For the storage of scrap will be used the 45 m remaining bay length. Considering a 45 degrees storage slope and a density of 0.85 t/m^3 the following capacity is obtained:

$$0.85\ t/m^3 \times (1/2 \times 15 \times 10 \times 45)\ m^3 = 2,868\ t$$

equivalent to almost 7 weeks production.

b) Furnace bay.

The electric arc furnace will be located in a bay with dimensions equal to those of the raw materials storage fixed near it.

The zone applicable to the furnaces is conceived in two levels, locating the furnace over an apron to level + 5.50 m leaving a free clearance for the possible circulation of a vehicle. At the bottom will be located the spaces for electrode storage, as well as ferroalloy and refractory storage.

Over the bed there will be located the addition hoppers, locating them at a level higher than the silos for daily storage of sponge iron.

c) Casting bay.

This is included here because it is a part of the section on the steel mill-continuous casting, it will be placed near the furnace bay, with 20 m head, height of the 18 m rail beam.

Besides using it for the furnace casting, the continuous casting machine platforms will be located, as well as the zones of preparation of the casting ladles, roofs, distributors, etc.

2.2 Production equipment

a) Electric arc furnaces.

Main features:

Number of furnaces	1
Rated capacity	30 t
Transformer power	16,000 KVA
Shaft diameter	4,200 mm
Electrode diameter	450 mm
Transformer voltages	150-400 V
Steps number	14
Tipping mechanism	Hydraulic
Frame turning mechanism	Hydraulic

Dome raising mechanism	Hydraulic
Electrode holder arm drive	Electrohydraulic
Door drive	Hydraulic

The furnace installation covers:

Mechanical part comprising shfat, platform, roof ring, tipping cylinder, casting nose, door, superstructure, electrode holder columns and arms, clamps, economizers, access platforms and roof lifting and rotation mechanisms.

Asynchronous motors for driving the hydraulic circuits pumps.

High voltage switchgear.

Power and voltage and intensity measurement transformers.

Bars, flexible cables and terminals.

Control, measurement and regulation cabinet.

b) Fume abatement equipment.

The gases produced in the electric arc furnace will be captured by a fourth hole made in the dome, and conducted to a tuyere filter, where they will be purified after being cooled enough.

A suction flow of 10,650 Nm^3/h is foreseen, equivalent to about 73,000 m^3h, at the suction temperature close to 1,600 degrees C.

At the same time at the top of the furnace there will be, above the rails of the bridge cranes, a suction canopy hood in order to absorb the gases to be produced at the moments of opening the roof and during the casting. A canopy flow of 40,000 Nm^3/h is considered, simultaneous with the flow sucked by the fourth hole, which will then be 50,000 Nm^3/h at the loading and the casting of the furnaces.

The facility will consist of:

- Captation elbows, cooled by water.
- Open flanges.
- First piping section cooled by water and control valve.
- Canopy hoods.
- Piping.
- Gas cooler.
- By-pass.
- Tuyere filter.
- Ventilator and chimney stacks.
- Regulation and control cabin.

The production of dust is estimated at 12 kg per ton of liquid steel, so that the production per day will be 2.7 t. With a density of 1 t/m^3, there must be foreseen a storage hopper at the outlet of the tuyere filter of at the least 15 m^3.

For an efficient handling of these dusts, as well as for their possible treatment later, it is deemed convenient to have a briquet press after the storage hopper, with a capacity of 350 kg/h.

c) Sponge iron to furnace feed system.

The usefulness of loading the sponge iron to the furnace in a continuous manner is considered, for which we have considered the applicable facility consisting of:

- Reception hopper, capacity 25 m^3 equivalent to 3 castings.
- Hopper conveyor belt, capacity 30 t/h.
- Extractor-weighing belt for unloading and weight control, capacity 30 t/h, weighing variation range from 0 to 30 t/h.
- Air cooled tube for furnace loading, arranged at the center of the roof.

d) Flicker compensation system.

To avoid disturbance in the network produced by the electric arc furnace there is foreseen to have a static compensation installation with three harmonic filters for the 2nd grade, 3rd grade and 4th grade with an installed power of 20 MVA reactive, equivalent to an effective power of 12.2 MVA.

2.3 Maintenance equipment

- Scrap yard

Number of bridge cran	2
Capacity	10 t
Lifting speed	10 m/min.
Bridge speed	80 m/min.
Carriage speed	30 m/min.
Load suspension	Magnet and scrabbing

- Furnace load

Number of bridge cran	1
Capacity	30/10 t
Lifting speed	5/10 m/min.
Bridge speed	5 m/min.
Carriage speed	10 m/min.

- Casting

Number of bridge cranes	1
Capacity	60/20 t
Lifting speed	5/10 m/min.
Bridge speed	40 m/min.
Carriage speed	10 m/min.

2.4 Auxiliary equipment

Among the auxiliary equipment of the electric steel mill we must stand out the following:

- Scale for truck weighing.
- 4 scrap buckets.
- 2 cars for moving the scrap buckets to the furnace bay.
- 2 crane magnets and 2 scrabbings.
- Scale for weighing the scrap buckets.
- Addition storage hoppers, with their feed and weighing systems.
- 4 casting ladles.
- 4 slag cones.
- Installation for roof preparation.
- Installation for repair of the furnace shaft.

- Oxygen injection system.
- Immersion pyrometers.
- Ladle preparation and drying.
- Rod drying oven.
- Eletrode connection station.

3) Labor

The direct labor staff necessary for the electric steel mil. would be 63 persons with the following break down:

Position	Category	Number
Furnace master	Master	3
Scrap bucket carrier	Qualified	9
Sponge iron carrier	Qualified	6
Furnacemen	Non-qualified	9
Furnace loading cranemen	Qualified	3
Casting cranemen	Qualified	3
Masons	Qualified	6
Laborers	Non-qualified	6
Maintenance	Qualified	12
Absence coverers	Qualified	6
Total		63

Considering 2,304 hours annual work per person, the labor required per t of liquid steel would be:

$$\frac{2,304 \times 63}{64,210} = 2.26 \text{ man hour per ton}$$

The mean cost of labor results US$ 2,649.4 per year, equivalent to US$ 1.15 per man hour.

4) Investments

The investments in an electric steel mill such as the one proposed in this Alternative II, based on a 30 t capacity per casting electric arc furnace and a 14 MVA transformer, may be considered with an approximation of +20% and have been estimated with the following criteria.

- The bays have been estimated on the base of Spanish conditions, with a metallic structure, representing the foundations 30% of the investment, enclosure another 30% and the metallic structure the remaining 40%. In the scrap bay there is considered a steel weight of 80 kg per m^2, in the furnace 110 kg per m^2.

- The steel mill has been asigned only 50% of the value of the casting bay.

- The equipment has been estimated on the base of brought to date tenders in the hands of Teniberia.

- The transport price to Mutun US$ 350 per ton have been considered with the inclusion of packing, transport, insurance and fees.

- The water, oxygen, compressed air and electric distribution facilities, can not be considered only for the electric steel mill, as they would be integrated with the other plant needs. They have been estimated on the base of available data.

An investment is obtained in the steel mill of US$ 7,766,570, with the following breakdown.

Bays	x US$ 10^3
Scrap (900 m^2 x US$ 345 per m^2)	310.50
Furnace (900 m^2 x US$ 375 per m^2)	337.50
Casting (450 m^2 x US$ 405 per m^2)	182.25
Equipment	
30 t/14 MVA electric arc furnace	1,100
Furnace civil engineering	205
Furnace assembly material	140.30
Scrap transport cars	124
Ladles and baskets	159
Fume purification	687.50
Purification civil engineering	12
Flicker compensation	124
Sponge iron and addition continuous load	525
Other steel mill auxiliary equipment	200
Crane	
Scrap yard (2 x 10/10 t)	425
Furnace load (1 x 30/10 t)	294
Casting (1 x 60/10 t)	320
Facilities	
Water	205
Oxygen	85
Compressed air	8.50
Electric energy distribution	265

Spare parts	x US$ 10^3
Furnace	119
Gas purification equipment	26
Flicker compensation	6
Steel mill and continuous load auxiliary equipment	29
Cranes	32
Transport, insurance and fees	
Metallic structure (211.5 t)	74.02
Furnace (350 t)	122.50
Ladles, baskets and scrap transport cars	80.75
Sponge iron continuous load (80 t)	28
Gas purification equipment (275 t)	96.25
Flicker compensation (50 t)	17.50
Other steel mill auxiliary equipment (25 t)	8.75
Cranes (385 t)	134.75
Subtotal	6,454.07
Assembly, tests and commissioning	235.10
Personnel training	142
Engineering	290
Unforeseen expenses	645.40
Total	7,766.57

For the foreseen production of 64,210 t/year, we obtain a specific investment of US$ 120.96 per ton and year of liquid steel.

5) Manufacturing cost

The manufacturing cost of liquid steel in an electric arc furnace starting from 80% sponge iron and 20% scrap has been estimated in table 3.13, arriving at figures of US$ 225.28 per ton.

The following breakdown by concepts is obtained:

- Raw material (sponge iron and scrap)	65%
- Fusion agents, oxidizers and recarburizers	7%
- Energy (electricity, electrodes, fuel-oil and oxygen	19%
Remaining costs	9%
Total	100%

As a comparison, in Spain, operating 100% with scrap at US$ 100 per ton, translated into less electric energy and fusion agents consumptions, we obtain liquid steel costs of about US$ 170 per ton, with the following breakdown:

- Scrap	61%
- Energy	18%
- Fusion agents, etc.	4%
- Other costs	17%
Total	100%

TABLE 3.13

Estimate of the Liquid Steel Fabricating Cost in Electric Arc Furnace (Depreciation overhead & financing costs excluded)

Item	Units	Unit price US$/U	Consumption Units/Mt Steel	Production Cost US$/t Steel
Sponge Iron	Kg	0.142	885.02	125.69
Scrap	Kg	0.110	209.73	23.07
Fe - Mn 75 %	Kg	0.500	7.5	3.75
Fe - Si 50 %	Kg	0.470	9	4.23
Iron Ore	Kg	0.0025	12	0.03
Aluminium	Kg	1.330	1.2	1.60
Fluxes	Kg	0.050	50	2.50
Fluorite	Kg	0.202	12	2.42
Coke	Kg	0.150	10	1.50
Electrodes	Kg	2.100	6	12.60
Electric energy	Kwh	0.045	630	28.35
Fuel-Oil	x 10^3 Kcal	0.0057	85	0.48
Oxygen	Nm^3	0.030	14	0.42
Refractories	Kg	0.350	30	10.50
Water	m^3	0.090	0.8	0.07
Maintenance (1)	-	-	-	4.84
Manpower	Man Hours	1.150	2.26	2.60
Miscellaneous fabricating costs	-	-	-	1.75
Scrap recovery	Kg	0.110	10	- 1.10
Total	-	-	-	225.28

(1) 4 % of the specific investment (120.96 $/Mt year)

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6) Use value of sponge iron in an electric arc furnace

This is a concept developed by the French IRSID which tries to set up the price that a determined sponge iron should have, used in a proportion of 80% the load of the arc furnace, to obtain a cost of the liquid steel the same as would be with runs of 100% scrap. To set it up it is necessary to consider the advantages and the disadvantages of sponge iron against runs of 100% scrap.

a) Advantages.

- Less consumption of electrodes due to a larger stability of the electric arc established between the graphite electrodes and the liquid bath A 5% saving is considered.

- More productivity due to the elimination of dead times tied to the continuous load of th sponge and less refining time, since the fusion and the refining are carried out almost simultaneously. A 10% improvement is estimated. It affects labor, maintenance and amortization.

b) Disadvantages.

- More consumption of electric energy, since in the furnace it is necessary to finish reducing the FeO the sponge contains and the acid gangue must be slagged. The larger consumption of energy depends on the chemical analysis of the sponge iron, in this case it is estimated in about 9%.

- Larger consumption of lime and fluorite to slag the acid gangue of the sponge iron. 30% more slag is estimated when operating with sponge.

- Larger expense in refractories due to the larger production of slag. It is estimated at 40%.

The other costs are supposed to be the same. Calling P the use value of the sponge iron in US$ appear in table 3.14 comparing the production costs with both metallic loads, so that in order to obtain a liquid steel manufacturing cost in both cases, we will have for a cost of scrap US$ 110 a ton the price that follows for sponge iron:

$$P = \frac{200.92 - 114.97}{0.885} = \text{US\$ } 97.12 \text{ per ton}$$

That is, there is obtained a use value of the sponge iron lower by US$ 1.7 per ton than the cost price obtained with the processes based on natural gas (N.G). This would be the available margin under the present conditions of prices in Bolivia in respect to sponge iron, to obtain the same cost price of liquid steel to be reached with scrap at US$ 110 a ton.

In other words, with sponge iron at US$ 142 a ton, we obtain with loads of 80% sponge and 20% scrap, a liquid steel almost US$ 38 per ton more expensive than with 100% scrap at US$ 110 a ton.

The price of scrap to obtain a manufacturing cost of liquid steel with loads of 100% scrap the same as loads of 80% sponge and 20% scrap would be:

100% scrap	86.67 + 1.03863 P
0% scrap	217.82 + 0.20973 P

$$P = \frac{131.15}{0.83} = \text{US\$ } 158.01 \text{ per ton}$$

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TABLE 3.14

Electric Arc Furnace Sponge Iron Use Value Determination (US$/Mt liquid Steel)

Item	Unit Price	100 % Scrap		80 % Sponge Iron	
		Consumption/Mt Steel	Cost US $/Mt Steel	Consumption/Mt Steel	Cost US $/Mt Steel
Exterior Scrap (1)	110 US $/Mt	1,038.66 Kg	114.25	199.73 Kg	22.82
Sponge Iron (DRI)	P US $/Mt	-	-	885.02 Kg	0.885 P
Fluxes	0.05 US $/Kg	35 Kg	1.75	50 Kg	2.50
Fluorite	0.202 US $/Kg	9 Kg	1.82	12 Kg	2.42
Electrodes	2.1 US $/Kg	6.30 Kg	13.23	6 Kg	12.60
Electric Power	0.045 US $/Kwh	574 Kwh	25.83	630 Kwh	28.35
Refractories	0.35 US $/Kg	18 Kg	6.30	30 Kg	10.50
Manpower	1.15 US $/m. h	2.49 m. h	2.86	2.26 m. h	2.60
Maintenance	-	-	5.33	-	4.84
Depreciation	-	-	13.31	-	12.10
Miscellaneous	-	-	16.24	-	16.24
Total cost par T.	-	-	200.92	-	0.885 P + 114.97
Balance Point	$P = \frac{200.92 - 114.97}{0.885} = 97.12$ US$/Mt DRI				

(1) A discount of 10 kg scrap recovered in the furnace per Mt liquid steel has been applied

09402(240)/86

As a summary it can be seen that under the conditions of prices in Bolivia, operating with sponge iron in the electric arc furnace would be more economical when the scrap would surpass the price of US$ 158 per ton not realistic under actual conditions. For scrap lower than said price, it would be more economical to operate the arc furnace with loads of 100% scrap. As it is now the case, it would be much more economical to operate the electric arc furnace using 100 % scrap load.

3.6 ALTERNATIVES I & II COMPARISON

3.6.1 Previous Consideration

Alternative I will be located at Mutun, Alternative II in Santa Cruz, but the continuous casting facilities would be identical for both altenatives. These facilities will be analized and defined in order to get billet prices in Santa Cruz and Mutun.

3.6.2 Determination of the number of lines of the continuous casting (C.C) facilities

To determine the number of lines there is considered billet with a section of 100 x 100 mm. The normal casting speed today is 2.2 m per min. The casting speed in kg per min. will be:

$$0.1 \text{ m} \times 0.1 \text{ m} \times 7{,}850 \text{ kg per m}^3 \times 2.2 \text{ m per min.} = 172.7 \text{ kg per m.}$$

The less favourable casting time applies to the maximum capacity of 10,000 kg of the converter as follows:

$$\frac{10{,}000 \text{ kg}}{172.7 \text{ kg per min.}} = 57.9 \text{ min.}$$

This time is higher than the converter casting estimated in 45 min., for which one line is not sufficient. With two lines one half the time is obtained, which will permit to make sequential castings in the future. These equipments will be also valid for Alternative II.

The choice will therefore be, a continuous casting machine with two lines.

3.6.3 Bays

The bavs foreseen by the Promoting Unit are deemed suitable.

1) Converter pouring

Bay 30 m long and 22 m wide. The height of the bav to the rail beam is deemed at 15 m. For the casting a 20/5 t bridge crane is required. In it will be located the continuous casting platform and the zones for the preparation of casting ladles, rods and distributors.

2) Billet warehouse

Back to the casting bay, with the same dimensions as the latter. Height of the rail beam, 10 m. It will lodge the cooling and evacuation zones of the continuous casting machine, storage of billets and loading table of the preheating furnace. Served bv two 10 t bridge cranes.

3.6.4 Description of the continuous casting machine

- Number of lines	2
- Distance between lines	1,200 mm
- Type	Curved continuous casting with curved mould
- Radius	6 m
- Casting section	100 x 100 mm
- Casting speed	2.2 m per min.
- Billet length	2 to 4 m
- Cutting system	Oxygen cutting

	Product evacuation	By roller track to two coolers
-	Mould oscillation frequency	150 rpm
-	Oscillation amplitude	10.5 mm

The machine will consist of:

- Metallic structure with the inclusion of a casting platform, intermediate platform, support for the emergency ladle, rails for the distributor holder car, ladders, handrails, bottom plates and anchors.

- Mechanical equipment consisting of a distributor for two lines without cover, distributor holder car, preheating station for the distributor over the casting platform, slag box and channel, ingots, drives, ingot lubrication, devices for lifting and lowering the roller panels, billet extraction and straightening units, intermediate roller way, cooling chamber vapor extraction facility, lubrication center, control panels, piping, accessories and anchors.

- Casting equipment including ingot molds, roller panels, Dummy bars and calipers.

- Devices for integrated cut by the oxycutting machines with their electric equipment and an inclined plane for the evacuation of cropheads.

- Device for the evacuation of billets and cooling.

- Electric equipment, constituted by the drive electric motors, control facility and regulation and control desks.

3.6.5 Cranes

- Casting crane

Number of bridge cranes	1
Capacities	20/5 t
Lifting speed	5/10 m per min.
Bridge speed	30 m per min.
Car speed	10 m per min.

- Billet bay cranes

Number of bridge cranes	2
Capacities	10 t
Lifting speed	10 m per min.
Bridge speed	50 m per min.
Car speed	30 m per min.

3.6.6 Auxiliary Equipment

Among the auxiliary equipment it is worth mentioning the ones that follow:

- 4 casting ladles, 10 t capacity.
- Preparation and drying of ladles station.
- Rod drying oven.
- Billet revision station.

3.6.7 Labor

The direct labor staff necessary for continuous casting would be 72 persons with the following breakdown, considering a 4 shift work:

Position	Category	Number
Casting foreman	Master	4
Casting foreman	Qualified	4
Ladle operator	Semiqualified	4
Casting operator	Qualified	8
Billet evacuation	Non-qualified	8
Billet yard foreman	Qualified	8
Billet yard head	Master	4
Billet yard assistant	Non-qualified	8
Maintenance	Qualified	16
Absence coverage	Qualified	8
		72

Considering 2,304 hours of annual work per person, the direct labor required per ton of billet will be:

$$\frac{2,304 \times 72}{61,000} = 2.72 \text{ man hours per ton}$$

The labor mean cost results to be US$ 2,358.6 a year, equivalent to US$ 1.02 per man hour.

3.6.8 Required Investments

The same criteria of section 3.5.6, point 4, are utilized, above, that served to estimate the investments in the electric arc furnace steel mill, arriving at an investment of US$ 4,107.10 with the following breakdown:

	x US$ 10^3
Bays	
- Casting (660 m^2 x US$ 345 per m^2)	227.70
- Billet (660 m^2 x US$ 330 per m^2)	217.80
Equipment	
- Continuous casting	1,250
- Continuous casting civil engineering	375
- Auxiliary equipment	85
Cranes	
- Casting (20/5 t)	435
- Billet yard (2 x 10 t)	295
Facilities	
- Water	230
- Oxygen	10
- Compressed air	8
- Electric distribution	55
Spare parts	
- Continuous casting	87.50
- Auxiliary equipment	4

	x US$ 10^3
Transport, insurance and fees	
- Metallic structure (102.3 t)	35.80
- Continuous casting (240 t)	84
- Auxiliary equipment (70 t)	24.50
Subtotal	3,424.30
Assemblv and commissioning	121
Personnel training	75
Engineering	145
Sundries	342.40
Total	4,107.70

For the foreseen production of 61,000 t per year, there is obtained a specific investment of US$ 67.34 per ton of billet.

3.6.9 Manufacturing Cost

Alternatives I & II cost comparison will be obtained in the assumption that billets are located in Santa Cruz in both cases, as indicated in paragraph 3.6.1.

Taking into consideration Alternative I liquid steel production costs as given in Table 3.5 and the corresponding ones for Alternative II, given in Table 3.13, Table 3,15 providing billet production costs-excluding depreciation, is overhead and financing costs-could be completed.

Thus, a cost of US$ 225.85/Tm is reached for Alternative I and other of US $ 243.33 for Alternive II. Then a difference of US $ 17.45/Tm is quite significant, specially when considering that depreciations are excluded.

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TABLE 3.15

Santa Cruz Delivered Billet Fabricating Cost Comparison for Alternatives I & II

Item	Units	Unit Price in US$/Unit	Consumption in Units per Billet Mt	Cost Price in US$/Mt of billet	US$/Mt of Billet Alternative II
Liquid Steel	Mt	137.84 (1) 225.28 (2)	1.053 -	145.15 -	237.22 -
Electric Power	Kwh	0.036 (1) 0.045 (2)	10	0.36	0.45
Fuel Oil	x 10^3 Kcal	0.034	25	0.85	-
Natural Gas	x 10^3 Kcal	0.0057	25	-	0.14
Refractories	Kg	0.4	3	1.20	1.20
Pouring Moulds	-	-	-	0.60	0.60
Water	m^3	0.09	0.7	0.06	0.06
Manpower	Man Hours	1.02	2.72	2.77	2.77
Fabricating Miscellaneous costs	-	-	-	1.50	1.50
Maintenance (3)	-	-	-	2.69	2.69
Transportation to Santa Cruz	Mt	74	1	74	-
Scrap recovery	Kg	0.110	- 30	- 3.30	- 3.30
Total		-	-	225.88	243.33

(1) Alternative I
(2) Alternative II
(3) 4 % of specific Investment (US$ 67.34/Mt of billet)

For Alternative II, the D.R unit alone, will suppose an investement of roughly US$ 85 x 10^6, which would force to sell, the excesses of DRI production at a minimum selling price of US$ 175/Tm well above the US$ 125/Tm actual CIF Price for this product the International Market.

Table 3.16 compares the Specific Investment (per Tm/year of capacity) required for both alternatives, in order to produce liquid steel, because, as previously indicated, the continuous casting unit will be the same in both cases. So, a difference in favour of the electric furnace (Alternative II) of 39.5 US$/Tm of steel is obtained. Assuming now a 10 % depreciation we would reach a figure of US $ 3.95/Tm which evidently does not compensate the difference of US$ 17.45/Tm shown in Table 3.15.

Summarizing all above points, from a merely economic point of view Alternative I with charcoal appears more favourable. Alternative II can not be justified either, through an excess in production of DRI, as it would become rather difficult selling it in view of the high production cost there shown.

Under these circumstances, we will or compare Alternatives I and III (this is re-rolling of imported billets) in the following sections.

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TABLE 3.16

Required Investment for getting Liquid Steel under Alternatives I & II

Alternative I				Alternative II			
Facility	Specific investment US$/Mt of product	Consumption (Mt per Mt liquid steel)	Specific invest. US$/Mt liquid steel	Facility	Specific invest. US$ of product	Consumption (Mt per Mt liquid steel)	Specific invest. US$/Mt liquid steel
Charcoal Unit	77.7	0.770	59.83	Direct Reduction	215	0.885	190.27
Pig Iron in Blast Furnace	150	0.873	130.95	Electric Steel shop	121	1	121
Liquid Steel (LD converter)	160	1	160				
Total US$/Mt liquid steel	-	-	350.78		-	-	311.28

3.7 ALTERNATIVE III

3.7.1 Introduction and Rolling Mill Definition

As indicated in paragraph 3.3.1 above, Alternative III considers only a production of rolled products from billets. Not with standing the definition here of the required rolling mill facilities and their respective investments are also valid for Alternative I with an eventual difference in location.

As a matter of fact, Alternative III because of Market neigh bourhood, apppears most conveniently located in Santa Cruz, but Alternative I would accept a rolling mill both at Santa Cruz or Mutun, with an only limitation depending on fabricating costs, as in Santa Cruz N.G is available much cheaper than fuel oil, but oppositely electric power is more expensive than the one available from Brasil in Mutun.

For rolling mill definition, a schedule of two shifts per day is considered, which is the normal practice in this type of installations, with the purpose of assigning a third shift to maintenance and a contingent change in the rolling program. Therefore, 4,000 hours per year of real work are supposed, that is, an average of 14 h/per day during 285 days a year.

To produce 55,000 t/year requires an average production of 13.75 t/hr. This estimate of lamination installations will be based on this figure.

The reheating furnace should be of dimensions so as to permit maximum production, which, as will be seen, correspond to the heaviest pieces.

The rolling mill program illustrated in Table 3.17 requires a versatile installation to produce the different types of rods, squares, rectangles and angles.

In the mentioned Table 3.17 the weights per lineal meter of the products to be rolled are also given.

Depending on said weights, an installation with two finishing points has been selected, with the following distribution:

1st Outlet

Rods weighing more than 1 kg/m and the rest of the products, all of them ending in bars.

- Rods > 12.5
- Squares All
- Rectangles All
- Angles All

2nd Outlet

Product· weighing less than 1 kg/m ending in coils.

- Bars < 12.5 diameter

Taking into account the two cited outlets, the installation selected should be composed of four mills, for which the following selected speeds have been chosen based on exnerience.

TABLE 3.17

Product Mix

Product	Dimension mm	Weight Kg/m	Production Mt/year
Wire rod	6.3	0.245	6,300
	8	0.395	2,400
	10	0.617	2,500
	12.5	0.963	2,500
Concrete bar	6.3	0.245	5,900
	8	0.395	3,700
	10	0.617	4,200
	12.5	0.963	5,700
	16	1.578	3,900
	20	2.466	3,000
	25	3.853	5,900
	32	6.313	900
Square	12	1.130	600
	18	2.458	100
	25	4.906	200

Product	Dimension mm	Weight Kg/m	Production Mt/year
Round	Ø 10	0.617	1,000
	Ø 12.5	0.963	600
	Ø 16	1.578	300
	Ø 20	2.466	200
	Ø 25	3.853	100
	Ø 32	6.313	100
Rectangular bar	25 x 6	1.178	200
	32 x 6	1.507	100
	40 x 6	1.884	100
	50 x 6	2.355	100
Angle Section	20 x 3	0.926	600
	30 x 3	1.360	1,500
	35 x 3	1.890	400
	40 x 5	2.662	1,100
	50 x 6	4.147	800

- Roughing mill 3 m/sec.
- Preparation mill 5 m/sec.
- 1st Finishing mill Variable speed depending on product
- 2nd Finishing mill Variable speed depending on product

Passes and Production Plan

a) Products obtained on 1st finishing mill

The most characteristic products are considered to be rods with diameters of 16, 20 and 25 mm, which in total represent 25% of the production. In tables 3.18, 3.19, and 3.20 the different parameters related to the rolling of each one of these are analyzed and characterized by:

- Number of passes.
- Corresponding stand in which each pass is made (R: roughing, P: Preparation, F_1: 1st finisher).
- Section corresponding to each pass.
- Draw coefficient of each pass (the quotient of the section of the previous pass by the new section).
- Length obtained in each pass, which results from multiplying the length of the previous pass by the draw coefficient.
- Machine time (quotient between the length of each pass and rolling speed).
- Total time: This has been broken down by mill. It results from the sum of machine time obtained previously, plus the supposed maneuver time, in all cases of three seconds from pass to pass.

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TABLE 3.18

Round Bar ∅ 16

Pass N.	Mill	Section Dimensions mm	Section mm^2	Rolling Reduct. Coefficient	Length m	Speed m/s	Under Rolls time sec.	Total Time sec
0	-	100 x 100	10,000	-	3	-	-	
1	R	146.6 x 110	8,064	1.240	4.96	3	1.65	
2	R	80 x 80	6,400	1.260	6.24	3	2.08	
3	R	114 x 42	4,788	1.336	8.34	3	2.78	
4	R	116 x 30.5	3,546	1.350	11.26	3	3.75	
5	R	52 x 52	2,704	1.311	14.76	3	4.92	
6	R	oval	1,866	1.448	21.37	3	7.12	
7	R	36.5 x 36.5	1,332	1.400	29.92	3	9.97	32.27 + 18 = 50.27
8	P	oval	968	1.379	41.26	5	8.25	
9	P	26.5 x 26.5	702	1.378	56.86	5	11.37	
10	P	oval	543	1.293	73.52	5	14.70	
11	P	∅ 24	452,4	1.201	88.30	5	17.66	
12	P	oval	374	1.209	106.75	5	21.35	73.33 + 12 = 85.33
13	F_1	∅ 20	314	1.191	127.14	5.96	21.35	
14	F_1	oval	254.5	1.233	156.76	7.34	21.35	
15	F_1	∅ 16	221.7	1.148	179.96	8.43	21.35	64.05 + 6 = 70.05

TABLE 3.19

Round Bar Ø 20

Pass N.	Mill	Section Dimensions mm	Section mm^2	Rolling Reduct. Coefficient	Length m	Speed m/s	Under Rolls Time sec	Total Time sec
0	R	100 x 100	10,000	-	4	-	-	
1	R	146.6 x 110	8,064	1.240	4.96	3	1.65	
2	R	80 x 80	6,400	1.260	6.24	3	2.08	
3	R	114 x 42	4,788	1.336	8.34	3	2.78	
4	R	116 x 30.5	3,546	1.350	11.26	3	3.75	
5	R	52 x 52	2,704	1.311	14.76	3	4.92	
6	R	oval	1,866	1.448	21.37	3	7.12	
7	R	36.5 x 36.5	1,332	1.400	29.92	3	9.97	32.27 + 18 = 50.27
8	P	oval	968	1.379	41.26	5	8.25	
9	P	26.5 x 26.5	702	1.378	56.86	5	11.37	
10	P	oval	543	1.293	73.52	5	14.70	34.32 + 9 = 43.32
11	F_1	Ø 24	452,4	1.201	88.30	6.0	14.70	
12	F_1	oval	374	1.209	106.75	7.26	14.70	
13	F_1	Ø 20	314	1.191	127.14	8.65	14.70	44.10 +6 = 50.10

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TABLE 3.20

Round Bar Ø 25

Pass N.	Mill	Section Dimensions mm	Section mm^2	Rolling Reduct. Coefficient	Length m	Speed m/s	Under Rolls Time sec.	Total Time sec
0	R	100 x 100	10,000	-	4	-	-	
1	R	146 x 110	8,064	1.240	4.96	3	1.65	
2	R	80 x 80	6,400	1.260	6.24	3	2.08	
3	R	114 x 42	4,788	1.336	8.34	3	2.78	
4	R	116 x 30.5	3,546	1.350	11.26	3	3.75	
5	R	52 x 52	2,704	1.311	14.76	3	4.92	15.18 + 12 = 27.18
6	P	oval	1,866	1.448	21.37	5	4.27	
7	P	36.5 x 36.5	1,332	1.400	29.92	5	5.25	32.27 + 18 = 50.27
8	P	oval	968	1.379	41.26	5	8.25	
9	F_1	26.5 x 26.5	702	1.378	56.86	6.89	8.25	
10	F_1	oval	543	1.293	73.52	8.91	8.26	
11	F_1	Ø 25	490	1.108	81.47	9.87	8.25	24.75 + 6 = 30.75

The resulting production in each mill has been obtained by the formula:

$$P\ (kg/h) = \frac{\text{Billet weight (kg)} \times 3{,}600\ \text{sec./h.}}{\text{Total time (seconds)}}$$

Two installations efficiencies are considered: 60%, valid (start-up) for the first period and 75% once the normal functioning of the installation is achieved.

In these circumstances the following productions in kg/hr. are obtained for a billet of 100 x 100 m section and 4 m in length (314 kg weight).

Mill	Ø 16		Ø 20		Ø 25	
	60%	75%	60%	75%	60%	70%
R	13,492	16,865	13,492	16,865	24,953	31,192
P	7,948	9,935	15,656	19,570	27,683	34,605
F_1	9,682	12,102	13,537	16,922	22,056	27,570

Said productions have been obtained for the most disfavorable case of bar to bar rolling. If a new bar is inserted one or two passes before completing the cycle of anterior rolling, production would increase by 20 to 30%.

Lower productions are obtained with the finisher than in the roughing and preparation mills. As already expected, the greatest productions correspond to the thickest pieces.

b) <u>Products obtained in the 2nd finisher</u>

Characteristic products are considered to be wirerods of diameter 6.3, 8 and 10 mm which in total represent 47% of production.

In table 3.21 the number of passes and the corresponding stand in which each pass is made (F_2 2^{nd} finisher) are analyzed.

Using as a base the same table 3.21, the following productions in kg/h are obtained with billet of 100 x 100 mm.

Mill	Dia. 6.3		Dia. 10		Dia. 8	
	60%	75%	60%	75%	60%	70%
R	13,492	16,865	13,492	16,865	13,492	16,865
P	7,426	9,283	7,426	9,283	7,426	9,283
F_1	4,642	5,303	4,642	5,803	4,642	5,803
F_2	3,979	4,974	9,284	11,606	5,570	6,963

Since to obtain diameter 8, two passes less are required than for 6.3 and for diameter 10, 4 passes less, greater production is obtained in the second finisher with the larger rod.

With the second finisher a velocity of almost 60 m/sec. is required for diameter 6.3, which is considered high in this type of small production mills.

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TABLE 3.21

Round Bar Ø 6.3

Pass N.	Mill	Section Dimensions mm	Section mm^2	Rolling Reduct. Coefficient	Length m	Speed m/s	Under Rolls Time sec	Total Time sec
0	-	100 x 100	10,000	-	4	-	-	
1	R	146.6 x 110	8,064	1.240	4.96	3	1.65	
2	R	80 x 80	6,400	1.260	6.24	3	2.08	
3	R	114 x 42	4,788	1.336	8.34	3	2.78	
4	R	116 x 30.5	3,546	1.350	11.26	3	3.75	
5	R	52 x 52	2,704	1.311	14.76	3	4.92	
6	R	oval	1,866	1.448	21.37	3	7.12	
7	R	36.5 x 36.5	1,332	1.400	29.92	3	9.97	32.27 + 18 = 50.27
8	P	oval	968	1.379	41.26	5	8.25	
9	P	26.5 x 26.5	702	1.378	56.86	5	11.37	
10	P	oval	543	1.293	73.52	5	14.70	
11	P	Ø 24	452	1.201	88.30	5	17.66	
12	P	oval	374	1.209	106.75	5	21.35	73.33 + 18 = 91.33
13	F_1	Ø 20	314	1.191	127.15	5.96	21.35	
14	F_1	oval	255	1.231	156.57	7.33	21.35	
15	F_1	Ø 16	221	1.154	180.66	8.47	21.35	
16	F_1	oval	198	1.116	201.64	9.44	21.35	
17	F_1	Ø 14.5	165	1.200	241.97	11.31	21.35	
18	F_1	oval	138	1.196	289.31	13.55	21.35	128.10 + 18 = 146.10
19	F_2	Ø 12	113	1.221	353.32	16.55	21.35	
20	F_2	oval	94	1.202	424.74	19.89	21.35	
21	F_2	Ø 10	78	1.205	511.87	23.98	21.35	
22	F_2	oval	62	1.258	643.96	30.16	21.35	
23	F_2	Ø 8	50	1.240	798.57	37.40	21.35	
24	F_2	oval	39	1.282	1,023.73	47.95	21.35	
25	F_2	Ø 6.3	31.2	1.250	1,279.66	59.94	21.35	149.45 + 21 = 170.45

In order to diminish the velocity it is possible to use an 80 x 80 billet, with which two passes can be spared, and in the final one reaching a velocity of 40 m/sec.

Since the continuous casting machine has been planned to have two lines, by working the machine systematically casting on one line a 100 x 100 mm billet and on the other an 80 x 80 one, the following production would be obtained.

-	Billet	80 x 80 mm	23,800 t/year
-	Billet	100 x 100 mm	37,200 t/year
		Total	61,000 t/year

The production of rods of 6,3 and 8 mm in diameter represents in sum, following table 3.17, a total of 18,300 t/year. With an estimated billet rolling efficiency of 90%, the billet requirement for both diameters would be 20,300 t/year. Considering that in small products the efficiency would be somewhat lower, it can be seen that by working simultaneously to produce the two billet sections considered, the production of the continuous casting machine would be balanced with consumption.

The solution given by Cobrapi of using 2.2 m/sec. on the roughing mill and preparer would lead to a maximum velocity of 26 m/sec. on the second finisher but at the cost of having a much lower production. In the case of the 6.3 diameter, at 60% efficiency, production would be only 1,855 kg/hr. With an 80 x 30 mm billet, rolling on the last pass at 40 m/sec., a production of 3,690 kg/hr. is obtained with the same efficiency.

c) Reheating Furnace

The reheating furnace's production should be equal to the maximum production of the mill, that is, about 30 t/hr. for when the heaviest products are rolled.

3.7.2 Description of Installation

1) Bays

Two bays are required, one to house the reheating furnace, rolling mill and cylinder room and the second for storage of the finished product.

a) Rolling bay

The foreseen dimensions are 24 m in width, 190 m length, with 12 m rail girder height. For the service of the rolling mill and the removal of products a bridge crane with 10/3 t lifting capacity is necessary.

b) Finishing bay and store room for rolled products

The same dimensions as above. In this case, two bridge cranes of 5 t are foreseen.

2) Description of mill

a) Reheating furnace

Type	Thrust
Inward Thrust	Frontal

Outward Draw	Lateral
Dimensions	Length 20 m. Width 6 m.
Capacity	30 t/h
Fuel	Natural Gas (N.G)

The furnace will be equipped with the following services for the movement of the billet.

- Transferrer loader to service furnace loading
- Load thrust group
- Outward thruster with slidable wagon

b) Roughing mill

Composed of:

- Billet hauler in service at furnace exit.
- Trio roughing stand, 500 mm roll diameter and 1,500 table.
- Two steel founding towers connected by means of spacers and tie-rods.
- Fastening gaskets of the cylinders made of forged steel complete with ball-bearings.
- Vertical regulation device for upper cylinders by means of worm gears reducers.
- Vertical regulation of the lower cylinder by insertion or calibrated gauges.
- Axial regulation of the upper cylinders by means of clamps and tie-rods. Fixed lower cylinder.
- Tool carrying bars at the entrance and exit.
- Installation of the circulation of cooling water.
- Grease lubrication for the fastening gaskets.

- A speed reducer with horizontal axles and triple pair of cylindrical bihelical gears, servicing the roughing stand.

Transmissible power	1,500 CV
Ingoing velocity	1,000 rpm
Exit velocity	115 rpm

- An alternating current motor with 1,500 CV power at 1,000 rpm for the operation of this stand.
- Roller tracks before and after this stand.
- Hoisting panels before and after the stand.

c) <u>Preparation mill</u>

Will be composed of:

- Five duo alternate stands with diameter of 350 mm and 800 mm table, arranged in line.

Each stand will consist of:

- Two steel founding towers connected by means of spacers and tie rods.
- Roll fastening gaskets made of forged steel complete with ball bearings.
- Balance of upper riders by means of spring device.
- Independent or joint vertical regulation of the upper roll for both riders by means of worm gear reducers.
- Lower roll regulation via insertion of calibrated gauges.
- Axial regulation of the upper roll via clamps and tie rods. Fixed lower roll.

- Installation for circulation of cooling water.
- Grease lubrication of the fastening gaskets.
- A speed reducer with horizontal axles and cylindrical bihelical gears servicing the five preparation stands in line.

Transmissible power	1,200 CV
Ingoing velocity	800 rpm
Exit velocity	175 rpm

- An alternating current motor with 1,200 CV power at 800 rpm.
- Roller tracks before and after each stand.
- Flangers located among the roller tracks for the movement of bars between the stands.
- Edging stand with vertical cylinders located before the last preparation stand and operated by an independent motor of 300 kw.

d) First finishing mill

Consisting of:

- Flywheel shear with rotary knives for hot shearing.
- Six duo horizontal rolling groups with independent control panel, arranged continuously with stands appropriate for mounting rolls on bearings.

6 direct current motors with variable speed and 200 kw each.
Pinion axle base 300 mm max.
Roll diameter 260 mm
Roll panel 500 mm

- Six velocity reducers for simple reduction with octogonal axles.

e) <u>Outlet and cooldown services of first finisher</u>

Composed of:

- Roller outlet track.
- Cooldown table of the galloping panel type, size 62 m x 8 m with regulatable velocity according to the size of the product, equipped with 6 disc saws mounted over the measurements cutting carriage.
- Two finishing straighteners.
- Finished products packing section.

f) <u>Second finisher group</u>

The principal characteristics are:

Number of stands	7 individually controlled (1)
Rolls diameter	180 mm
Distance between rolles	635 mm
Operation	1 direct current motor of 750 kw
Regulation	Synchronic

- Flywheel shear for hot cropping
- Water cooler and coil former

(1) Due horizontal stands, laid in continuous one after the other, Stands adequate to erect wolls with bearings.

- Coiler with mechanical thruster
- Spool transporter

g) Handling equipment

Rolling Mill Bay

1 bridge crane for the movement of the mill pieces

Capacity	10/3 t
Elevation velocity	10 m/min.
Bridge velocity	50 m/min.
Cart velocity	30 m/min.

Warehouse & Shipping

Number of bridge cranes	2
Capacity	5 t
Elevation capacity	15 m/min.
Bridge velocity	80 m/min.
Cart velocity	30 m/min.

3.7.3 Manpower

The crew of direct manpower working two shifts total 88 people with the following breakdown:

Position	Category	Number
Reheating furnace chief	Foreman/Master	2
Furnacemen	Qualified	4
Furnace loaders and unloaders	Non-qualified	4

Position	Category	Number
Rolling foreman	Foreman/Master	2
Rolling mill operators	Semi-qualified	8
Control pulpit operators	Qualified	8
Hookers	Non-qualified	6
Saw cutters	Semi-qualified	2
Crane operator	Qualified	4
Straightener	Semi-qualified	4
Packer and Marker	Semi-qualified	6
Storeroom and Dispatch	Non-qualified	8
Maintenance:		
- Cylinder shop	Qualified	4
- Greasers	Qualified	4
- Machine room overseers	Qualified	6
- Fast action electricians	Qualified	4
- Fast action mechanics	Qualified	4
Absence coverage	Qualified	8
		88

Considering 2,304 annual work hours per person, the direct manpower required per t of rolled product will be:

$$\frac{2,304 \times 88}{55,000} = 3.67 \text{ hr. manpower/t}$$

The average manpower cost turns out to be 2,602 US$ per year, equivalent to 1.13 US$/manpower hour.

3.7.4 Required Investment

The required investments have been obtained using ONUDI available ratios, reaching an amount of US $ 13,953,700 with the following break down:

	US dollars x 10^3
Bays	
Rolling mill (4,560 m^2 x 190 US$/$m^2$)	866.4
Product Warehouse (4,560 m^2 x 170 US$/$m^2$)	775.2
Equipment	
Reheating furnace of 30 t/h	325
Furnace feeder and unloader	70
Roughing mill, 500 diameter, complete (R)	1,255
Preparation mill, 350 diameter complete (P)	710
Finishing mill, 260 diameter, complete (F_1)	450
Cutting, cooling and bar pickup	325
Roll finisher (F_2)	1,140
Electrical equipment and motors	1,760
Tools	65
Rolls and rolling guides (included in each mill)	
Foundation of equipment and reheating furnace	1,630
Cranes	
Rolling mill Bay (1 x 10/3 t)	150
Product Warehouse (2 x 5 t)	180

	US dollars x 10^3
Installations	
Hydraulic plant	160
Lubrication plant	220
Compressed air	40
Water	14
Electrical wiring and lighting	80
Roll workshop	355
Spare parts	
Spare parts, including general stock	205
Transportation, insurance and taxes	
Metallic structure (350 t)	122.5
Rolling equipment (1,500 t)	525
Installations and cranes (580 t)	203
Subtotal	11,626.1
Assembly and starting up	585
Personnel training	115
Engineering	465
Contingencies	1.162.6
Total	13,953.7

For a foreseen production of 55,000 t/year, a specific investment of US$ 253,70/annual ton of rolled products is obtained.

3.7 Alternatives I & III Comparison

The rolled products cost comparison for Alternatives I & III will be based on billets production cost for both cases.

For Alternative I, paragraph 3.6.9 Table 3.15 gave a Santa Cruz delivered billet production cost of US$ 225.88/Tm (depreciation, overhead and financing expenses excluded).

In connection with imported billets used as raw material for Alternative III, we should start from the International free market F.O.B price-today it is US$ 185/Mt -. Assuming those billets come from the Altos Hornos de Zapla, we will reach the following cost:

F.O.B Price	US$ 185/Tm
Transp. till Bolivian border	US$ 15/Tm
Total CIF Border	US$ 200/Tm
Custom Taxes (15% over CIF)	US$ 30/Tm
Transp. Boliv. border Santa Cruz	US$ 62.13/Tm
Handling in Sta Cruz plus other expenses	US$ 5.0/Tm
Total CIF Rolling Mill	US$ 297.13/Tm

When comparing this figure for Alternative III with that of the second paragraph a difference of US$ 71.25 will appear.

From these prices for billets for both alternatives, going to Table 3.22 we reach prices of US$ 263.30 for Alternative I and 342.32 for Alternative III, i.e. an even higher difference of US$ 79.02/mt in favour of Alternative I. Notwithstanding we should insist upon this difference being merely appearance, as the depreciation, overhead, and financing expenses were excluded. Chapter 4 will analvze in detail those three items to be able to properly compare both alternatives.

TABLE 3.22

Rolling Fabricating Cost Estimate (Excluding depreciation, overhead and financing costs)

Item	Units	Unit Price US$/Unit	Consumption Units/Rolled Mt	Cost Price US$/Mt of product
Billet	Mt	225.88 (1) 297.13 (2)	1.109	250.50 (1) 329.52 (2)
Electric Power	Kwh	0.045	75	3.38
Natural Gas	x 10^3 Kcal	0.0057	600	3.42
Rolling rolls	Kg	4.70	0.5	2.35
Water	m^3	0.09	1.5	0.13
Maintenance (3)	-	-	-	5.07
Manpower	Man hour	1.13	3.67	4.15
Miscellaneous fabricating costs	-	-	-	2
Scrap Recovery	Kg	0.110	- 70	- 7.70
Total				263.30 (1) 342.32 (2)

(1) Alternative I Billet Price

(2) Alternative III (imported) Billet Price

(3) 2 % of the specific Investment (US$ 253.7/Mt/year)

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IV. FORMULATION OF THE PROJECT

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IV. SELECTION OF ALTERNATIVES AND PROJECT FORMULATION

4.1 CRITERIA FOR SELECTION OF ALTERNATIVES

As previously pointed out in Chapter III, the criteria used in evaluation alternatives were on one hand the economic and efficiency aspects of the installations, and on the other technical aspects. Alternatives I (based on charcoal) and III (based on imported billets) have been selected.

4.1.1 Economic and Efficiency Criteria

In view of the idiosyncracies of the Bolivian economy and its serious foreign debt repayment problem it has been considered in first term that the installation be as economical as possible in order to avoid an even further indebtedness.

In this sense, the most economical alternative with regard to investment, is that consisting of the blast furnace and LD converter, if country resources are intended and used (iron ore and charcoal). If only investments are considered, the rolling unit of imported billets shows a much investment.

4.1.2 Location

The site was also selected due to economic criteria, for although technically it is possible to locate the blast furnace in Santa Cruz, the iron ore transport costs made it necessary to discard this spot.

One the location has been fixed for economic reason in the Mutun, doubts might arise as to where to situate the rest of the installations.

In principle, one could think of tranportating the crude iron to Santa Cruz and building the rest of the installations there, steelworks, continuous casting and rolling mill. However, form a technical point of view it is completely irrational to let the crude iron solidify only to liquify it again at the steelworks with the consequent energy waste. Nor is it possible to transport it in a liquid form in view of the quantity of refractory and isolation that the torpedo would need to maintain it liquid during the minimum of 24 hours that transport would last until its use in the converter.

Therefore, the blast furnace as well as the LD converter and casting still must be as close as possible to the deposit, that is, they must be located in the Mutun, so as not to have to transport by railroad either the iron mineral, lime or limestone, charcoal or the crude iron. The only possible alternative that still exists is that of the rolling mill.

Keeping in mind that Santa Cruz consumes 25% and is an obligated through-point for distribution to other departments where siderurgical products form the Mutun are consumed, the possibility has been studied of locating the rolling mill there. In Santa Cruz one would profit from the low cost of natual gas and would have as a disadvantage the higher electricity and transport rates, since for each ton of rolled product 1,109 kg of billet would have to be tranported.

In table 4.1 a summary is given of the resource availabilities of Mutun and Santa Cruz. Taking as a base the cost for transforming billet into rolled product from tables 3.15 and 3.22 these costs have once again been calculated for both alternatives in table 4.2. The items varying according to their location are; billet; electrical energy; fuel for the reheating furnace (fuel-oil in Mutun and natural gas in Santa Cruz). The rest of the cost remain the same.

TABLE 4.1

Disponibility of Resources in Mutun and Santa Cruz

Resources	Mutun	Santa Cruz	Price
Iron ore	yes	no	2.50 $ US/t concentrated ore
Manganese ore	yes	no	75.22 $ US/t
Limestone	yes	no	2.24 $ US/t
Timber for production of Charcoal	yes	--	Is not priced neither COBRAPI nor in U. Promotora
Natural Gas	no	yes	1.50 $ US/1000 cubic feet (5.7 US$/million kcal)
Bolivian electric power	yes (coming from Brasil)	yes	Mutun: 0.036 US$/kwh Sta. Cruz (máx) 0.045 $ US/kwh
Water	yes	yes	0.09 US$/$m^3$
Transportation Mutún-Sta Cruz	yes	--	Railway. Ore: 72.45 US$/t Timber: 49.85 US$/t Charcoal: 70.44 US$/t Iron and Steel products : 74.00 US$/t Truck: 0.15 US$/t-km
Qualified manpower for the project	no	yes	Superior: 6,747 US$/year Technician: 3,217.8 $ US/year Master: 3,217.8 $ US/year Qualified: 2,802.6 $ US/year Semi-Qualified: 2,491.2 $ US/year Non Qualified: 2,076 $ US/year

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TABLE 4.2

Rolling Mill Costs Comparison betweem Mutun and Santa Cruz (Depreciation, Overhead & financing costs excluded)

Item	Unit	Consumption	Unit Price US$/Unit		Costs US$/Mt of Rolled/Products	
			Mutun	Santa Cruz	Mutun	Santa Cruz
Billet	Mt	1,109	151.88	225.88 (1)	168.43	250.50
Electric Power	kwh	75	0.036	0.045	2.70	3.37
Fuel-oil	x 10^3 kcal	600	0.034	--	20.40	--
Natural Gas	x 10^3 kcal	600	--	0.0057	--	3.42
Remainder Costs	--	--	--	--	6.0	6.0
Rolled products transportation to Sta Cruz	Mt	1	74.00	--	74.00	--
TOTAL					271.53	263.29

(1) 74 + 151.88 = 225.88 where 74 US$/Mt is the railway transportation price from Mutun to Santa Cruz for iron and steel products independently of their type.

With a railroad transport price for siderurgical products (according to the latest ENFE statistics) of 74 US$/t, a lower production cost is obtained in Santa Cruz, estimated to be 8,2 US$/t less than in Mutun, due to the much lower price of natural gas compared to fuel-oil.

It is of interest to note that said difference accordingly increases as the transport price decrases. This is of great importance, since according to the D.S. 21060 the railroad rates may never be higher than those which foreign railways charges in the corresponding connecting routes, in this case Corumbá/Santos.

With the various transport prices between Puerto Suárez and Santa Cruz, the following differences in US$/rolled ton are obtained in favor of the Santa Cruz location:

Transport Charges US$/t Siderurgical Products	Difference in favor of Santa Cruz US$/t
15	14,7
30	13,0
45	11,4
60	9,8
74	8,2

It can be observed that the difference lessens as the transport price rises. The fee that would balance the cost prices of both alternatives would be 144 US$/transported ton, far beyond the present fees.

In this way one arrives at a rolling mill location for alternatives I a III, which from an economic point of view, is much more favorable in Santa Cruz. Other advantages of this location would be:

- Creater proximitv to consumption points
- Less dependence on Brazilian electric power
- Lower infrastructure costs, since it could be installed in the "Parque Industrial de Santa Cruz", which already has urbanisation services, water, natural gas and electrical enerav.

4.1.2 Technical Criteria

Blast furnace technology with charcoal has been used in Sweden and Russia since the XVIII century and in a country neighboring Bolivia such as Brazil, the first charcoal blast furnace appeared in 1814 in the "Real Fábrica de Ferro do Morro do Pilar".

It is considered therefore to be a well known and developed technology, whose operating problems have been solved over the years and could work without surprise in Bolivia with a good program of personnel training. It would possibly work with more guarantees than another more advanced technology that needed a greater degree of specialization.

Moreover, in another country neighboring Bolivia such as Paraguay, where there was no siderurgical industrv or tradition, a charcoal blast furnace is being built for "Aceros del Paraguay" (ACEPAR) at Villa Hayes with capacity for an annual production of 150.000 t.

4.2 PROJECT DEFINITION

4.2.1 Location

The location, as has already been mentioned, will be in Mutun for the blast furnace and continuous casting at the same site which was considered by Unidad Promotora.

The rolling mill plant, common to both alternatives, will have to be situated in the "Parque Industrial Pesado de Santa Cruz", in which a 150,000 lot (300 x 500 m as a rough idea) will have to be acquired, equipped with the necessary infrastructure of: water with a flow not less than 25m^3/hr; natural gas with a daily flow of 350,000 ft^3; an electrical network to mount an installation of 2MVA.

All of these services would have to be able to be widened if the case arose.

4.2.2 Buildings

The installation to be made at Mutun would consist of the following principal buildings:

1) At the depost.

A preventive maintenance hall for machinery and to store materials and spare parts. The dimensions would be:

Length	50 m
Width	20 m

2) <u>At the Iron and Steel Plant.</u>

A blast furnace with the following characteristics:

Melting Pot diameter	2,9 m
Shaft diameter	4,0 m
Shaft top diameter	2,5 m
Total height	15,3 m

Building for steelworks and continuous casting divided into the three following halls:

a) Converter Bay

Length	60 m
Width	10 m
Track beam height	15 m

b) Loading Bay

Length	72 m
Width	16,5 m
Track beam height	15 m

c) Casting Bay

Length	72 m
Width	22 m
Track beam height	15 m

Following the casting hall and with the same dimensions, would be found the hall for cooling and billet storage until its dispatch to Santa Cruz. The track beam height would be 10 m.

3) At the Rolling Mill Plant in Santa Cruz

A hall for the rolling mill:

Height	190 m
Width	24 m
Track beam height	12 m

Following this hall and having the same dimensions would be found the hall for finishing and storage of finished products.

For investments calculation purpose a series of auxiliary building have also been considered, such as: workshops; offices; storerooms; dressing rooms; social services, etc.

4.2.3 List of Equipment

Only the key plant equipment will be mentioned, since the study and definition of all the auxiliary equipment corresponds to the supplier of the principal equipment, according to his necessities. Thus, this equipment cosists of the following:

1) A blast furnace with the following parameters:

Shaft top diameter	2,5 m
Shaft diameter	4,0 m
Crevet well diameter	2,9 m
Total height	15,3 m
Serviceable height	12,3 m
Serviceable volume	115,- m
Productivity (t/d/m^2 shaft)	23
Productivity (t/d/m^3 serviceable vol.)	1,3

The blast furnace be equipped with the corresponding conveyor belts, hoppers, bens, screens and scales necessary for the loading of the pre-established quantities of mineral, coal and fluxes, as well as the equipment for gas purification, hot air blows, ovens to heat this air, etc, and ignition devices necessary for functioning.

2) Two 9/10 ton LD Oxygen converters, with basic coating. They will at the same time ne equipped with: charging spoon; transfer cars; and system of oxygen blow; spoon heating; refractory demolition; smoke purifiers. The supply will also include a crude iron mixer.

3) A continuous casting machine with the following specifications:

Number of strands	2
Distance between strands	1,200 mm
Type	continuous curve casting with shell curves
Radius	6 m
Casting section	100 x 100 mm
Casting velocity	2,2 m/min
Billet length	4 m
Cutting system	oxigen cutting
Product outler	by roller track to two coolers
Mold oscillation frequency	150 rpm
Oscillation range	+ 10,5 mm

4) A rolling mill which should consist of the following main equipments and characteristics:

a) Rehating furnace

Type	Thrust
Inward Thrust	Frontal
Outward Thrust	Lateral
Dimension	Length: 20 m
	Width: 6 m
Capacity	30T/hr
Fuel	Natural gas

The furnace will be equipped with the following services for billet movement:

Transfer loader servicing furnace loading
Load thrust group
Furnace unloader with slidable cart

b) Roughing Mill

Composed of:

Billet hauler servicing furnace exit
1 trio roughing stand with 500 mm roll diameter and 1500 mm table

c) Preparation Mill

Composed of:

5 duo stands of 350 mm in diameter and 800 mm table, arranged in line

d) First Finishing Mill

Composed of:

Flywheel shears with rotating knives for hot shearing.
Six horizontal two-high rolling groups with 260 Ø rolls and 500 mm table with independent controls, arranged continuously with stands appropriate for mounting cylinders on bearings

e) First finisher and cooling services

Composed of:

Roller outler track
Cooloown table of the galloping panel type, size 62 m x 8 m, with regulatable velocity according to the size of the product equipped with 6 disc saws mounted over the measurement cutting carriage
Two finishing straighteners
Finished products packing section

f) Second Finisher Group

Number of stands	7
Roll diameter	180 mm
Distance between rolls	635 mm
Operation	. direct current motor of 750 kw
Regulation	Synchronic

Flywheel Shear for hot
cropping
Water cooler and coil former
Coiler with mechanical thruster
Spool transporter

4.2.4 Raw Materials

The foressen total raw material consumption is provided on table 4.3 broken down each productive unit.

It is preferible to provide the consumption of reposition water separately. This is given in table 4.4.

4.2.5 Energy

Electrical energy and fuel consumption (fuel-oil, diesel-oil, natural gas in Santa Cruz) are indicated in tabla 4.5. for each fuel the left column indicates the kilocalories consumption per produced ton. The middle column provides the total annual consumption in thousands of kilocalories, and the right one the annual consumption in tons of fuel-oil or in ft^3 for natural gas. The diesel-oil consumption is given only in liters.

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TABLE 4.3

Plant Consumptions (Except Water and Energy)

Consumption / Productive Unit	Lump ore	Timber	Gross Charcoal	Net Char-coal	Limestone	Lime	Quartzite	Fluorite
Mining	--	--	--	--	--	--	--	--
Blast Furnace	86,256	346,094	49,442	39,554	2,803	--	1,962	--
LD Steel Shop	2,568	--	--	--	--	6,552	--	262
Continuous casting	--	--	--	--	--	--	--	--
Rolling Mill	--	--	--	--	--	--	--	--
Total	88,824	346,094	49,442	39,554	2,803	6,552	1,962	262
	Refractories	Manganese Ore	Ferro-Silicium	Ferro-Manganese	Scrap	Oxygen		
Mining	--	--	--	--	--	--		
Blast Furnace	56	1,401	--	--	1,904	--		
LD Steel Shop	321	--	578	449	11,243	3,595,760		
Continuous casting	183	--	--	--	--	18,300		
Rolling Mill	--	--	--	--	--	--		
Total	560	1,401	578	449	13,147	3,614,060		

Note: All solid products consumptions are stated in Mt/year
All gaseous consumptions are stated in Nm^3/year

TABLE 4.4

Water Consumption of the Plant (m^3)

Productive Unit	Consumption m^3/Mt	Total yearly Consumption m^3	Consumption m^3/hr
Mining and Concentration	0.44	69,021	29
Blast furnace	6.47	362,708.2	46
LD Steel Shop	1.5	96,315	12
Continuous casting	0.7	42,700	5
Rolling mill	1.5	82,500	21
Offices and W.C	0.25	13,750	2
Total	--	666,994.2	115

TABLE 4.5

Energy Consumption

Productive Unit	Electric Power		Natural Gas			Fuel-Oil			Diesel-Oil	
	Consumption Kwh/Mt	Total Consumption $x10^3$ kwh	Consumption 10^3 x Kcal/Mt.	Yearly Consumpt. 10^3 x Kcal	Yearly consumpt. 10^3 x Feet^3	Consumption 10^3 x kcal/Mt	Yearly Consumpt. $x10^6$ kcal	Yearly Consumption lts.	Consumption in lts/Mt	Total Yearly Consumption Litres
Mining and Concentration	3.4	510	--	--	--	--	--	--	1.70	255,000
Calcining	40	320	--	--	--	900	7,200	645,548	--	--
Blast Furnace	103	6,614	--	--	--	--	--	--	--	--
LD Steel Shop	40.3	2,588	--	--	--	87	5,586	500,838	--	--
Continuous Casting	10	610	--	--	--	25	1,525	136,730	--	--
Utilities and aux. services	250	13,750	--	--	--	--	--	--	--	--
Ligthing	55	3,025	--	--	--	--	--	--	--	--
Rolling Mill	75	4,125	600	33,000	116,000	--	--	--	--	--
Total	--	31,542	--	--	116,000	--	--	1,283,116	--	255,000

4.3 MANPOWER

4.3.1 General List of Work Positions for Alternative I

A description of each position is given below, as well as the number of workers who should fill it and their required category.

1) Charcoal Plant

Although the charcoal plant is not thought to be an integral part of the siderurgical plant, but rather a separate entity, below the work positions are given which have been considered for coal price calculation purposes. As can be seen, the charcoal has its own administration.

Administration

Manager	1	Superior
Administrative Manager	1	Superior
Executive Secretary	1	Technician
Bookkeeper	1	Technician
Personnel Department Manager	1	Technician
Secretaries	3	Qualified
Cleaning Services Forman	1	Non-qualified
Watchman	1	Non-qualified

Transport to siderurgical plant

Truck drivers	14	Semi-qualified
Helpers	14	Non-qualified

Coal Production

Department Chief	1	Superior
Battery foreman	15	Technician
Battery operators	16	Semi-qualified
Operator helpers	284	Non-qualified

Road construction and maintenance

Foreman	1	Technician
Caterpillar tractor operators	2	Qualified
Motor grader operator	1	Qualified
Helpers	17	Non-qualified

Electrical-mechanical maintenance

Maintenance and shop head	1	Technician
Electricians	2	Qualified
Mechanics	6	Qualified
Solderer	1	Qualified
Helpers	15	Non-qualified
Spare parts storeroom foreman	1	Qualified
Helpers	2	Semi-qualified

Forestry Regulation

Department Head	1	Superior
Assistant	1	Technician
Motorsawers for timber cutting and knocking down (6 months)	116	Semi-qualified
Helpers (6 months)	176	Non-qualified

Pinion-jointed haul tractor operators	13	Qualified
Helpers	13	Non-qualified
Charger tractor operators	9	Qualified
Agricultural trailer tractor operators	40	Semi-qualified
Helpers	40	Non-qualified

Silviculture

Department Head	1	Superior
Plantation assistant	1	Technician
Nursery assistant	1	Technician
Nursery tractor operators	2	Semi-qualified
Nursery helpers	1	Non-qualified
Ground preparation foremen	2	Semi-qualified
Workman for ground preparation (6 months)	1	Non-qualified
Workmen for bagging (6 months)	6	Non-qualified
Seed laboratory foreman	1	Technician
Cording and stripping tractor operators	5	Qualified
Scrape-plow tractor operators	8	Semi-qualified
Plantation workmen	11	Semi-qualified
Plantation workmen (6 months)	21	Non-qualified
Total Charcoal Plant	873	

2) <u>Mining, ore preparation and lime plant</u>

<u>Ore production</u>

Topographer's helper	1	Non qualified
Draughtsman	1	Qualified
Machine operators	3	Semi-qualified
Driver/tractor driver	6	Semi-qualified

<u>Preparation</u>

Control Room Operator	1	Master
Plant operator	2	Semi-qualified
Areal track Operator	2	Semi-qualified
Helpers	4	Non-qualified
Driver	1	Semi-qualified

<u>Limestone Operation</u>

Shovel operator	1	Semi-qualified
Perforator	2	Semi-qualified
Calcination operator	4	Semi-qualified
Helpers	8	Non-qualified
Trituration operator	1	Semi-qualified
Driver/tractor driver	2	Semi-qualified

<u>Area maintenance</u>

a) Electrical maintenance

Electrician	1	Qualified
Helper	1	Semi-qualified

b) Mechanical maintenance

Foreman	1	Master
Mechanic	2	Qualified
Solderer	1	Qualified
Helper	2	Semi-qualified
Total Mining	47	

3) Blast furnace and scrap vard

Operation

Blast furnace masters	4	Master
Blast furnace foremen	4	Qualified
Blast furnace operators	16	Semi-qualified
Blast furnace helpers	24	Non-qualified

Raw Material Yard

Raw material supervisors	4	Master
Raw material yard foremen	4	Qualified
Raw material yard helpers	16	Non-qualified
Absence coverage personnel	8	Qualified
Total Blast Furnace	80	

4) LD Steelworks

Scrap yard

Scrap yard foremen	4	Qualified
Helpers	12	Non-qualified

Converter Area

Converter operators	4	Qualified
Foremen	8	Qualified
Crane operators	12	Semi-qualified
Aides	8	Semi-qualified
Helpers	16	Non-qualified
Rapid action mechanics	4	Qualified
Absence coverage personnel	8	Non-qualified
Total Steelworks	80	

5) Continuous Casting

Casting Master	4	Master
Crane operator	4	Qualified
Spoon operator	4	Semi-qualified
Casting operator	8	Qualified
Billet removal helper	8	Non-qualified
Billet yard chief	4	Master
Billet yard helper	8	Non-qualified
Maintenance personnel	16	Qualified
Absence coverage personnel	8	Qualified
Total Continuous Casting	72	

6) Rolling mill and Finishing (in Santa Cruz)

Production

Reheating furnace chief	2	Master
Furnacemen	4	Qualified
Furnace loading and unloading helpers	4	Non-qualified

Rolling masters	2	Master
Laminators	8	Semi-qualified
Control Pulpit operators	8	Qualified
Hookers	6	Non-qualified
Saw operators	2	Semi-qualified
Crane operators	4	Qualified
Straightener operators	4	Semi-qualified
Packing and marking	6	Semi-qualified
Storeroom and Dispatch		
Helpers	8	Non-qualified
Absence Coverage Personnel	8	Qualified

Maintenance

Cylinder shop	4	Qualified
Greasers	4	Qualified
Machine room overseers	6	Qualified
Rapid action electricians	4	Qualified
Rapid action mechanics	4	Qualified
Total Rolling mill	88	

7) Maintenance

Mechanical Maintenance

Shop foreman	6	Master
Mechanic	7	Qualified
Mechanic	7	Semi-qualified
Auto mechanic	4	Qualified
Adjuster mechanic	2	Qualified
Fitter mechanic	2	Qualified
Hydraulic mechanic	1	Qualified

Greasers	3	Semi-qualified
Greaser/vehicle washing	2	Qualified
Wheel changing mechanic	1	Qualified
Boilerman	3	Qualified
Solderer	5	Qualified
Forger	1	Qualified
Turner	2	Qualified
Cutter	1	Qualified
Rectifier	1	Qualified
Tracer	1	Qualifier
Driller	1	Qualifier
Tool Foreman	1	Semi-qualified
Tool Sharpener	1	Non-qualified
Helpers	15	Non-qualified
	67	

Electrical Maintenance

Shop foreman	1	Master
Instrumentation electro-technician	1	Master
Electrotechnicians	4	Qualified
Electricians	6	Qualified
Fitting electrician	2	Qualified
Spooler	1	Qualified
Instrument technician	1	Semi-qualified
Helpers	6	Non-qualified
	22	

General Maintenance

Bricklayer	2	Semi-qualified
Carpenter	1	Qualified
Helper	3	Non-qualified
Total Maintenance	95	

8) Systems Operation

Water

Operation supervisor	1	Master
Operator	4	Qualified
Intake opeation overseers	4	Semi-qualified

Oxygen

Plant foreman	1	Master
Operator	4	Qualified

Compressors

Foreman	1	Master
Opeator	4	Qualified

Steam Boiler

Foremen	1	Master
Operator	4	Qualified

Transport System

Foreman	1	Master
Piler Operator	4	Qualified
Driver	3	Qualified
Total Systems Operation	31	

9) Quality Control

Metallographic Tests Laboratory (in Mutún)

Analysis Foreman	4	Qualified
Sample preparation	8	Qualified
Aides	4	Semi-qualified
Helpers	8	Non-qualified
	24	

Physical Tests Laboratory (in Santa Cruz)

Tests and inspection foreman	3	Qualified
Sample preparation	3	Qualified
Helpers	6	Non-qualified
	12	
Total Laboratories	36	

10) Supplies

General Storage

Material Controller	1	Qualified
Reception Foreman	1	Qualified

Dispatch Foreman	3	Semi-qualified
Helpers	5	Non-qualified
Ferroalloy Warehouse		
Material Controller	4	Qualified
Helper	4	Non-qualified
Total Storage	18	

11) General Management

General Manager	1	Superior
Management Control Chief	1	Technician
Legal Adviser	1	Superior
Chief of Public Relations	1	Superior
Administrative Aides	3	Qualified
Total General Management	7	

12) Financial Management

Manager	1	Superior
Chief of Accounting Dept.	1	Superior
Accounting Technician	1	Technician
Insurance Technician	1	Technician
Administrative Aide	3	Qualified
Chief of Financial-Economic Department	1	Superior
Budget Chief	1	Superior
Cost Control Chief	1	Superior
Billing Chief	1	Technician

Accountant's Aide	2	Semi-qualified
Administrative Aide	2	Qualified
Total Financial Management	15	

13) Supply Management

Supply Manager	1	Superior
Purchase Manager	1	Superior
Buyer	2	Technician
Administrative Aide	2	Qualified
Storeroom Chief	1	Superior
Storeroom Foreman	1	Technician
Ferroalloy Storeroom Foreman	1	Technician
Finished products and quality control chief	1	Superior
Physical tests laboratory chief	1	Superior
Metallographer	1	Technician
Product controller	1	Qualified
Loading and unloading foreman	2	Master
Helpers	4	Non-qualified
Administrative Aide	3	Qualified
Total Supply Management	22	

14) Engineering and Operations Management

Manager	1	Superior
Secretary	1	Technician
Planning Chief	1	Superior
Programmer	1	Technician
Administrative Aide	2	Qualified
Chief of mine working	1	Superior
Administrative Aide	1	Qualified

Mineral Working Technician	1	Technician
Topographer	1	Technician
Limestone working Technician	1	Technician
Mineworks mechanical maintenance supervisor	1	Technician
Mineworks electrical maintenance supervisor	1	Technician
Blast furnace superintendent	1	Superior
Raw materials chief	1	Superior
Reduction chief	1	Superior
Operation supervisor	1	Technician
Raw material yard supervisor	1	Technician
Administrative aide	1	Qualified
Steelworks superintendent	1	Superior
Converter chief	1	Superior
Casting chief	1	Superior
Metallographic tests laboratory chief	1	Superior
Metallographer	1	Technician
Systems operation chief	1	Technician
Converter supervisor	4	Technician
Continuous casting chief	1	Superior
Continuous casting supervisor	1	Technician
Rolling mill superintendent	1	Superior
Rolling mill chief	1	Technician
Total Engineering and Operations management	33	

15) Maintenance Management

Manager	1	Superior
Mechanical Maintenance Chief	1	Superior

Electrical and instrumentation maintenance chief	1	Superior
Metallurgical area mechanical maintenance supervisor	1	Technician
Central workshop mechanical maintenance supervisor	3	Technician
Vehicle workshop mechanical maintenance superivosr	1	Technician
Metallurgical area electrical maintenance supervisor	3	Technician
Instrument electrical maintenance supervisor	1	Technician
Programmer	2	Qualified
Designer	2	Qualified
Administrative Aide	2	Qualified
Total Maintenance Management	18	

16) <u>Commercial and Sales Management</u>

Manager	1	Superior
Commercial Agent in Santa Cruz	1	Technician
Commercial Agent in La Paz	1	Technician
Comercial Agent in Cochabamba	1	Technician
Comercial Agent in Oruro	1	Technician
Administrative Aide	5	Qualified
Total Commercial Management	10	

17) <u>Administrative Management</u>

Manager	1	Superior
Secretary	1	Technician
General Services Chief	1	Technician

Telephone Operator	5	Semi-qualified
Telex operator	4	Semi-qualified
Office boy	2	Non-qualified
Fire fighting service chief	2	Qualified
Cleaning Service/Garden and Street Maintenance Chief	1	Qualified
Safety Chief	1	Technician
Administrative Aide	1	Qualified
Watchmen and Personnel Control	11	Semi-qualified
Kitchen supervisor and nutrition expert	1	Technician
Head cook	1	Qualified
Helpers	2	Non-qualified
Chief of personnel	1	Superior
Personnel Administration Chief	2	Technician
Human Relations Chief (psychologist)	1	Superior
Paymaster	1	Technician
Cashier	2	Qualified
Administrative aides	6	Qualified
Doctor	1	Superior
Work safety and hygiene engineer)	1	Superior
Administrative aide	1	Qualified
Sanitary technique aides	2	Technician
Total Administrative Management	53	

The total of employment post created by the iron and steel plant and mine works (Alternative I) amounts to 705, the summary of which by categories in each productive unit is provided on Table 4.6.

TECNIBERIA

TABLE 4.6

Jobs Summary (Alternative I)

Qualification / Working Area	Superior	Technician	Master	Qualified	Semi-qualified	Non Qualified	Total
Mining, ore preparation and lime plant	1	5	2	6	27	13	54
Blast furnace and scrap yard	3	2	8	17	16	40	86
LD Steel Shop	3	4	--	24	20	36	87
Continuous casting	1	1	8	44	4	16	74
Rolling Mill	1	1	4	46	20	18	90
Maintenance	2	9	8	48	14	25	106
System operation	--	1	5	22	4	--	32
Quality control	2	2	--	18	4	14	40
Supply	1	2	--	6	3	9	21
General management	3	1	--	3	--	--	7
Financial management	5	3	--	5	2	--	15
Supply management	3	2	2	6	--	4	17
Engineering and operations management	2	2	--	2	--	--	6
Maintenance management	1	--	--	6	--	--	7
Marketing management	1	4	--	5	--	--	10
Administrative management	5	9	--	14	20	5	53
Total	34	48	37	272	134	180	705

4.3.2 General Listing of Job Positions for Alternative III

1) Rolling Mill Direct Manpower

a) Production

Preheating Furnace Foreman	2	Master
Furnace Operators	4	Qualified
Furnace Loading & unloading helpers	4	Non-qualified
Rolling Mill Foremen	2	Master
Rolling Mill Operators	8	Semiqualified
Control Pulpit Operators	6	Qualified
Hookmen	6	Non-qualified
Sawing Shear Operators	2	Semiqualified
Crane Men	4	Qualified
Straightener Operators	4	Semiqualified
Packaging & Labelling Men	6	Semiqualified
Warehouse & Shipping Helpers	8	Non-qualified
Absence Coverage Personnel	8	Qualified
	66	

b) Maintenance

Roll shop	4	Qualified
Grease & Oil Gunners	4	Qualified
Control Room Watchmen	6	Qualified
Fast Action Electrician	4	Qualified
Fast Action Engineer	4	Qualified
	22	

c) Laboratory

Chemical Analyst	1	Master
Testing Men and Inspectors	3	Qualified
Sampler	3	Qualified
Helpers	8	Non-qualified
	15	

2) Mining Manpower

a) Mining

Machine Operators (Eng.) (Tractor shovel & Bulldozer)	3	Semiqualified
Drivers (3 dumpers, 1 van, 1 jeep, 1 crane truck	6	Semiqualified
Surveyor Helper	1	Non-qualified
Draftsmen	1	Qualified
	11	

b) Crushing & Sieving Plant

Control Room Operator	1	Master
Plant Operator	2	Semiqualified
Cable Track Operator	2	Semiqualified
Helpers	4	Non-qualified
Driver (Fines & thick gravel evacuation)	1	Semiqualified
	10	

c) Machinery & Facilities Experience

Mechanist or engineer	1	Qualified
Welder	1	Qualified
Electrician	1	Qualified
Helpers	2	Semiqualified
	5	

d) Laboratory

Analyst	2	Master
Helper	4	Semiqualified
	6	
Direct Manpower Total	135	

3) Administration

a) Overall Management

General Manager	1	Superior
Legal Advisor	1	Superior
Administrative Aids	1	Qualified

b) Financing Management

Manager	1	Superior
Accountant	1	Technician
Accountant Aids	1	Qualified
Administrative Aids	2	Qualified

c) Engineering & Operating Management

Rolling Mill Manager	1	Superior
Mining Manager	1	Superior
Mining Technician	1	Technician
Surveyor	1	Technician
Mining Mechanical Maintenance Supervisor	1	Technician
Mining Electrical Supervisor	1	Technician
Administrative Aids	2	Qualified

d) Quality Control Management

Quality Control Manager	1	Superior
Mutun Laboratory Supervisor	1	Technician
Santa Cruz Laboratory Supervisor	1	Technician

e) Commercial & Sales Management

Manager & Sales Coordinator	1	Technician
Commercial Agent in Santa Cruz	1	Technician
Commercial Agent in La Paz	1	Technician
Commercial Agent in Cochabamba	1	Technician
Commercial Agent in Oruro	1	Technician
Administrative Aids	5	Qualified

f) Administrative Management

Manager	1	Technician
Telephone Operator	2	Semiqualified
Telex Operator	2	Semiqualified
Sanitarian	2	Technician
Watchmen & Personnel Control	8	Semiqualified
Cashier	2	Qualified
Total Administration	46	

Total number of jobs in Alternative III is 181 with a breakdown by categories as shown in table 4.7.

4.3.3 Local Personnel

It is considered that with an adequate training program all the operative personnel can be Bolivian, under the advisory of foreign technicians during the first three years of plant operation.

4.3.4 Foreign Experts

During the first three working years it has been deemed necessary to have the technical assistance provided by the suppliers of the principal equipment, the blast furnace, steelworks, continuous casting, as well as assesorship in the management of the company. The foreign technician requirements during the first three years have been figured to be eight persons for Alternative I and two for Alternative III.

4.3.5 Training Programs

The training criteria will be the following:

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TABLE 4.7

Jobs Summary
Alternative III

Qualification / Working Area	Superior	Technician	Master	Qualified	Semiquali-fied	Non qualified	Total
Mining	1	5	3	5	20	5	39
Rolling Mill	1	1	5	58	20	26	111
Management & Administration	4	9	-	6	12	-	31
Total	6	15	8	69	52	31	181

For the shift chiefs of each productive unit - six months' training in a similar plant in the position they are to later occupy.

For the operation supervisors and unit chiefs, three months's training in the above-mentioned conditions.

Subsequently, and before plant start-up, theoretical courses and maintenance personnel, which will be completed by practical training during the assembly and start-up period.

Once the start-up period has ended, the training phase will continue for two more months, with the aide of the engineering firm that carries out the plant project and the principal equipment suppliers.

4.4 INFRAESTRUCTURE

4.4.1 Means of Transport Necessary

The means of transport on which the functioning of the plant has been based are:

- Cable-carrier for transporting mineral to siderurgical plant.
- Truck to transport coal from bunkers to the plant.
- Railway for billet transport from Mutún to Santa Cruz or from border (argentinian) to Santa Cruz.

We wish to point out here that while for the mining investments study the cablecarrier has been considered as the means of transportation, belt transport could also be thought of as an alternative means. Among the studies which the "Compañía Minera del Oriente" must perform prior to the installation of the siderurgical plant one should be a comparison of the two alternatives both in investment and cost operation terms.

4.4.2 New Highways, Railways and Fluvial Ports

No work is considered necessary to add to those existing, although:

- It is of interest that the fluvial port project at Port Quijarro be developed in order to obtain greater agility both in mineral exportation as well as in refractory and other insumption products import.

- The construction by the ENFE of a railway terminal u to the siderurgical plant would be very recommendable, for it wou enormously facilitate the billet transport/loading/unloading process, instead of having to take it to Puerto Suárez by truck and then transport it to the railroad.

- ENFE should perform systematic maintenance on the Puerto Suárez-Santa Cruz line and repair several stretches which are presently in very bad condition.

4.4.3 Electrical Power Network, Natural Gas, Water, etc.

As has been said, electrical energy will be imported from Brazil, not only for the obvious reason that theses lines are geographically closer than the Bolivian ones, but also because it is cheaper.

The electrical energy auto generation solution is not considered necessary for the project.

With the rolling mill plant located in Santa Cruz no natural gas network is necessary, for one already exists in the "Parque Industrial de Santa Cruz". In addition the transport of more than 3,000,000 liters of fuel-oil per year to Mutún is avoided, apart from contributing to an increase in safety at the plant.

As to the water network, the plant's consumption (see table 4.4) amply allows supply from the San Juan River. A pipe-line would run from the river intake pumphouse to the siderurgical plant.

4.5 FINANCING-ECONOMIC STUDY

4.5.1 Preliminary Observations

The financial-economic study is focused so as to determine in the last instance the investment and equity yield and in therefore leadas to two net cash-flow statements, one for each case, for in the analysis of the global investment yield naturally one mus considerer in abstract the fund provider are financed totally by one's own funds. On the other hand, for the equity yield analysis, alternate financial source are considered with their price and corresponding rate.

4.5.2 Investments

1) Total Sum of Investments

The real investment in terms of fixed assets amounts to US$ 59,722,300, for Alternative I and US$ 19,539,200 for Alternative III with the following breakdown in US$ x 10^3:

	Alt. I US$ x 10^3	Alt. III US$ x 10^3
Investments Common to All Units	16,352.4	--
Mining	5,585.5	5,585.5
Limestone Calcinating	1,043	--
Blast Furnace	8,407	--
LD Converter and O_2 Plant	10,273	--
Continuous Casting	4,107.7	--
Rolling Mill	13,953.7	13,953.7
Total	59,722.3	19,539.2

Note:

For Alt. III common investments (utilities) are not required, as existing utilities in the Mine and in the Parque Industrial de Santa Cruz will be used.

In table 4.8 the general breakdown of said investments for Alt. I has been summarized. Those corresponding to the productive sections proceed from the previous chapter. The common investments have also been estimated for auxiliary units utilities, administration buildings urbanization and regional support units.

In tables 4.9 & 4.10, said investments have been broken down into national and foreign origin, thus obtaining the following:

	Alternative I		Alternative III	
Origin	%	US$ x 10^3	%	US$ x 10^3
National	22	13,129	16	3,218.3
Foreign	78	46,543.3	84	16,320.9
	100	59,722.3	100	19,539.2

2) Payment Schedule

For operative effects the years in which the plant is under construction are indicated with a negative sign (-3 to -1) and the years in which it is already in operation with a positive sign.

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TABLE 4.8

Investments Summary (x 10^3 US $)

Item	Mining	Calci-ning	Blast Furnace	O_2 Plant + LD Converter	Contin. Casting	Rolling Mill	Auxiliary Units	Administration & urban development	Regional backing units	Total
Previous studies and research	250	25	--	--	--	--	--	--	--	275
Bays and buildings (1)	469	71	--	1,016	445.5	1,641.6	1,830	1,510	6,000	12,983.1
Equipment (2)	2,765	545	5,588	3,648	1,710	7,730	1,740	50	1,915	25.691
Cranes	--	--	--	770	730	330	--	--	--	1,830
Utilities	536	94	290	2,598	303	869	--	10	15	4,715
Spare parts	138	28	126	198	91.5	205	90	5	96	977.5
Transport., insurance & taxes	517	100	324	358	144.3	850.5	225	3.5	100	2,622.3
Subtotal	4,675	863	6,328	8,588	3,424.3	11,626.1	3,885	1,578.5	8,126	49,093.9
Erection and start-up	211	42	568	311	121	585	280	1	7	2,126
Personnel training	17	4	121	172	75	115.5	106	--	--	610
Engineering	215	47.5	758	344	145	465	665	100	245	2,984.5
Contingencies	467.5	86.5	632	858	342.4	1,162.6	338.5	157.8	812.6	4,907.9
Total	5,585.5	1,043	8,407	10,273	4,107.7	13,953.7	5,324.5	1,837.3	9,190.6	59,722.3

(1) Carbon steel section structure, foundations, closing walls and roofs included
(2) Equipment foundations (except for mining and calcining) included

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TABLE 4.9

Investments Break Down by Origins
(Alternative I)

Item	Origin				Total	
	National		Foreign			
	%	x 10^3 US $	%	x 10^3 US $	%	x 10^3 US $
Previous Studies	50	137.5	50	137.5	100	275.0
Bays	60	7,789.9	40	5,193.2	100	12,983.1
Equipment (1)	10	2,569.1	90	23,121.9	100	25,691
Cranes	--	--	100	1,830	100	1,830
Utilities	15	707.2	85	4,007.8	100	4,715
Spare parts	--	--	100	977.5	100	977.5
Transportation insurance and taxes	2	52.4	98	2,569.9	100	2,622.3
Subtotal	23	11,256.1	77	37,837.8	100	49,093.9
Erection and start-up	35	744.1	65	1,381.9	100	2,126
Personnel training	--	--	100	610.5	100	610.5
Engineering	--	--	100	2,984.5	100	2,984.5
Contingencies	23	1,128.8	77	3,779.1	100	4,907.9
Total	22	13,129.0	78	46,593.3	100	59,722.3

(1) Foundations (except for mining) included

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TABLE 4.10

Investments Breakdown by Origins
(Alternative III)

Item	Origin				Total	
	National		Foreign			
	%	x 10^3 US $	%	x 10^3 US $	%	x 10^3 US $
Previous Studies	50	125	50	125	100	250
Bays	60	1,266.4	40	844.2	100	2,110.6
Equipment (1)	10	1,049.5	90	9,445.5	100	10,495
Cranes	--	--	100	330	100	330
Utilities	15	210.7	85	1,194.3	100	1,405
Spare parts	--	--	100	343	100	343
Transportation insurance and taxes	2	27.3	98	1,340.2	100	1,367.5
Subtotal	16	2,678.9	84	13,622.2	100	16,301.1
Erection and start-up	35	278.6	65	517.4	100	796
Personnel training	--	--	100	132	100	132
Engineering	--	--	100	680	100	680
Contingencies	16	260.8	84	1,369.3	100	1,630.3
Total	16	3,218.3	84	16,320.9	100	19,539.2

(1) Foundations (except for mining) included

Keeping in mind the orientative schedule included in section 4.6, tables 4.11 & 4.12 have been prepared as a payment schedule, for Alt.I & III respectivelly on the usual supplier conditions and without financing on their side. The summary of the mentioned tables of real investment payment in fixed assets is a follows for both alternatives:

Investement US$ x 10^3

Year	Alternative I	Alternative III
-3	10,925.2	3,210.2
-2	20,489.5	5,164.1
-1	21,436.1	7,815.7
1	6,871.5	3,349.2
Total	59,722.3	19,539.2

4.5.3 Fixed Assets Financing

1) Financing Sources

From tables 4.9 & 4.10, an investment breakdown is obtained of US$ 13,129,000/3,218,300 of national and US$ 46,593,300/16,320,900 of foreign origin for Alt. I & III respectively.

In the preparatory meeting for the Ferro-Mining-Siderurgical Sector, Bolivian-Argentinian Commission, the Argentinian representative indicated that they could and were willing to finance the project for a total of 95% of the Argentinian exports. Therefore the following financing sources are considered:

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TABLE 4.11

Investments Payment Schedule
Alternative I

Item	Years								Total	
	-3		-2		-1		+1			
	%	10^3 US $	%	10^3 US $	%	10^3 US $	%	10^3 US $	%	10^3 US $
Common	25	4,088.1	50	8,175.2	25	4,088.1	--	--	100	16,352.4
Mining and calcining	20	1,325.7	30	1,988.8	40	2,651.4	10	662.8	100	6,628.5
Blast furnace	15	1,261.1	30	2,522.1	40	3,362.8	15	1,2621.0	100	8,407.0
LD Steel shop	15	1,541.0	30	3,081.9	40	4,109.2	15	1,540.9	100	10,273.0
Continuous casting	15	616.2	30	1,232.3	40	1,643.1	15	616.1	100	4,107.7
Rolling mill	15	2,093.1	25	3,488.4	40	5,581.5	20	2,790.7	100	13,953.7
Total	18	10,952.2	34	20,489.5	36	21,436.1	12	6,871.5	100	59,722.3

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TABLE 4.12

Investments Payment Schedule
Alternative III

Item	Years								Total	
	-3		-2		-1		+1			
	%	10^3 US $	%	10^3 US $	%	10^3 US $	%	10^3 US $	%	10^3 US $
Mining	20	1,117.1	30	1,675.7	40	2,234.2	10	558.5	100	5,585.5
Rolling Mill	15	2,093.1	25	3,488.4	40	5,581.5	20	2,790.7	100	13,953.7
Total	16	3,210.2	26	5,164.1	40	7,815.7	17	3,349.2	100	19,539.2

	Financing US$ 10^3	
	Alt. I	Alt. III
Credit (95% of foreign investiments)	44,263.6	15,504.9
Equity (balance)	15,458.7	4,034.3
Total	59,722.3	19,539.2

The following conditions applicable to both alternatives are considered for credit:

Interest rate: 8% per year over pending balance

Grace period: 4 yrs

Repayment: In the ten subsequent years, in 20 equal installments (half-yearly), the first of which reaches maturity six months after the grace period.

2) Interests

Working under the above mentioned hypothesis, tables 4.11 & 4.14 have been obtained. They include: loan agreement and repayment dates; debit balances at the beginning, during and at the end of every half-year period; period interests.

The interests of the construction years (years -3 to -1 have been attributed to interpolated interests, increasing the real investment for amortization purposes. They amount US$ 4,07 million for alternative I and US$ 12,5 million for alternative III.

TABLE 4.13 Sheet 1

Availability, Return, and Interests of the Credits for Fixed Assets (x 10^3 US $)
(Alternative I)

Year	Half yearly payment	Availability (1st day of the period)	Return (Last day of the period)	Debit balance at the begining and during the period)	Debit balance at the end of the period	Interests of the period
- 3	1 2	-- 8,095.6	-- --	-- 8,095.6	-- 8,095.6	-- 323.8
- 2	1 2	-- 15,182.7	-- --	8,095.6 23,278.3	8,095.2 23,278.3	323.8 931.1
- 1	1 2	- 15,884.2	-- --	23,278.3 39,162.5	23,278.3 39,162.5	931.1 1,566.5
1	1 2	-- 5,101.1	-- --	39,162.5 44,263.6	39,162.5 44,263.6	1,566.5 1,770.5
2	1 2	-- --	-- 2,213.0	44,263.6 44,263.6	44,263.6 42,050.6	1,770.5 1,770.5
3	1 2	-- --	2,213.2 2,213.2	42,050.6 39,837.4	39,837.4 37,624.2	1,682.0 1,593.5
4	1 2	-- --	2,213.2 2,213.2	37,624.2 35,411.0	35,411.0 33,197.8	1,505.0 1,416.6
5	1 2	-- --	2,213.2 2,213.2	33,197.8 30,984.6	30,984.6 28,771.4	1,327.9 1,239.4
6	1 2	-- --	2,213.2 2,213.2	28,771.4 26,558.2	26,558.2 24,345.0	1,150.9 1,062.3

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TABLE 4.13

Sheet 2

Disposition, Return, and Interests of the Credits for fixed Investments (x 10^3 US $)
(Alternativa I)

Year	Half yearly payment	Availability (1st day of the period)	Return (Last day of the period)	Debit balance at the begining and during the period)	Debit balance at the end of the period	Interests of the period
7	1	--	2,213.2	24,345.0	22,131.8	973.8
	2	--	2,213.2	22,131.8	19,918.6	885.3
8	1	--	2,213.2	19,918.6	17,705.4	796.7
	2	--	2,213.2	17,705.4	15,492.2	708.2
9	1	--	2,213.2	15,492.2	13,279.0	619.7
	2	--	2,213.2	13,279.0	11,065.8	531.2
10	1	--	2,213.2	11,065.8	8,852.6	442.6
	2	--	2,213.2	8,852.6	6,639.4	354.1
11	1	--	2,213.2	6,639.4	4,426.2	265.6
	2	--	2,213.2	4,426.2	2,213.0	177.0
12	1	--	2,213.0	2,213.0	--	88.5
	2	--	--	--	--	--
Total		44,263.6	44,263.6	--	--	27,774.6

To pre-production capital expenditures (interpolated interests) 4,076.3
To financing costs 23,698.3

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TABLE 4.14

Sheet 1

Availability, Return, and Interests of the Credits for Fixed Assets (x 10^3 US $)
(Alternative III)

Year	Half yearly payment	Availability (1st day of the period)	Return (Last day of the period)	Debit balance at the begining and during the period)	Debit balance at the end of the period	Interests of the period
- 3	1	--	--	--	--	--
	2	2,547.4	--	2,547.4	2,547.4	101.9
- 2	1	--	--	2,547.4	2,547.4	101.9
	2	4,097.9	--	6,645.3	6,645.3	265.8
- 1	1	--	--	6,645.3	6,645.3	265.8
	2	6,202.0	--	12,847.3	12,847.3	513.9
1	1	--	--	12,847.3	12,847.3	513.9
	2	2,657.6	--	15,504.9	15,504.9	620.2
2	1	--	--	15,504.9	15,504.9	620.2
	2	--	775.3	15,504.9	14,729.6	620.2
3	1	--	775.2	14,729.6	13,954.4	589.2
	2	--	775.3	13,954.4	13,179.1	558.2
4	1	--	775.2	13,179.1	12,403.8	527.2
	2	--	775.3	12,403.8	11,628.6	496.2
5	1	--	775.2	11,628.6	10,853.3	465.1
	2	--	775.3	10,853.3	10,078.1	434.1
6	1	--	775.2	10,078.1	9,302.8	403.1
	2	--	775.3	9,302.8	8,527.6	372.1

TABLE 4.14 Sheet 2

Disposition, Return, and Interests of the Credits for fixed Investments (x 10^3 US $)
(Alternativa III)

Year	Half yearly payment	Availability (1st day of the period)	Return (Last day of the period)	Debit balance at the begining and during the period)	Debit balance at the end of the period	Interests of the period
7	1	--	775.2	8,527.6	7,752.3	341.1
	2	--	775.3	7,752.3	6,977.1	310.1
8	1	--	775.2	6,977.1	6,201.8	279.1
	2	--	775.3	6,201.8	5,426.1	248.1
9	1	--	775.2	5,426.1	4,651.3	217.0
	2	--	775.3	4,651.2	3,876.1	186.1
10	1	--	775.2	4,876.1	3,100.8	155.0
	2	--	775.3	3,100.8	2,325.6	124.0
11	1	--	775.2	2,325.6	1,550.3	93.0
	2	--	775.3	1,550.3	775.1	62.0
12	1	--	775.1	775.1	--	31.0
	2	--	--	--	--	--
Total		15,504.9	15,504.9	--	--	9,484.5

To pre-production capital expenditures (interpolated interests) 1,249.3
To financing costs 8,235.2

The balance of the interests are attributed to the operating accounts of the various accounting periods, amounting to US$ 23,7 million for alternative I and US$ 1,25 million for alternative III.

3) Summary of Investment and Financiancing of Fixed Assets

According to the previous sections, the total investment in fixed assets amounts -depending of Alternatives- as follows:

	Investment US$ x 10^3	
	Alt. I	Alt. III
Equity	59,722.3	19,539.3
Interpolated interests	4,076.3	1,249.2
Total	63,798.6	20,788.5

This investment will be financed the following way:

	Alternative I		Alternative III	
Origin	%	US$ x 10^3	%	US$ x 10^3
Equity	30.6	19,532.0	25.4	5,283.6
Credit	69.4	44,263.6	74.6	15,504.6
	100	63,798.3	100	20,788.5

More details about these two concepts, including the yearly schedule, may be found in tables 4.15 & 4.16.

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TABLE 4.15

Payment and Financing Resources schedule for Total Fixed Assets
(Alternative I)

So	Year -3		Year -2		Year -1		Year 1		Total	
	%	10^3 US $	%	10^3 US $	%	10^3 US $	%	10^3 US $	%	10^3 US $
A. Effective Asset										
- Equity	25.9	2,829.6	25.9	5,306.8	25.9	5,551.9	25.9	1,770.4	25.9	15,458.7
- Credits	74.1	8,095.6	74.1	15,182.7	74.1	15,884.2	74.1	5,101.1	74.1	44,263.6
Total A.	100.0	10,925.2	100.0	20,489.5	100.0	21,436.1	100.0	6,871.5	100.0	59,722.3
B. Interpolated interests										
- Equity	100.0	323.8	100.0	1,254.9	100.0	2,497.6	--	--	100.0	4,076.3
C. Total Fixed Assets										
- Equity	28.0	3,153.4	30.2	6,561.7	33.6	8,049.5	25.9	1,770.4	30.6	19,535.0
- Credits	72.0	8,095.6	69.8	15,182.7	66.4	15,884.2	74.1	5,101.1	69.4	44,263.6
Total C.	100.0	11,249.0	100.0	21,744.4	100.0	23,933.7	100.0	6,871.5	100.0	63,798.6

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TABLE 4.16

Payment and Financing Resources schedule for Total Fixed Assets
(Alternative III)

Sources	Year -3		Year -2		Year -1		Year 1		Total	
	%	10^3 US $	%	10^3 US $	%	10^3 US $	%	10^3 US $	%	10^3 US $
A. Effective Asset										
- Equity	20.6	662.8	20.6	1,066.2	20.6	1,613.7	20.6	691.6	20.6	4,034.3
- Credits	79.4	2,547.4	79.4	4,097.9	79.4	6,202.0	79.4	2,657.6	79.4	15,504.9
Total A.	100.0	3,210.2	100.0	5,164.1	100.0	7,815.7	100.0	3,349.2	100.0	19,539.2
B. Interpolated interests										
- Equity	100.0	101.9	100.0	367.7	100.0	779.7	--	--	100.0	1,249.3
C. Total Fixed Assets										
- Equity	23.1	764.7	25.9	1,433.9	27.8	2,393.4	20.6	691.6	25.4	5,283.6
- Credits	76.9	2,547.4	74.1	4,097.9	72.2	6,202.0	79.4	2,657.6	74.6	15,504.9
Total C.	100.0	3,312.1	100.0	5,531.8	100.0	8,595.4	100.0	3,349.2	100.0	20,788.5

4.5.4 Sales and Revenue Schedule

The following sales schedule is foreseen for the rolling products sold within the country, as well as for the excess of calibrated iron ore to be exported:

		Rolling (t/y)	Iron ore (t/yr.)	
Year	%	Alt. I & III	Alt I	Alt. III
1	50	27,500	31,900	75,000
2	70	38,500	44,600	105,000
3	80	44,000	51,000	120,000
4 and subsequent	100	55,000	63,800	150,000

Refering to sales prices and taking into consideration the FOB International Market price US$ 400/Mt for the type of rolled products here analyzed, two levels of prices are selected: US$ 450 & US$ 500/Mt of rolled product - i.e imported rolled product in Bolivia - on the assumption of a reduction, already applied, of 4% for commercial expenses and Bank discount on invoices.

Both level of sales prices above selected, stay at a level well below the average retail price in Santa Cruz on Feb. 1985 - US$ 591.70/Mt - and so the sensitivity studies on those bases are really based on more pessimistic conditions than the actual ones.

A sales price of US$ 14/t. is estimated for Mutun ore as considered by Unidad Promotora.

In the case of the export iron ore, commissions and commercial expenses of 11 % over FOB price are foreseen, equivalent to US$ 1.50/Mt. Transportation expenses to port of US$ 3.80/Mt are to be additionally considered so, final net revenue for Mutun ore is US$ 8.70/t.

Under these assumptions and identifying year 1 of the plant as 1989, table 4.12 has been set up. Expected revenue starts from US$ 15,8 millions on year 1 and reaches 31.79 millions from year 4 on.

4.5.5 Costs

Table 3.2.2 gives calculated rolling costs for both alternatives -excluding depreciation, overhead and financing costs- reaching a US$ 253.30/Tm for Alternative I and US$ 342.32/tm for Alternative III.

Overhead including non productive personnel costs (Managemente, top Technical personnel, Administration personnel, Utilities & Maintenance Personnel, etc) reach an ammount of US$ 1.11 million/year for Alternative I and of US$ 0.16 million/year for Alternative III.

Considering a project life of 15 years, for the depreciation a yearly amount of 2% has been estimated for year 1, and of 7% for the remaining years (2 to 15), considering both the real investment (effective asset) and the interpolated interests, a summary of which is given on Table 4.17

The interpolated interests should be written off in a shorter period with the subsequent light positive impact on the cash flow. The civil work, in turn, should follow at a slower pace, and at the end of 15 years, have a residual value of certain significance which would be recovered. None of the abovetwo items has been considered but only assuming that the plant is written off in 15 years, and no residual value will be recovered.

TABLE 4.17

Depreciation

	Alternative I	Alternative III
1. Effective assets (real investment) to depreciate	59,722.3	19,539.2
2. Year 1 depreciation (2% of 1)	1,194.4	390.8
3. Depreciation for years 2 to 15 (7% of 1)	4,180.6	1,367.7
4. Interpolated interests	4,076.3	1,249.3
5. Total assets to depreciate (1 + 5)	63,798.6	20,788.5
6. Year 1 depreciation (2% of 5)	1,276.0	415.8
7. Depreciation for years 2 to 15 (7% of 5)	4,465.9	1,455.2

Table 3.22 gives costs for a typical year. Taking into consideration the costs of said table and the US$ 2.5/Mt of sellable iron ore, the total costs with the complete staff of personnel -excluding financing expenses- would evolve the following way, in millions of U.S. dollars for alternatives I and III:

1) Alternative I

Item	Year 1	Year 2	Year 3	Balance years
Costs, except depreciation & overhead	7,240.8	10,137.1	11,585.2	14,481.5
Start up	384.0	384.0	384.0	-
Depreciation	1,276.0	4.465.9	4,465.9	4,465.9
Overhead	1,110.0	1,110.0	1,110.0	1,110.0
Total	10,010.8	16,097.0	17,545.1	20,057.4

2) Alternative III

Item	Year 1	Year 2	Year 3	Balance years
Costs, except depreciation & overhead	9,413.8	13,179.3	15,062.1	18,827.6
Start up	96.0	96.0	96.0	-
Depreciation	415.8	1.455.2	1,455.2	1,455.2
Overhead	155.1	155.1	155.1	155.1
Total	10,080.7	14.885,6	16,768.4	20,437.9

As start-up and assesment for adjustment costs during the first three years since commissioning, 8 and 2 respectively foreign advisers have been considered, with a cost of 4,000 US$ per person and month, for Alternative I and III.

4.5.6 Working Capital

1) Alternative I

Table 4.18 gives an estimate of the investment requirements in working capital for a typical year. The chart is self-explanatory, although it is necessary to point out that we have used international parameters interpreted in a very disfavorable way. With regard to the storage of raw materials, it is supposed that the yards will have in stock an average of 75% of its capacity, attributing the balance of column 1 in table 4.18 to transportation.

As it is assumed that on year 4 production reaches 100% of its nominal capacity, it should be also assumed that on year 3 (theoretically at year end), the necessary investment in working capital of US$ 1.8 million will have been reached, according to table 4.18 the purpose being to avoid creating large expense stresses at the beginning of that year 4.

The same reasoning is applicable to year 2 with respect to year 3, whereby it is supposed that 80% of the investment of table 4.18 is carried out in year 2. This assumption is exaggerated, given that in the first months of year 3, 80% of nominal capacity will not be reached, although this figure will indeed be achieved as an average during said year.

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TABLE 4.18

Investment in Working Capital in one Typical Year
(Alternative I)

Item	Months						US $	
	1 Transport and storage as raw material	2 Fabrication and storage as finished product	3 Sales and collection	4 = 1+2+3 Ribening period	5 Postponement of the payment to the suppliers	6 Period to be financied	7 Mounthly cost	8 = 6x7 Investment in working capital
Exterior scrap	0.75	2	0.50	3.25	3	0.25	120,514	30,128
Ferro alloys	2	2	0.50	4.50	3	1.50	41,669	62,503
Billets transport	-	2	0.50	2.50	1	1.50	376,167	564,250
Electric power	-	2	0.50	2.50	1	1.50	98,085	147,128
Fuel-oil	-	2	0.50	2.50	1	1.50	40,632	60,948
Natural Gas	-	2	0.50	2.50	1	1.50	14,500	21,750
Diesel-Oil	-	2	2.50	2.50	1	1.50	5,762	8,643
Refractories	2	2	0.50	4.50	3	1.50	56,007	84,010
Manpower	-	2	0.50	2.50	-	2.50	175,560	438,900
Maintenance	4	2	0.50	6.50	3	3.50	98,225	343,783
Overhead	-	2	0.50	2.50	-	2.50	--	--
Other Costs	2	2	0.50	4.50	2	2.50	17,193	42,982
Total	-	-	-	-	-	-	1,044,314	1,805,025

This overevaluation is up to a certain point compensated by not forseeing working capital investment in year -1 to begin production in year 1. In any case it should be kept in mind that the initial working capital requirements are very low since production will begin at a slow pace, although, afterwards, it will increase rapidly.

Corresponding to all the aforementioned, the working capital investment will be carried out following the schedule as follows:

Working capital investment (US$ x 10^3)

Year	Of year	Accumulated
1	902,513	902,513
2	361,005	1.263,518
3	541,507	1.805,025
4 and subsequent		1.805,025

It will not be necessary to use credit to finance the working capital, since generation of funds is already sufficient since the earlier year. In addition, it must be remenbered that invoicing is bank discounted, the corresponding cost having been charged under section 4.4 to the sales price in order to obtain the net revenue. Just due to the assumption of invoicing bank discount, the payment period included in table 4.18 is reduced to 0,5 months, which is estimated to be sufficient for the bureaucratic transaction of bank invoicing discount. In fact, it would be identical to delete this assumption, to increase the payment period, to obtain credit to finance the working capital, to enter the corresponding interest and then delete the section 4.4 items called commercial expenses, or to work under the assumption that has been considered.

TABLE 4.18

Investment in Working Capital in one Typical Year (Alternative I)

Item	Months						US $	
	1 Transport and storage as raw material	2 Fabrication and storage as finished product	3 Sales and collection	4 = 1+2+3 Maturing period	5 Postponement of the payment to the suppliers	6 Period to be financied	7 Mounthly cost	8 = 6x7 Investment in working capital
Exterior scrap	0.75	2	0.50	3.25	3	0.25	120,514	30,128
Ferro alloys	2	2	0.50	4.50	3	1.50	41,669	62,503
Billets transport	-	2	0.50	2.50	1	1.50	376,167	564,250
Electric power	-	2	0.50	2.50	1	1.50	98,085	147,128
Fuel-oil	-	2	0.50	2.50	1	1.50	40,632	60,948
Natural Gas	-	2	0.50	2.50	1	1.50	14,500	21,750
Diesel-Oil	-	2	2.50	2.50	1	1.50	5,762	8,643
Refractories	2	2	0.50	4.50	3	1.50	56,007	84,010
Manpower	-	2	0.50	2.50	-	2.50	175,560	438,900
Maintenance	4	2	0.50	6.50	3	3.50	98,225	343,783
Overhead	-	2	0.50	2.50	-	2.50	--	--
Other Costs	2	2	0.50	4.50	2	2.50	17,193	42,982
Total	-	-	-	-	-	-	1,044,314	1,805,025

2) Alternative III

Repeating here the same sequence followed in 1) above for Alternative I, and using Table 4.19, the following figures are obtained:

Working capital investment (US$ x 10^3)

Year	Of year	Accumulated
1	340,625	340,625
2	136,250	476,875
3	204,375	681,250
4 and subsequent		681,250

4.5.7 Profitability

1) Investment Yield

In order to measure investment yield, the Internal Rate of Return (IRR) has been calculated through the discount cash flow method.

As it is known, to calculate the IRR of the total investments one proceeds as if all the investments (wether speaking of fixed assets/working capital or any other item) were financed by one's own funds. Under this hypothesis, therefore, there are neither credits, nor interpolated interests, financing expenses, etc.

Tables 4.20 to 4.23 present the yearly cash flows under this assumption. It is considered that all items on those tables have been sufficiently explained in tne foregoing pages.

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TABLE 4.19

Investment in Working Capital in one Typical Year
(Alternative III)

Item	Months						US $	
	1 Transport and storage as raw material	2 Fabrication and storage as finished product	3 Sales and collection	4 = 1+2+3 Maturing period	5 Postponement of the payment to the suppliers	6 Period to be financied	7 Mounthly cost	8 = 6x7 Investment in working capital
Billets	0.75	2	0.50	3.25	3	0.25	1,575,704	393,962
Electric power	-	2	0.50	2.50	1	1.50	17,154	25,731
Natural Gas	-	2	0.50	2.50	1	1.50	15,675	23,512
Diesel-Oil	-	2	0.50	2.50	1	1.50	5,762	8,643
Manpower	-	2	0.50	2.50	-	2.50	29,360	73,400
Maintenance	4	2	0.50	6.50	3	3.50	22,275	77,963
Overhead	-	2	0.50	2.50	-	2.50	11,290	28,225
Other Costs	2	2	0.50	4.50	2	2.50	19,940	49,850
Total	-	-	-	-	-	-	1,697,160	681,250

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TABLE 4.20

Cash-Flow Without Financing (10^3 US$) (Alternative I) Sales Price US$ 450/Mt — IRR: 7.37%																		
Item / Years	-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. Outflow																		
1. Initial Fixed Investment	10,825.2	20,489.5	21,436.1	6,871.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Working capital	-	-	-	902.5	361.0	541.5	-	-	-	-	-	-	-	-	-	-	-	-
3. Total Outflow (1 + 2)	10,925.2	20,489.5	21,436.1	7,774.0	361.0	541.5	-	-	-	-	-	-	-	-	-	-	-	-
B. Inflow																		
4. Sales	-	-	-	12,652.5	17,713.0	20,243.7	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1
5. Costs except depreciat	-	-	-	8,734.8	11,631.1	13,079.2	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5
6. Depreciation	-	-	-	1,194.4	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6
7. Gross or taxable profit (4 - 5 - 6)	-	-	-	2,[illegible]	1,901.3	2,583.9	5,533.0	5,533.0	5,533.0	5,533.0	5,533.0	5,533.0	5,533.0	5,533.0	5,533.0	5,533.0	5,533.0	5,533.0
8. Tax	-	-	-	817.0	570.4	895.2	1,659.9	1,659.9	1,659.9	1,659.9	1,659.9	1.659.9	1,659.9	1,659.9	1,659.9	1,659.9	1,659.9	1,659.9
9. Net profit	-	-	-	1,906.3	1,330.9	2,088.7	3,873.1	3,873.1	3,873.1	3,873.1	3,873.1	3,873.1	3,873.1	3,873.1	3,873.1	3,873.1	3,873.1	3,873.1
10. Self-financing	-	-	-	3,100.7	5,511.5	6,269.3	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7
11. Working capital recovery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,805.0
12. Total Inflow (10 + 11)	-	-	-	3,100.7	5,511.5	6,269.3	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	9,858.7
C. Net cash flow (12 - 3)	-10925.2	-20489.5	-46737.3	5,150.5	5,727.8	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	8,053.7	9,858.7

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TABLE 4.21

Cash-Flow Without Financing (10^3 US$) (Alternative I) Sales Price US$ 500/Mt IRR:16.19																		
Item / Years	-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. Outflow																		
1. Initial Fixed Investment	10,925.2	20,489.5	21,436.1	6,871.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Working capital	-	-	-	902.5	361.0	541.5	-	-	-	-	-	-	-	-	-	-	-	-
3. Total Outflow (1 + 2)	10,925.2	20,489.5	21,436.1	7,774.0	361.0	541.5	-	-	-	-	-	-	-	-	-	-	-	-
B. Inflow																		
4. Sales	-	-	-	14,027.5	19,638.0	22,443.7	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1
5. Costs except depreciation	-	-	-	9,734.8	11,631.1	13,079.2	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5
6. Depreciation	-	-	-	1,194.4	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6	4,180.6
7. Gross or taxable profit (4 - 5 - 6)	-	-	-	4,098.3	3,826.3	5,183.9	8,283.0	8,283.0	8 283.0	8,283.0	8,283.0	8,283.0	8,283.0	8,283.0	8,283.0	8,283.0	8,283.0	8,283.0
8. Tax	-	-	-	1,229.5	1,147.9	1,555.2	2,484.9	2,464.9	2,484.9	2,484.9	2,484.9	2,484.9	2,484.9	2,484.9	2,484.9	2,484.9	2,484.9	2,484.9
9. Net profit	-	-	-	2,868.8	2,678.4	3,628.7	5,798.1	5,798.1	5,798.1	5,798.1	5,798.1	5,798.1	5,798.1	5,798.1	5,798.1	5,798.1	5,798.1	5,798.1
10. Self-financing	-	-	-	4,063.2	6,859.0	7,809.3	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7
11. Working capital recovery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,805.0
12. Total Inflow (10 + 11)	-	-	-	4,063.2	6,859.0	7,809.3	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9 978 7	11,783.7
C. Net cash flow (12 - 3)	-10925.2	-20489.5	-21436.1	-3,710.8	6,498.0	7,267.8	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,978.7	9,97- 7	9,978.7	9,978.7	9,978.7	9,978.7	11,783.7

TABLE 4.22

Cash-Flow Without Financing (10^3 US$) (Alternative III) Sales Price US$ 450/Mt   IRR: 22.16%

Item / Years	-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. Outflow																		
1. Initial Fixed Investment	3,210.2	5,164.1	7,815.7	3,349.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Working capital	-	-	-	340.6	136.6	204.4	-	-	-	-	-	-	-	-	-	-	-	-
3. Total Outflow (1 + 2)	3,210.2	5,164.1	7,815.7	3,689.8	136.3	204.4	-	-	-	-	-	-	-	-	-	-	-	-
B. Inflow																		
4. Sales	-	-	-	13,027.5	18,238.5	20,844.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0
5. Costs except depreciation	-	-	-	9,664.9	13,430.4	15,313.2	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7
6. Depreciation	-	-	-	3,908.8	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7	1,367	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7
7. Gross or taxable profit (4 - 5 - 6)	-	-	-	2,971.8	3,440.4	4,163.1	7,704.6	7,704.6	7,704.6	7,704.6	7,704.6	7,704.6	7,704.6	7,704.6	7,704.6	7,704.6	7,704.6	7,704.6
8. Tax	-	-	-	891.5	1,032.1	1,248.9	2,311.4	2,311.4	2,311.4	2,311.4	2,311.4	2,311.4	2,311.4	2,311.4	2,311.4	2,311.4	2,311.4	2,311.4
9. Net profit	-	-	-	2,080.3	2,408.3	2,914.2	5,393.2	5,393.2	5,393.2	5,393.2	5,393.2	5,393.2	5,393.2	5,393.2	5,393.2	5,393.2	5,393.2	5,393.2
10. Self-financing	-	-	-	2,471.1	3,776.0	4,281.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9
11. Working capital recovery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	681.3
12. Total Inflow (10 + 11)	-	-	-	2,471.1	3,776.0	4,281.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	7,442.2
C. Net cash flow (12 - 3)	-3,210.2	-5,164.1	-7,815.7	-1,218.7	3,639.7	4,077.5	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	6,760.9	7,442.2

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TABLE 4.23

Cash-Flow Without Financing (10^3 US$) (Alternative III) Sales Price US$ 500/Mt IRR: 25.48%

Item / Years	-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. Outflow																		
1. Initial Fixed Investment	3,210.2	5,164.1	7,815.7	3,349.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Working capital	-	-	-	340.6	136.6	204.4	-	-	-	-	-	-	-	-	-	-	-	-
3. Total Outflow (1 + 2)	3,210.2	5,164.1	7,815.7	3,689.8	136.3	204.4	-	-	-	-	-	-	-	-	-	-	-	-
B. Inflow																		
4. Sales	-	-	-	14,402.5	20,163.5	23,044.0	28,805.0	28,805.0	28,805.0	28,805.0	28,805.0	28,805.0	28,805.0	28,805.0	28,805.0	28,805.0	28,805.0	28,805.0
5. Costs except depreciation	-	-	-	9,664.9	13,430.4	15,313.2	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7
6. Depreciation	-	-	-	3,908.8	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7	1,367.7
7. Gross or taxable profit (4 - 5 - 6)	-	-	-	4,346.8	5,365.4	6,363.1	8,454.6	8,454.6	8,454.6	8,454.6	8,454.6	8,454.6	8,454.6	8,454.6	8,454.6	8,454.6	8,454.6	8,454.6
8. Tax	-	-	-	1,304.0	1,609.6	1,908.9	2,536.4	2,536.4	2,536.4	2,536.4	2,536.4	2,536.4	2,536.4	2,536.4	2,536.4	2,536.4	2,536.4	2,536.4
9. Net profit	-	-	-	3,04[illegible].8	3,755.8	4,454.2	5,918.2	5,918.2	5,918.2	5,918.2	5,918.2	5,918.2	5,918.2	5,918.2	5,918.2	5,918.2	5,918.2	5,918.2
10. Self-financing	-	-	-	3,433.6	5,123.5	5,821.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9
11. Working capital recovery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	681.3
12. Total Inflow (10 + 11)	-	-	-	3,433.6	5,123.5	5,821.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,967.2
C. Net cash flow (12 - 3)	-3,210.2	-5,164.1	-7,815.7	-256.2	4,987.2	5,617.5	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,285.9	7,967.2

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The IRR figures found following flows of above tables range between 7.4 - 10.4 for Alternative I and 22.2 - 25.5% for Alternative III. This shows the economical advantage of using imported Billet instead of Bolivian produced billets through blast furnace + LD converter.

2) Equity Yield

Here again the same discounted cash flow method has been used to calculate the IRR figures on the equity, and now, of course, considering financing, interpolated interests, (with subsequent repercussion both on the investment to be developed and the corresponding depreciation quotas), financing expenses, etc.

Tables 4.24 to 4.27 show the cash flows, considering external financing. (The set of items numbered 6 to 12 of said table present in a schematic form the yearly operating account, and therefore profits and losses will not be considered apart from that account).

The IRR figures range from 8.3 - 16.5% for Alternative I till 36.6 - 51.8% for Alternative III which show higher rates than those estimated for the total investment.

Table 4.28 complements tables 4.24 to 4.27, providing the yearly capital yield in conventional terms without discounting profits from the beginning. Yield for Alternative I stays, for year 13 up, above 18% with a sales price of US$ 450/Mt, and reaches 28.7% with a price of US$ 500/Mt for Alternative III, figures in terms of yield are exceptionally high for any sales price (74 and 110.9% respectively)

TABLE 4.24

Cash-Flow With Financing (10^3 US$) (Alternative I). Sales Price US$ 450/Mt																		IRR: 8.33%
Item / Years	-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. Outflow																		
1. Initial Fixed Investment	10,925.2	20,489.5	21,436.1	6,871.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Interpolated interests	323.8	1,254.[illegible]	2,497.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Working capital	-	-	-	902.5	361.0	541.5	-	-	-	-	-	-	-	-	-	-	-	-
4. Repayment of credits for initial fixed investment	-		-	-	2,213.0	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	2,313.0	-	-	-
5. Total Outflow (1 to 4)	11,249.0	21,744.4	23,933.7	7,774.0	2,574.0	4,967.9	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	2,313.0	-	-	-
B. Inflow																		
6. Sales	-	-	-	12,652.5	17,713.0	20,243.7	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1	25,305.1
7. Financial costs	-	-	-	3,337.0	3,541.0	3,275.5	3,021.6	2,567.3	2,223.2	1,859.1	1,504.9	1,150.9	796.7	442.5	88.5	-	-	-
8. Costs except depreciation	-	-	-	8,734.8	11,631.1	13,079.2	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5
9. Depreciation	-	-	-	1,276.0	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9
10. Gross or taxable profit (6 - 7 - 8 - 9)	-	-	-	-695.3	-1,924.9	-576.9	2,226.1	2,680.4	3,024.5	3,388.6	3,742.8	4,096.8	4,451.0	4,805.1	5,159.2	5,247.7	5,247.7	5,247.7
11 Taxes (30% of 10)	-	-	-	-	-	-	*494.8	804.1	907.4	1,016.6	1,122.8	1,229.0	1,335.3	1,441.5	1,547.8	1,574.3	1,574.3	1,574.3
12. Net profit (10 - 11)	-	-	-	-695.3	-1,924.9	-576.9	1,731.3	1,876.3	2,117.2	2,372.0	2,620.0	2,867.8	3,115.7	3,363.6	3,311.4	3,673.4	3,673.4	3,673.4
13. Self-financing (9 + 12)	-	-	-	580.7	2,541.0	3,889.0	6,197.2	6,342.2	6,583.1	6,837.9	7,085.9	7,333.7	7,581.6	7,829.5	8,077.3	8,139.3	8,139.3	8,139.3
14. Credits for fixed investment	8,095.6	15,182.7	15,884.2	5,101.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15. Working capital recovery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,805.0
16. Total Inflow (13 + 14 + 15)	8,095.6	15,182.7	15,884.2	5,681.8	2,541.0	3,889.0	6,197.2	6,342.2	6,583.9	6,837.9	7,085.9	7,333.7	7,581.6	7,829.5	8,077.3	8,139.3	8,139.3	9,944.3
C. Net cash flow (16 - 5)	-3,153.4	-6,561.7	-8,049.5	-2,092.2	-33.0	-1,078.9	1,770.8	1,915.8	2,156.7	2,411.5	2,659.5	2,907.3	3,155.2	3,403.1	5,764.3	8,139.3	8,139.3	9,944.3

(*) includes deduction for losses of previous years

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TABLE 4.25

Cash-Flow With Financing (10^3 US$) (Alternative I), Sales Price US$ 500/Mt — IRR: 8.33%

Item / Years	-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. Outflow																		
1. Initial Fixed Investment	10,925.2	20,489.5	21,436.1	6,871.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Interpolated interests	323.8	1,254.9	2,497.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Working capital	-	-	-	902.5	361.0	541.5	-	-	-	-	-	-	-	-	-	-	-	-
4. Repayment of credits for initial fixed investment	-	-	-	-	2,213.0	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	2,313.0	-	-	-
5. Total Outflow (1 to 4)	11,249.0	21,744.4	23,933.7	7,774.0	2,574.0	4,967.9	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	2,313.0	-	-	-
B. Inflow																		
6. Sales	-	-	-	14,027.5	19,630.0	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1	28,055.1
7. Financial costs	-	-	-	3,337.0	3,541.0	3,275.5	3,021.6	2,567.3	2,223.2	1,859.1	1,504.9	1,150.9	796.7	442.6	88.5	-	-	-
8. Costs except depreciation	-	-	-	8,734.8	11,631.1	13,079.2	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5	15,591.5
9. Depreciation	-	-	-	1,276.0	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9	4,465.9
10. Gross or taxable profit (6 - 7 - 8 - 9)	-	-	-	679.1	-	7,234.5	4,976.1	5,430.4	5,774.5	6,138.6	6,492.8	6,846.8	7,201.0	7,555.1	7,909.2	7,997.7	7,997.7	7,997.7
11. Taxes (30% of 10)	-	-	-	203.9	-	2,170.4	1,492.8	1,629.1	1,732.4	1,841.6	1,947.8	2,054.0	2,160.3	2,266.5	2,372.8	2,399.3	2,399.3	2,399.3
12. Net profit (10 - 11)	-	-	-	475.8	-	5,064.2	3,483.3	3,801.3	4,042.2	4,297.0	4,545.0	4,792.8	5,040.7	5,298.6	5,536.4	5,598.4	5,598.4	5,598.4
13. Self-financing (9 + 12)	-	-	-	1,751.8	4,465.9	9,530.1	7,949.2	8,267.2	8,508.1	8,762.9	9,010.9	9,258.7	9,506.6	9,754.5	10,002.3	10,064.3	10,064.3	10,064.3
14. Credits for fixed investment	8,095.6	15,182.7	15,884.2	5,101.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15. Working capital recovery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,805.0
16. Total Inflow (13 + 14 + 15)	8,095.6	15,182.7	15,884.2	6,852.9	4,465.9	9,530.1	7,949.2	8,267.2	8,508.1	8,762.9	9,010.9	9,258.7	9,506.6	9,754.5	10,002.3	10,064.3	10,064.3	11,869.3
C. Net cash flow (16 - 5)	-3,153.4	-6,561.7	-8,049.5	921.1	1,891.9	4,562.2	3,522.8	3,840.8	4,081.1	4,336.5	4,584.5	4,832.3	5,080.2	5,328.1	7,689.3	10,064.3	10,064.3	11,869.3

(*) Includes deduction for losses of previous years

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TABLE 4.26

Cash-Flow With Financing (10^3 US$) (Alternative III). Sales Price US$ 450/Mt IRR: 8.33%																		
Item / Years	-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. Outflow																		
1. Initial Fixed Investment	3,210.2	5,164.1	7,815.7	3,349.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Interpolated interests	101.9	367.7	779.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Working capital	-	-	-	340.6	136.3	204.4	-	-	-	-	-	-	-	-	-	-	-	-
4. Repayment of credits for initial fixed investment	-	-	-	-	775.3	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	775.1	-	-	-
5. Total Outflow (1 to 4)	3,312.1	5,531.8	8,595.4	3,689.8	991.6	1,754.9	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	775.1	-	-	-
B. Inflow																		
6. Sales	-	-	-	13,027.5	18,238.5	20,844.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0	26,055.0
7. Financial costs	-	-	-	1,134.1	1,240.4	1,147.4	1,023.4	899.2	775.2	651.2	527.2	403.1	279.0	155.0	31.0	-	-	-
8. Costs except depreciation	-	-	-	9,664.9	13,430.4	15,313.2	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7
9. Depreciation	-	-	-	415.8	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2
10. Gross or taxable profit (6 - 7 - 8 - 9)	-	-	-	1,812.7	2,112.5	2,928.2	4,593.7	4,717.9	4,841.9	4,965.9	5,089.9	5,214.0	5,338.1	5,462.1	5,586.1	5,617.1	5,617.1	5,617.1
11. Taxes (30% of 10)	-	-	-	543.8	633.8	878.5	1,378.1	1,415.4	1,452.6	1,489.8	1,527.0	1,564.2	1,601.4	1,638.6	1,675.8	1,685.1	1,685.1	1,685.1
12. Net profit (10 - 11)	-	-	-	1,268.9	1,478.8	2,049.7	3,215.6	3,302.5	3,389.3	3,476.1	3,562.9	3,649.8	3,736.7	3,723.5	3,910.3	3,932.0	3,932.0	3,932.0
13. Self-financing (9 + 12)	-	-	-	1,684.7	2,934.0	3,504.9	4,670.8	4,757.7	4,844.5	4,931.3	5,018.1	5,105.0	5,191.9	5,278.7	5,365.5	5,387.2	5,387.2	5,387.2
14. Credits for fixed investment	2,547.4	4,097.9	6,202.0	2,657.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15. Working capital recovery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	681.3
16. Total Inflow (13 + 14 + 15)	2,547.4	4,097.9	6,202.0	4,342.3	2,934.0	3,504.9	4,670.8	4,757.4	4,844.5	4,931.3	5,018.1	5,105.0	5,191.9	5,278.7	5,365.5	5,387.2	5,387.2	6,068.0
C. Net cash flow (16 - 5)	-764.7	-1,433.9	-2,393.4	652.5	1,942.4	1,750.0	3,120.3	3,207.2	3,294.0	3,380.8	3,467.6	3,554.5	3,641.4	3,728.2	4,590.4	5,387.2	5,387.2	6,068.0

(*) Includes deduction for losses of previous years

TABLE 4.27

Cash-Flow With Financing (10^3 US$) (Alternative III), Sales Price US$ 500/Mt — IRR: 8.33%

Item \ Years	-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. Outflow																		
1. Initial Fixed Investment	3,210.2	5,164.1	7,815.7	3,349.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Interpolated interests	101.9	367.7	779.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Working capital	-	-	-	340.6	136.3	204.4	-	-	-	-	-	-	-	-	-	-	-	-
4. Repayment of credits for initial fixed investment	-	-	-	-	775.3	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	775.1	-	-	-
5. Total Outflow (1 to 4)	3,312.1	5,531.8	8,595.4	3,689.8	991.6	1,754.9	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	775.1	-	-	-
B. Inflow																		
6. Sales	-	-	-	14,402.5	[illegible]	23,044.0	28,805.0	28,805.0	28,805.0	28,805.0	26,805.0	28,805.0	28,805.0	28,805.0	28,805.0	28,805.0	28,805.0	28,805.0
7. Financial costs	-	-	-	1,134.1	1,240.4	1,147.4	1,023.4	899.2	775.2	651.2	527.2	403.1	279.0	155.0	31.0	-	-	-
8. Costs except depreciation	-	-	-	9,664.9	13,430.4	15,313.2	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7	18,982.7
9. Depreciation	-	-	-	415.8	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	1,455.2	[illegible]	1,455.2	1,455.2
10. Gross or taxable profit (6 - 7 - 8 - 9)	-	-	-	3,187.7	4,037.5	5,128.2	7,343.7	7,467.9	7,591.9	7,715.9	7,839.9	7,964.0	8,088.1	8,212.1	8,336.1	8,367.1	8,367.1	8,367.1
11. Taxes (30% of 10)	-	-	-	956.3	1,211.3	1,538.5	2,203.1	2,240.4	2,277.6	2,314.8	2,352.0	2,389.2	2,426.4	2,463.6	2,500.8	2,510.1	2,510.1	2,510.1
12. Net profit (10 - 11)	-	-	-	2,231.4	2,826.3	3,589.7	5,140.6	5,227.5	5,314.3	5,401.1	5,487.9	5,574.8	5,661.7	5,748.5	5,835.3	5,857.0	5,857.0	5,857.0
13. Self-financing (9 + 12)	-	-	-	2,647.2	4,289.5	5,044.9	6,495.8	6,882.7	6,769.5	6,856.3	6,943.1	7,030.0	7,116.9	7,203.7	7,290.5	7,312.2	7,312.2	7,312.2
14. Credits for fixed investment	2,547.4	4,097.9	6,202.0	2,657.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15. Working capital recovery	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	681.3
16. Total Inflow (13 + 14 + 15)	2,547.4	4,097.9	6,202.0	5,304.8	[illegible]	[illegible]	6,595.8	6,882.7	6,769.5	6,856.3	6,943.1	7,030.0	7,116.9	7,303.7	7,290.5	7,312.2	7,312.2	7,993.5
C. Net cash flow (16 - 5)	-764.7	-1,433.9	-2,393.4	1,615.0	3,369.9	3,290.0	5,045.3	5,132.2	5,219.0	5,305.8	5,392.6	5,479.5	5,566.0	5,653.2	6,515.4	7,312.2	7,312.2	7,993.5

(*) Includes deduction for losses of previous years

TABLE 4.28

Equity Capital Profitability per Year

Year	Net Profit after Taxes (10^3 US$/Mt)				Equity Capital Profitability in % (1)			
	Alternative I		Alternative III		Alternative I		Alternative III	
	Sales Price US$ 450/Mt	Sales Price US$ 500/Mt	Sales Price US$ 450/Mt	Sales Price US$ 500/Mt	Sales Price US$ 450/Mt	Sales Price US$ 500/Mt	Sales Price US$ 450/Mt	Sales Price US$ 500/Mt
1	-695.3	475.8	1,268.9	2,231,4	-3.6	2.4	24.0	42.2
2	-1,924.9	0	1,478.8	2,826.3	-9.9	0	28.0	53.5
3	-576.9	5,064.2	2,049.7	3,589.3	-3.0	25.9	38.8	67.9
4	1,731.3	3,483.3	3,215.6	5,140.6	8.9	17.8	60.9	97.3
5	1,876.3	3,801.3	3,302.5	5,227.5	9.6	19.5	62.5	98.9
6	2,117.2	4,042.2	3,389.3	5,314.3	10.8	20.7	64.1	100.6
7	2,372.0	4,297.0	3,476.1	5,401.1	12.1	22.0	65.8	102.2
8	2,620.0	4,545.0	3,562.9	5,487.9	13.4	23.2	67.4	103.9
9	2,867.8	4,792.8	3,649.8	5,574.8	14.7	24.5	69.1	105.5
10	3,115.7	5,040.7	3,736.7	5,661.7	15.9	25.8	70.7	107.2
11	3,363.6	5,288.6	3,823.5	5,748.5	17.2	27.1	72.4	108.8
12	3,611.4	5,536.4	3,910.3	5,835.3	18.5	28.3	74.0	110.4
13	3,673.4	5,598.4	3,932.0	5,857.0	18.8	28.7	74.0	110.9
14	3,673.4	5,598.4	3,932.0	5,857.0	18.8	28.7	74.0	110.9
15	3,673.4	5,598.4	3,932.0	5,857.0	18.8	28.7	74.0	110.9

(1) Alternative I: 19,535,000 US$
Alternative III: 5,283,600 US$

Finally, tables 4.29 to 4.32 show sources and uses of funds in both Alternatives I & III.

The available amounts through capitalization up till year 15 are similar for both alternatives, which once more proofs the financial advantages of using imported billets.

4.5.8 Break-even Point

In order to define the break even point (B.E.P.) for both Alternatives (I & III), table 4.33 collecting fixed and variable costs, has been prepared.

In accordance with Fig. 4.1 the B.E.P. is shown as the crossing point of the Sales (passing by origin point) and Total Costs (whose ordinate over origin gives Fixed Costs) lines.

Said B.E.P. has been calculated for a typical year. Table 4.33 gives: for Alternative I a B.E.P. of 42,050 Mt/year for a rolled products selling price of US$ 450/Mt and 33,320 Mt/year for a price of US$ 500/Mt; these figures respectively correspond to an 81.9 and 64.9% of the average production of a typical year following the schedule foreseen in paragraph 4.5.4.

For Alternative III the situation appears even more favourable as B.E.P. of 29,930 Mt/year for a selling price of US$ 450/Mt equivalent to a 40.5% of an average production and a B.E.P. of only 14,460 Mt/year (28.2% of an average production) for a sales price of US$ 500/Mt.

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TABLE 4.29

Origin and Use of Funds (10^3 US$) (Alternative I). Sales Price US$ 450/Mt

Concept / Years	-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. Financing Sources																		
1. Self financing (*)	-	-	-	580.7	2,541.0	3,889.0	6,197.2	6,342.2	6,583.1	6,837.9	7,085.9	7,333.7	7,581.6	7,829.5	8,077.3	8,139.3	8,139.3	8,139.3
2. Equity capital	3,153.4	6,561.7	8,049.5	1,770.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Credits for initial fixed investment	8,095.6	15,182.7	15,884.2	5,101.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4. Total Financing Sources	11,249.0	21,744.4	23,933.7	7,452.2	2,541.0	3,889.0	6,197.2	6,342.2	6,583.1	6,837.9	7,085.7	7,333.7	7,581.6	7,829.5	8,077.3	8,139.3	8,139.3	8,139.3
B. Uses																		
5. Initial fixed investment costs	10,925.2	20,489.5	21,436.1	6,871.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6. Interpolated interests	323.8	1,254.9	2,497.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7. Working capital	-	-	-	902.5	361.0	541.5	-	-	-	-	-	-	-	-	-	-	-	-
8. Repayment of credits for initial fixed investment	-	-	-	-	2,213.0	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	2,313.0	-	-	-
9. Total Uses	11,249.0	21,744.4	23,933.7	7,774.0	2,574.0	4,967.9	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	2,313.0	-	-	-
C. Available capital																		
10. Each year (4 - 9)	-	-	-	-321.8	-33.0	-1,078.9	1,770.8	1,915.8	2,156.7	2,411.5	2,659.5	2,907.3	3,155.2	3,403.1	5,764.3	8,139.3	8,139.3	8,139.3
11. Cummulative	-	-	-	-321.8	-354.8	-1,433.7	337.1	2,252.9	4,409.6	6,821.1	9,480.6	12,387.9	15,543.1	18,946.3	24,710.6	32,849.9	40,989.2	49,128.5

- Available capital 49,128.5
- Working capital recovery 1,805.0
- Total available amount capitalized in year 15 50,933.5 x 10^3 US $

* The self financing is given on line 13 of table 4.24

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TABLE 4.30

Origin and Use of Funds (10^3 US$) (Alternative I). Sales Price US$ 500/Mt

Concept / Years	-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. Financing Sources																		
1. Self financing (*)	-	-	-	1,751.8	4,465.9	9,530.1	7,949.2	8,267.2	8,508.1	8,762.9	9,010.9	9,258.7	9,506.6	9,754.5	10,002.3	10,064.3	10,064.3	10,064.3
2. Equity capital	3,153.4	6,561.7	8,049.5	1,770.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Credits for initial fixed investment	8,095.6	15,182.7	15,884.2	5,101.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4. Total Financing Sources	11,249.0	21,744.4	23,933.7	8,623.3	4,465.9	9,530.1	7,949.2	8,267.2	8,508.1	8,762.9	9,010.9	9,258.7	9,506.6	9,754.5	10,002.3	10,064.3	10,064.3	10,064.3
B. Uses																		
5. Initial fixed investment costs	10,925.2	20,489.5	21,436.1	6,871.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6. Interpolated interests	323.8	1,254.9	2,497.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7. Working capital	-	-	-	902.5	361.0	541.5	-	-	-	-	-	-	-	-	-	-	-	-
8. Repayment of credits for initial fixed investment	-	-	-	-	2,213.0	4,425.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	4,426.4	2,313.0	-	-	-
9. Total Uses	11,249.0	21,744.4	23,933.7	7,774.0	2,574.0	4,967.9	4,426.4	4,426.4	4,426.4	4,426.4	4,476.4	4,426.4	4,426.4	4,426 [illegible]	[illegible],313.0	-	-	-
C. Available capital																		
10. Each year (4 - 9)	-	-	-	849.3	1,891.9	4,562.2	3,522.8	3,840.8	4,081.7	4,336.5	4,584.5	4,823.3	5,080.2	5,328.1	5,575.9	10,064.3	10,064.3	10,064.3
11. Cummulative	-	-	-	849.3	2,741.2	7,303.4	10,826.2	14,667.0	18,748.7	23,085.2	27,669.7	32,502.0	37,582.2	42,910.3	48,496.2	58,550.5	68,614.8	78,679.1

- Available capital 78,679.1
- Working capital recovery 1,805.0
- Total available amount capitalized in year 15 80,484.1 x 10^3 US $

* The self financing is given on line 13 of table 4.25

TABLE 4.31

Origin and Use of Funds (10^3 US$) (Alternative III). Sales Price US$ 450/Mt

Concept / Years	-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. Financing Sources																		
1. Self financing (*)	-	-	-	1,684.7	2,934.0	3,504.9	4,670.8	4,757.7	4,844.5	4,931.3	5,018.1	5,105.0	5,191.9	5,278.7	5,365.5	5,387.2	5,387.2	5,387.2
2. Equity capital	764.7	1,433.9	2,393.4	691.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Credits for initial fixed investment	2,547.4	4,097.9	6,202.0	2,657.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4. Total Financing Sources	3,312.1	5,531.8	8,595.4	5,033.9	2,934.0	3,504.9	4,670.8	4,757.7	4,848.5	4,913.3	5,018.1	5,105.0	5,191.9	5,278.7	5,365.5	5,387.2	5,387.2	5,387.2
B. Uses																		
5. Initial fixed investment costs	3,210.2	5,164.1	7,815.7	3,349.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6. Interpolated interests	101.9	367.7	779.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7. Working capital	-	-	-	340.6	136.3	204.4	-	-	-	-	-	-	-	-	-	-	-	-
8. Repayment of credits for initial fixed investment	-	-	-	-	775.3	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	775.1	-	-	-
9. Total Uses	3,312.1	5,531.8	8,595.4	3,689.8	911.6	1,754.9	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	775.1	-	-	-
C. Available capital																		
10. Each year (4 - 9)	-	-	-	1,344.1	2,022.4	1,750.0	3,120.3	3,207.2	3,294.0	3,380.8	3,467.6	3,554.5	3,641.4	3,728.2	4,590.4	5,387.2	5,387.2	5,387.2
11. Cummulative	-	-	-	1,344.1	3,366.5	5,116.5	8,236.8	11,444.0	14,738.0	18,118.8	21,586.4	25,140.9	28,782.3	32,510.5	37,100.9	42,488.1	47,875.3	53,269.5

- Available capital 53.262.5
- Working capital recovery 681.3
- Total available amount capitalized in year 15 53,943.8 x 10^3 US $

* The self financing is given on line 13 of table 4.26

TABLE 4.32

Origin and Us: of Funds (10^3 US$) (Alternative III). Sales Price US$ 500/Mt																		
Concept / Years	-3	-2	-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A. Financing Sources																		
1. Self finan:ing (*)	-	-	-	2,647.2	4,289.5	5,044.9	6,595.8	6,882.7	6,769.5	6,856.3	6,943.1	7,036 0	7,116.9	7,203.7	7,290.5	7,313.2	7,313.2	7,313.2
2. Equity capital	764.7	1,433.9	2,393.4	691.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Credits for initial fixed investment	2,547.4	4,097.9	6,202.0	2,657.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4. Total Financing Sourcee	3,312.1	5,531.8	8,595.4	5,996.4	4,289.5	5,044.9	6,595.8	6,882.7	6,769.5	6,856.3	6,943.1	7,030.0	7,116.9	7,203.7	7,290.5	7,312.2	7,312.2	7,312.2
B. Uses																		
5. Initial fixed investment costs	3,210.2	5,164.1	7,815.7	3,349.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6. Interpolated interests	101.9	367.7	779.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7. Working capital	-	-	-	340.6	13[illegible]	204.4	-	-	-	-	-	-	-	-	-	-	-	-
8. Repayment of credits for initial fixed investment	-	-	-	-	775.3	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	775.1	-	-	-
9. Total Uses	3,312.1	5,531.8	8,595.4	3,689.8	911.6	1,754.9	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	1,550.5	775.1	-	-	-
C. Available capital																		
10. Each year (4 - 9)	-	-	-	2,306.6	3,377.9	3,290.0	5,045.3	5,332.2	5,219.0	5,305.8	5,392.6	5,479.5	5,566.4	5,653.2	6,515.4	7,312.2	7,312.2	7,312.2
11. Cummulative	-	-	-	2,306.5	5,684.5	8,974.5	14,019.8	19,352.0	24,571.0	29,876.8	35,269.4	40,748.8	46,315.2	51,968.3	58,483.8	65,796.0	73,108.7	80,421.7

- Available capital 80,421.7
- Working capital recovery 681.3
- Total available amount capitzlized in year 15 81,103.0 x 10^3 US $

* The self financing is given on line 13 of table 4.27

FIGURE 4.1.

BREAK-EVEN POINT DETERMINATION
(EXAMPLE)

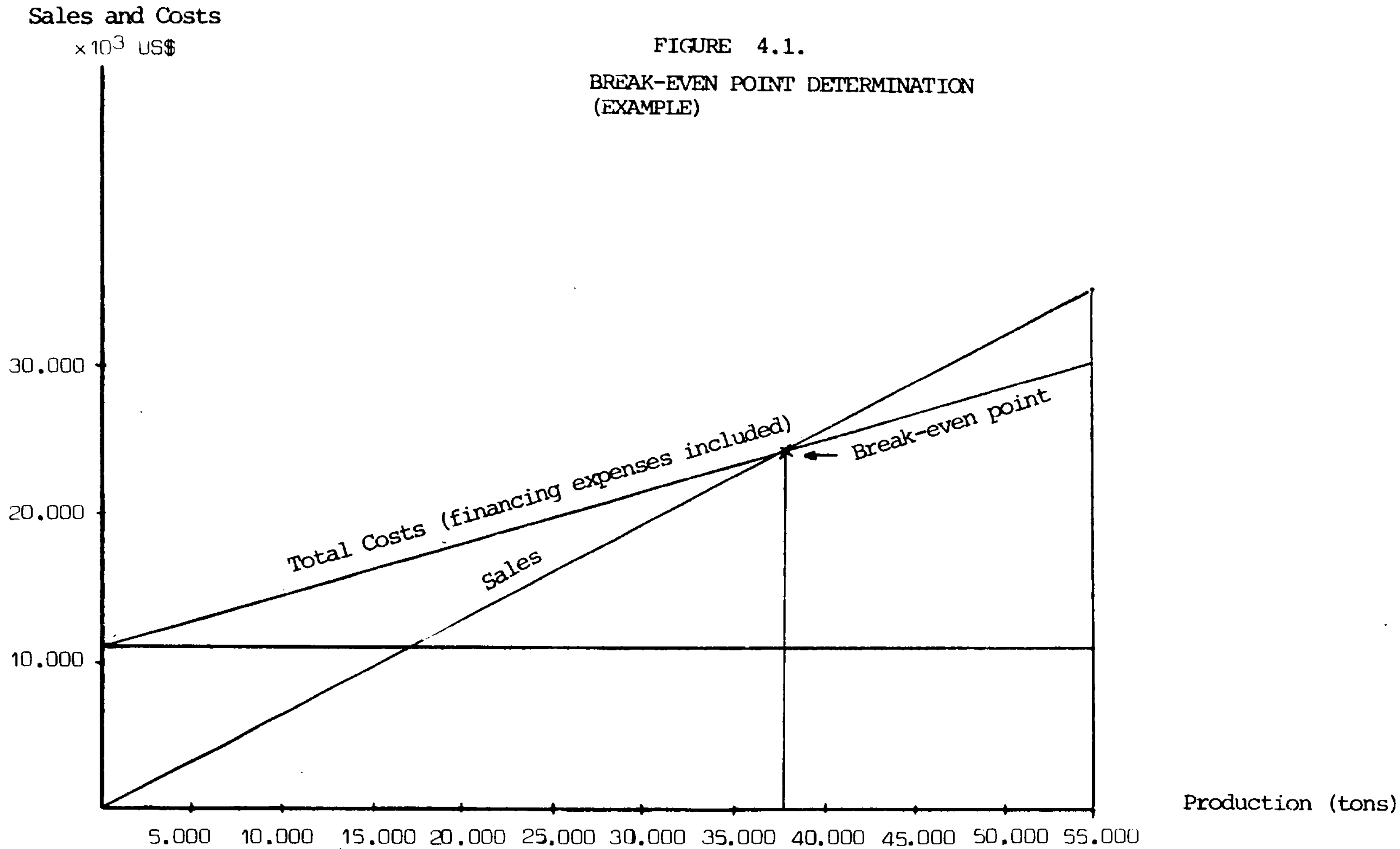

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TABLE 4.33

Break Even Point in a Typical Year

	Alternative I		Alternative II	
	Sales Price US$ 450/Mt	Sales Price US$ 500/Mt	Sales Price US$ 450/Mt	Sales Price US$ 500 Mt
1. Fixed Costs (10^3 US$)				
Manpower	996.6	996.6	228.3	228.3
Start-up	76.8	76.8	19.2	19.2
Depreciation	4,253.2	4,253.2	1,385.9	1,385.9
General costs	1,110.0	1,110.0	155.1	155.1
Financing costs	1,587.2	1,587.2	551.1	551.1
Total fixed costs	8,023.8	8,023.8	2,339.6	2,339.6
2. Variable Costs				
US$/Mt	-	-	338.2	338.2
3. Net Profit				
US$/Mt	450.0	500.0	450.0	500.0
4. Average production in a typical year				
Mt/year	51,330.0	51,330.0	51,330.0	51,330.0
5. Break even point				
Mt/year	42,050.0	33,320.0	20,930.0	14,460.0
% of production level	81.9	64.9	40.8	28.2

As a summary we can sav that Alternative III is appreciably more favourable from a financing point of view as the profitabilitv threshold lies on production figures of about 50% of these obtained for Alternative I.

4.5.9 Foreign Currency Investment Recovery

1) Aitenative I

Taking as a base the cost structure-according to the nature of products rolled in a typical year of table 4.34, where the items forming part of fabricating cost have been grouped by origin and financial expenses have now been included a total cost without depreciation of US$ 319.28/Mt of rolled product is obtained, out of which, import items represent US$ 83.05/Mt, i.e. 26%.

Above figures will be compared with the average sales price considered now in Bolivia of US$ 475/Mt, similar to the import products in Santa Cruz, which include commercial margins and custom taxes (these being estimated as 20% of CIF cost). Consequently, for the import rolled products like those considered in this project, a foreign currency cost of around US$ 400/Mt may be estimated.

The currency savings, without considering pay-off, in favor of manufacturing these products in Bolivia would be:

US$ (400 - 85)Mt = US$ 315/Mt

The investment in foreign currency following the breakdown per table 4.9 amounts to US$ 46,593,300. For an average production of 51,330 Mt/year, considering that a maximum production of 55,000 Mt is reached in the fourth year after start-up, the following investment recovery is obtained in foreign currencv:

TABLE 4.34

Costs Structures of the Rolled Products by Origin one Typical Year (Alternative I)

Item	Origin	Total cost US$/Mt rolled product	Cost of imported matters US$/Mt
Charcoal	National	75.37	-
Iron ore	National	3.92	-
Manganese ore	National	1.92	-
Limestone	National	0.11	-
Quartzite	National	2.36	-
Exterior scrap	Imp/National	13.65	6.83
Refractories	Imported	2.24	2.24
Lime	National	6.02	-
Fluorite	Imported	0.96	0.96
Ferroalloys	Imported	9.03	9.03
Fuel-Oil	National	4.40	-
Natural Gas	National	3.42	-
Oxygen	National	1.97	-
Electric energy	Imp/National	9.29	5.92
Ingot moulds	Imported	0.67	0.67
Water	National	0.96	-
Rolling rolls	Imported	2.35	2.35
Manpower	National	16.80	-
Miscellaneous	Imp/National	3.66	2.75
Billets transportation to Sta. Cruz	National	82.47	-
Maintenance	Imp/National	23.67	19.88
General costs	National	21.62	-
Financial costs	Imported	30.92	30.92
Start-up	Imported	1.50	1.50
Total US$/Mt		319.28	83.05
%		100.00	26.0

$$\frac{\text{US\$ }46,593,300}{\text{US\$ }315/\text{Mt } \times 51,330 \text{ Mt/year}} = 2,88 \text{ years}$$

2) Alternative III

Proceeding in a similar way, table 4.35 gives a Total Cost without depreciation of US$ 331.76/Mt; the imported items of which representing US$ 219.22/Mt i.e. 66.1%.

Foreign currency sparing - excluding depreciation - would then be:

US$ (400 - 219.22) = US$ 180.78/Mt

For a foreign currency investment, representing, per table 4.10 US$ 16,320,900 the following foreign currency recovery will be obtained:

$$\frac{\text{US\$ }16,320,900}{\text{US\$ }180.78/\text{Mt } \times 51,330 \text{ Mt/year}} = 1,76 \text{ years}$$

4.5.10 Conclusions

As conclusions from the above financing analysis performed for Alternatives I (charcoal + blast furnace + LD converter) and III (imported billet) for the production of rolled rods in Bolivia, we can say:

Alternative III requires less investment (US$ 19.5 millions) compared with (US$ 59.7 millions) Alternative I. This means a depreciation of US$ 27/Mt rolled product compared with US$ 82.9/Mt.

TABLE 4.35

Costs Structures of the Rolled Products
by Origin one Typical Year (Alternative III)

Item	Origin	Total cost US$/Mt rolled product	Cost of imported matters US$/Mt
Billet	Imported	297.13	200.00(1)
Electric Power	National	3.38	-
Natural Gas	National	3.42	-
Rolling rolls	imported	2.35	2.35
Water	National	0.13	-
Maintenance	Imp/National	5.07	4.26
Manpower	National	4.15	-
Miscellaneous	Imp/National	2.00	1.50
General costs	National	3.02	-
Financial costs	Imported	10.74	10.74
Start-up	Imported	0.37	0.37
Total US$/Mt		331.76	219.22
%		100.00	66.1

(1) Transport in Bolivia, custom taxes and other costs excluded

In connection with financing expenses, Alternative III requires US$ 10.74/Mt compared with US$ 30.9/Mt for Alternative I.

Apart from those two items (Depreciation & Financing Expenses), Alternative I gives less fabricating costs (US$ 263.3/Mt for US$ 342.3/Mt in Alternative III) Nevertheless, this last difference does not compensate the previous differences in depreciation and financing expenses. All together, Alternative I is more expensive with a total difference of US$ 31.7/Mt in favour of Alternative III.

Alternative I has the advantages of a higher national added value, a use of national raw materials, creation of more jobs and specially an important saving of foreign currency when comparing with rolled products imported at a cost of US$ 400/Mt as shown below:

	Foreign Currency Investment US$
(1) Alternative I	46,593.300
(2) Alternative II	16,320,900
Balance (1)-(2)	30,272,400

	Foreign Currency Savings (US$)	
	Yearly	15 years
(1) Alternative I	16,168,950	242,534,250
(2) Alternative III	9,279,440	139,191.600
Balance (1)-(2)	6,889,510	103,342,650

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4.6 Foreseen Implementations Planning

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IMPLEMENTATION PLANNING IN MONTHS

1. DETAILED PROJECT.
2. MINING AND CALCINATION.
   - Researching and previous studies.
   - Requisitions and contracts.
   - Equipment construction and delivery.
   - Equipment assembly.
3. BLAST FURNACE
   - Equipment requisitions and contracts.
   - Civil works requisitions and contracts.
   - Equipment construction and delivery.
   - Equipment assembly
4. STEEL SHOP - LD
   - Equipment requisitions and contracts
   - Civil works and structures requisitions and contracts.
   - Civil works execution
   - Structures manufacturing and assembly
   - Equipment construction and delivery
   - Equipment assembly
5. CONTINUOUS CASTING
   - Equipment requisitions and contracts.
   - Civil works and structures requisitions and contracts.
   - Civil works execution
   - Structures manufacturing and assembly
   - Equipment construction and delivery
   - Equipment assembly
6. ROLLING MILL
   - Equipment requisitions and contracts
   - Civil works and structures requisitions and contracts
   - Civil works execution
   - Structures manufacturing and assembly
   - Equipment construction and delivery
   - Equipment assembly
7. UTILITIES AND AUXILIARY FACILITIES
   - Requisitions and contracts
   - Construction and assembly
8. COMMISSIONING. FINAL AND PARTIAL TESTS.