4.9 Demand for Calcium Carbide

(1) Present Situation

Calcium carbide is supplied by Hornos Electricos Peruanos S.A. and Electrometalurgica Nacional S.A. Their combined production capacity is about 8,000 tons per year.

The demand is mostly for the production of acetylene for welding and lighting in mines, although there is minor demand for desulfurization in steelmaking and maturation of fruit.

1) Hornos Electricos Peruanos S.A.

Hornos Electricos uses quick lime supplied by Cimalza at 96 US$ per ton, small and medium-sized coke imported by Siderperu at 76 US$ per ton, and domestic coke at 98 US$ per ton. The company has a 500 kW hydroelectric power plant. In addition, stable electric power supply is guaranteed by a mutual supply agreement with Electroperu.

Production is currently about 3,000 tons per year, of which 95 percent is supplied to the domestic market and the remaining 5 percent is exported to Equador. Venezuela, Chile, Bolivia, and other Latin American countries. Domestic market sales are primarily to small and medium-sized mines, with distribution being handled by AGA (manufacturer of acetylene) and CODISA (distributor for Hornos products). Prices are as shown below:

Retail price	:	34 US$ per 50 kg drum
Wholesale price	:	480 US$ per ton

2) Electrometalurgica Nacional S.A. (ENSA)

ENSA uses limestone of Moro and Yautan quarries. The quality is generally low with $CaCO_3$ content ranging between 86 and 99 percent. As a result, about 13 tons per day of ferrosilicon is produced and disposed of. Production of calcium carbide is about 5,000 tons per year, of which 60 percent is exported to Latin American countries like Bolivia, Equador, Columbia, Venezuela, and Argentina.

(2) Forecast Future Demand

As was stated above, of about 13,000 tons per year of the total production, about 8,000 tons per year is exported and the remaning about 5,000 tons per year is sold on the domestic market. Given the recession now affecting Siderperu, there is little expectation that demand for desulfurization will increase. At present, Siderperu produces steel chiefly from recycled scrap steel which does not need carbide for desulfurization. There is also little hope for any major increase in demand for welding. It would therefore be reasonable to deduce that the present supply-demand balance will prevail for some time.

Looking at price, the current price of 557 US$ per ton, including a 16 percent sales tax is comparable to the ¥125,000 to 135,000 per ton, or 517 to 558 US$ per ton, price prevailing in Japan.

Their products have a quality level of 300 liters of acetylene per kilogram of carbide. The consumers are not demanding better product. The domestic market would remain unchanged for foreseeable future.

4.10 Demand for Calcium Cyanamide

(1) Characteristics of calcium cyanamide

Calcium cyanamide is produced by burning granulated or powdered calcium carbide in the atmosphere of nitrogen. Calcium cyanamide is an important nitrogenous fertilizer. It forms urea, ammonium carbonate, or nitric acid by the action of soil colloids or microorganisms in the soil and is absorbed by plants. Because it contains a large amount of calcium, approximately 60 percent as CaO, it is also recommended as a good alkaline fertilizer for improving the soil as well as neutralizing acid. Moreover, calcium cyanamide kills some bacteria in the soil and the weeds and also kills some insects.

To sum up calcium cyanamide has the following effects:

1) Good nitrogenous fertilizer

Calcium cyanamide is decomposed rather slowly and therefore the effect is lasting.

2) Soil neutralizer

Calcium cyananmide neutralizes acidic soils thereby creates a condition in which beneficial bacteria could grow.

3) Herbicide and pesticide

Calcium cyanamide is an effective herbicide and pesticide.

4) Soil conditioner

Calcium cyanamide helps grow beneficial microorganisms and thus creates favorable ecological balance between organic substances and bacteria.

5) Endemic disease preventive

Calcium cyanamide is also used to destroy bacteria and their host vermin.

(2) Present fertilizer consumption

Despite a variety of merits calcium cyanamide is not used in Peru.

1) Consumption and Price

Table 4-35 gives consumptions and prices in 1980 of more important fertilizers.

Table 4-35 Fertilizer Demand and Price

Fertilizer	Consumption (ton)	Price US$/t)
Urea	154,791	208
Ammonium nitrate	61,160	203
Ammonium sulfate	23,349	117
Single superphosphate	8,712	138
Double superphosphate	18,159	284
Triple superphosphate	15,569	269
Compound 12-12-12	13,106	138
Compound 7-14-7	1,347	144
Compound 9-11-2	18,740	154
Potassium chloride	12,728	88
Potassium sulfate	5,239	223
Magnesium potassium sulfate	1,439	156

By ingredient, Peruvian consumption in 1981 is as shown below.

Table 4-36 Fertilizer Ingredient Consumption

Ingredient	Consumption (t/y)
Nitrogen (N)	103,985
Phosphorus (P)	21,697
Potassium (K)	13,210

Seen historically, nitrogen consumption has been fairly constant as shown below.

Table 4-37 Nitrogen Consumption

Year	Nitrogen Consumption (t/y)
1976	98,076
1977	109,000
1978	104,000
1979	91,000
1980	87,000
1981	103,985

According to Empresa Nacional de Comercializacion Insumo (ENCI), it is reasonable, if all goes well, to expect NPK demand to grow at 3 to 4 percent per annum.

2) Nitrogen fertilizer

Peru has a production capacity of about 216,000 tons per year of nitrogen fertilizer. Table 4-38 shows manufacturers, locations of the plants, capacities and products.

Table 4-38 Nitrogenous Fertilizer Manufacturers

Name	Location	Capacity (t/y)	Product
Petroperu	Talara	160,000	Urea
Fertisa	Lima	30,000	Ammonium nitrate
		6,000	Ammonium sulfate
Cachimayo	Cuzco	20,000	Ammonium nitrate
Total		216,000	

Seen in terms of area, the alkaline soil coastal region accounts for approximately 50 percent of the total consumption of nitrogen fertilizers, with the remaining 50 percent divided more or less equally between the mountain region and the soil-acidic jungle region. Although a growth rate of 2 to 3 percent appears to be expected for the future, major increases in consumption can be expected as the jungle is opened for agricultural development.

3) Outlook for calcium cyanamide

The following reasons explain why calcium cyanamide has not been used in Peru.

a) Agriculture is concentrated on coastal and mountaneous alkaline soil with little need for soil improvement.

b) Calcium cyanamide is approximately twice as expensive as urea. (approximately ¥100 per kilogram)

c) Methods of administering calcium cyanamide is different from those of urea to which farmers are accustomed. It will naturally take time to fully instruct the rural population in its application.

The most promising area for calcium cyananide is for fertilizing and neutralizing the acidic jungle soil for rice cultivation. This potential demand is estimated at as high as about 50,000 tons per year. However, it is still premature to embark on production of calcium cyanamide and the following steps are recommended before actually attempting production.

a) Advertisement and market development for calcium cyanamide,

b) Demonstration of the benefits of calcium cyanamide,

c) Comprehensive comparative study of calclium cyanamide with urea,

d) Sales of imported calcium cyanamide,

e) Feasibility study of domestic production.

4.11 Demand for Quick Lime and Slaked Lime

Possibility of marketing part of quick lime and slaked lime was studied. Specifically, the cement market was surveyed because cement represents a big consumer of lime along with steelmaking and carbide manufacture.

(1) Quick lime

There are four cement companies in Peru, with a combined production capacity of 3,000,000 tons per year. The survey team visited Cementos Lima S.A. the largest of all and with a production capacity of 1,000,000 tons per year. The information obtained by interview and the subsequent study confirmed that cement companies have and will have idle capacities. The cement companies are all remote from Paramonga and all have convenient supplies of limestone. Cementos Lima S.A., for example, mines limestone at a quarry adjacent to the kilns. Not only does the company minimize transport costs, the limestone has an ideal balance of ingredients for cement making. In short, the company needs not purchase raw material from outside. Other cement companies are more or less in the same condition.

(2) Slaked lime

The byproduct slaked lime from the acetylene generator is grey in Color because it contains fine particles of carbon. SPL studied possibility of effective utilization of the byproduct slaked lime a sample of which the JICA study team left with SPL. Of 42,000 tons per year of production about 9,000 tons per year may be used within SPL's Paramonga complex to replace limestone now being purchased. SPL considers the value of slaked lime to be about 50 US$ per ton for slaked lime.

Slaked lime may also be used as a raw material for cement manufacture if demand exists. As is exactly the case with quick lime, Slaked lime cannot be Sold to Cement manufacturers.

4.12 Possibility of Acetylene Based Chemical Industry

The chemical industry of Peru is still in early developmental stage. Firstly, the domestic manufacturing industry is too small in size to support by product offtake a large chemical complex. Secondly, a huge deposit of limestone of good quality was not identified by this feasibility study. Thirdly, the development of the immense hydroelectric power resource would be costlier than was imagined. All these combined, the possiblitity of establishing an acetylene-based chemical industry is not very near.

4.13 Conclusions of Market and Demand Study

From the foregoing discussions are drawn the following conclusions. To summarize:

(1) Size of the domestic PVC market

The forecast domestic demand obtained by use category method which gives about 20,000 and 25,000 tons per year demands for 1988 and 1990, respectively, appears more realistic than the more optimistic demand given by the correlation method. In view of the inherent uncertainty of the market behavior, 10 to 15 percent deviations on both plus and minus sides must be taken into consideration when deciding the project size. Therefore, the results of the correlation method should not be used to support a larger capacity so that the project will not run a risk of having too big a capacity and under-utilizing it.

(2) Price of PVC

The price of domestic PVC, 1,100 US$ per ton as of June 1983, has been competitive with imported PVC, although there have been relative advantages and disadvantages depending upon the CIF prices and rate of customs duty and associated expenses with the duty. Therefore, use of 1,100 US$ per ton price for the financial analysis is recommended.

(3) Possibility of substitution for other plastics

The possibility of substitution by PVC for other types of plastic is not counted in forecasting the future domestic demand of PVC. This possibility certainly exists. On the other hand, however, there exists equally certain possibility of other plastics replacing PVC. Which possibility is more likely is not quantitatively assessed at this moment. Therefore these possibilities are both included in the demand forecast. It might be added that by establishing good reputation for quality, SPL could penetrate food wrapping plastic market so far occupied by PE.

(4) Possibility of export

Likewise, the possibility for exporting PVC to other Andean countries is not counted in the demand forcast. Depending upon the price of domestic PVC and import duty rate, there exist both possibilities; that is, possibilities of Peru exporting and importing PVC. It is far more important for this project to command the domestic market than try to sell under severe international conditions.

(5) Demands for intermediate, side productions and byproducts

The demands for intermediate products, side products or byproducts are negligble. Therefore, any added investments for the purpose of producing these products are not recommended. During the final stage of the study, the study team was informed that SPL's test on the slaked lime sample the study team left with SPL confirmed the possibility of using 9,000 tons per year of the slaked lime in Paramonga complex.

(6) Quality control

In view of the importance of the quality of the products in its competitive strength against imported products, establishment of quality control organizaitons in SPL is recommended.

CHAPTER 5 PROJECT SCHEME

Arriving at the optimum project scheme constitutes a great portion of a feasibility study unless a project scheme is defined from the beginning for some reasons or other. This is particularly true when there exist among conceivable schemes no clear advantages, disadvantages or risks of one scheme over others. The most important consideration is decision on capacity. Actually in many cases, marketing potential of products or availability of raw materials plays a decisive role as constraint in determining the project capacity. In other cases the maximum technically proven capacity or, quite oppositely, minimum economic capacity of a process is the determining factor. Also important a consideration is how diversified the project under study should be; or, in other words, whether the project should produce a number of products or the main product only. Availability of funds also works as constraint to limit possible alternatives. Usually, approaches to arriving at the optimum project scheme are at first to limit the possibilities by such costraints as mentioned above and then to examine relative advantages and disadvantages of the alternatives that have survived such tests.

In the case of this feasibility study, the project scheme was first preliminarily determined at the closing stage of the field survey as a result of the findings and then agreed on between SPL and JICA as recorded in Interin Report. The selected project scheme was finally confirmed by the subsequent study in Japan. The technical works and evaluations were done on the project scheme.

This chapter describes how JICA arrived at the project scheme, what alternatives have been examined, and the reasons for supporting the selected project scheme.

5.1 Conceivable Alternatives

Before the field survey started, JICA had prepared three basic alternative schemes as shown on Figures 5-1, 5-2, and 5-3 on Pages 5-3, 5-4, and 5-5.

Project Scheme (1) on Figure 5-1 is the simplest. All the operations from limestone quarrying to PVC polymerization are geared to the production of PVC only. Project Scheme (2) on Figure 5-2 produces calcium cyanamide, a nitrogenous fertilizer, together with PVC. Calcium cyanamide is a very good nitrogenous fertilizer with insecticide and soil nutralizing effects and can be easily produced by blowing nitrogen into a bed of hot calcium carbide. In both Project Schemes (1) and (2) VCM is supplied by the reaction between acetylene and hydrogen chloride to be produced in Paramonga Plant.

Project Scheme (3) is different in this respect. Project Scheme (3) assumes producing more PVC than possible with hydrogen chloride obtainable from the existing electrolysis plant. This project scheme leaves the present VCM production line from imported EDC operating which supplies additional VCM and hydrogen chloride.

Minor variations to these altenatives were also considered possible. Suppose there are markets for quick lime, calcium carbide or acetylene, production of additional quantities of these intermediate products may be contemplated with some allowances given to the capacities of the intermediate facilities.

Viability of Project Scheme (2) depends entirely upon market of calcium cyanamide which the field survey confirmed to be potentially great but virtually non-existent at present. Peru depends on the fertilizer plants in Talara, Cachimayo and Callao for the supply of nitrogenous fertilizer. The plant in Callao produces ammonium nitrate and ammonium sulfate. The latter two plants produce ammonia and urea. The products from these plants are distributed throughout the nation and the Peruvian farmers generally do not even know the name of calcium cyanamide.

Calcium cyanamide is considered suited to rice paddies in the jungle area. One estimate puts the ultimate demand at as high as 50,000 tons per year. There is, however, a long way to go to developing the market in view of the fact that calcium cyanamide is virtually unknown among farmers and that urea produced by Petroperu at Talara plant is distributed throught the nation. Having studied such market situation JICA considers it rather adventurous to include production of calcium cyanamide in the project scheme to which SPL has also agreed. Thus Project Scheme (2) has been dropped.

Project Scheme (3), as was mentioned previously, assumes producing more PVC than possible with hydrogen chloride obtainable from the existing electrolysis plant. The

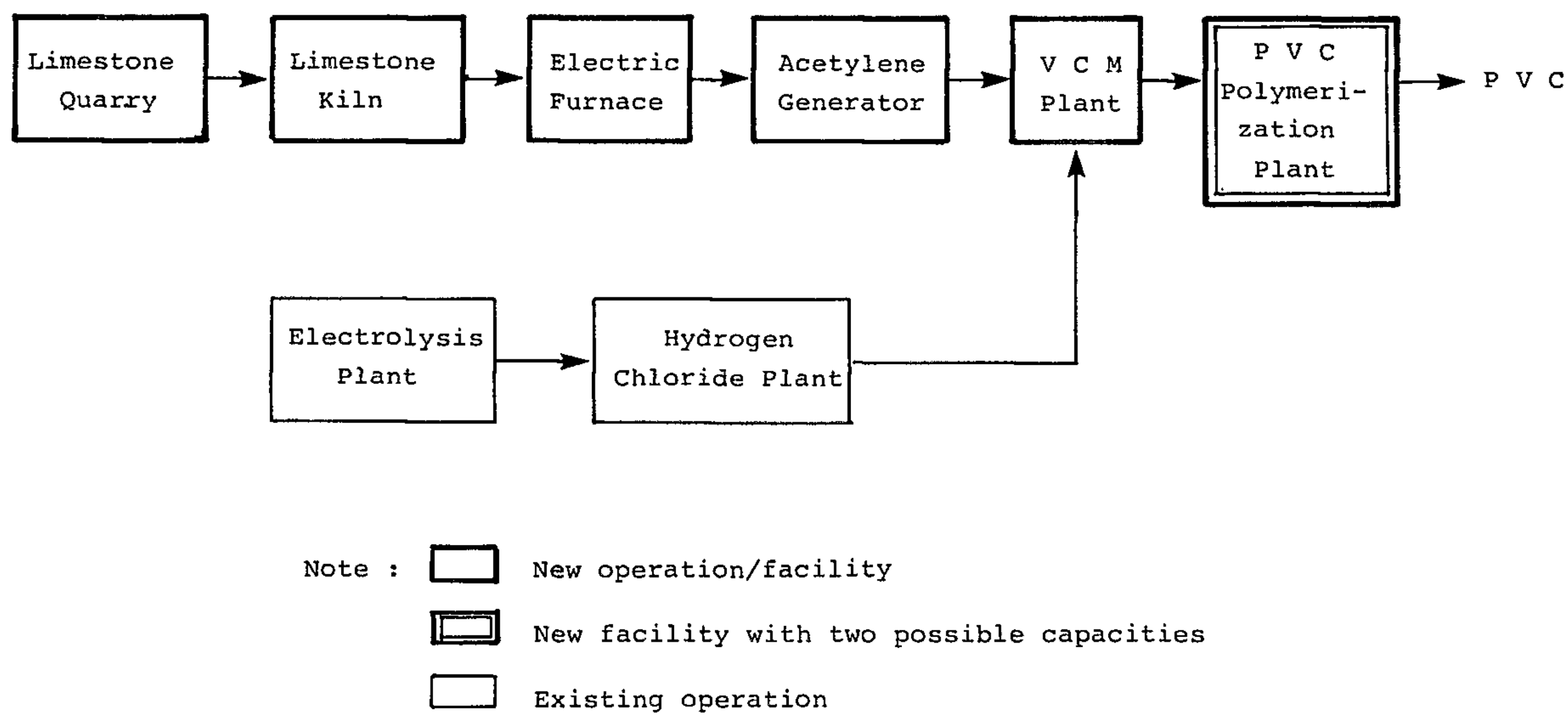


Figure 5-1 Project Scheme (1)

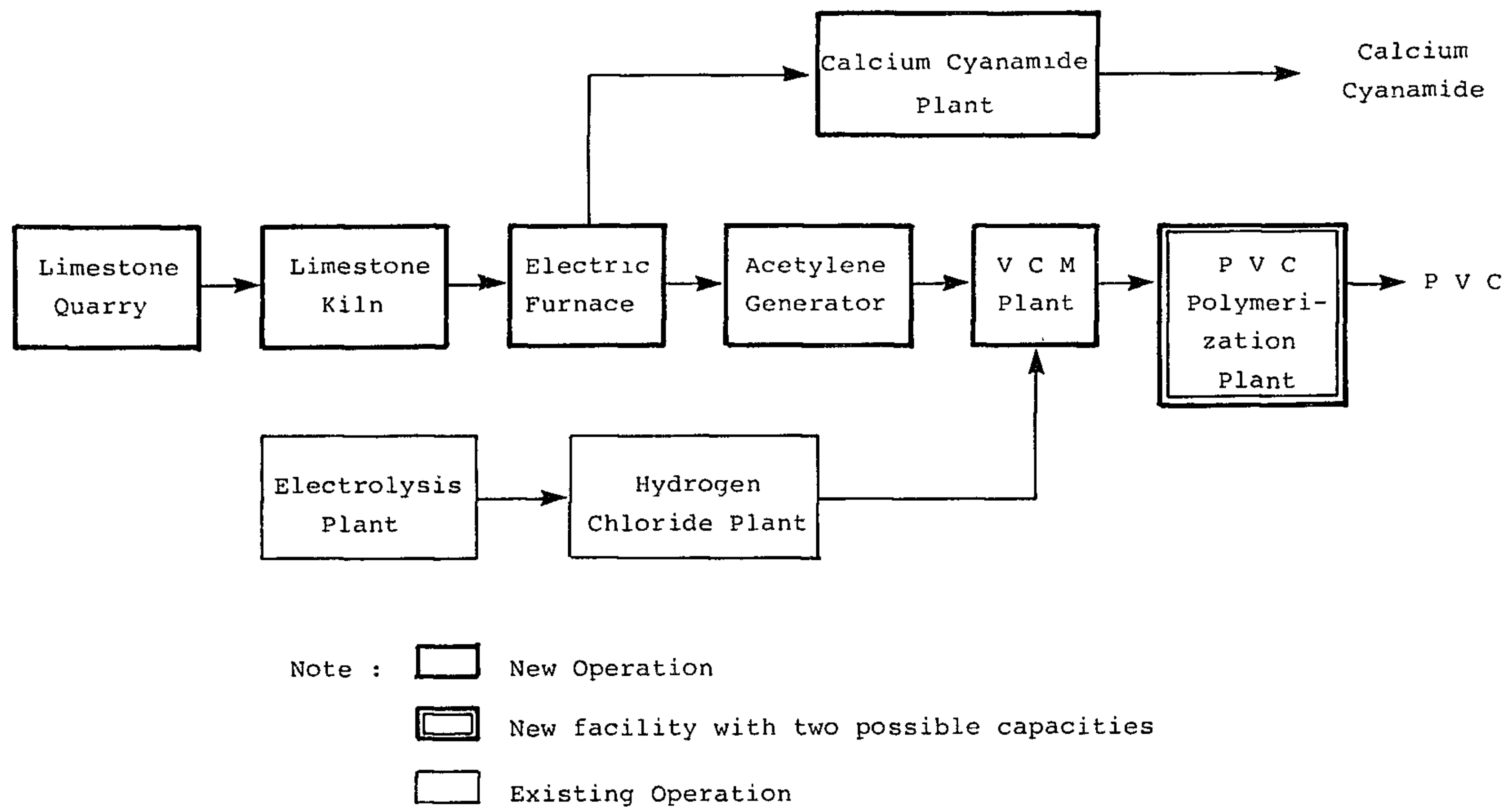


Figure 5-2 Project Scheme (2)

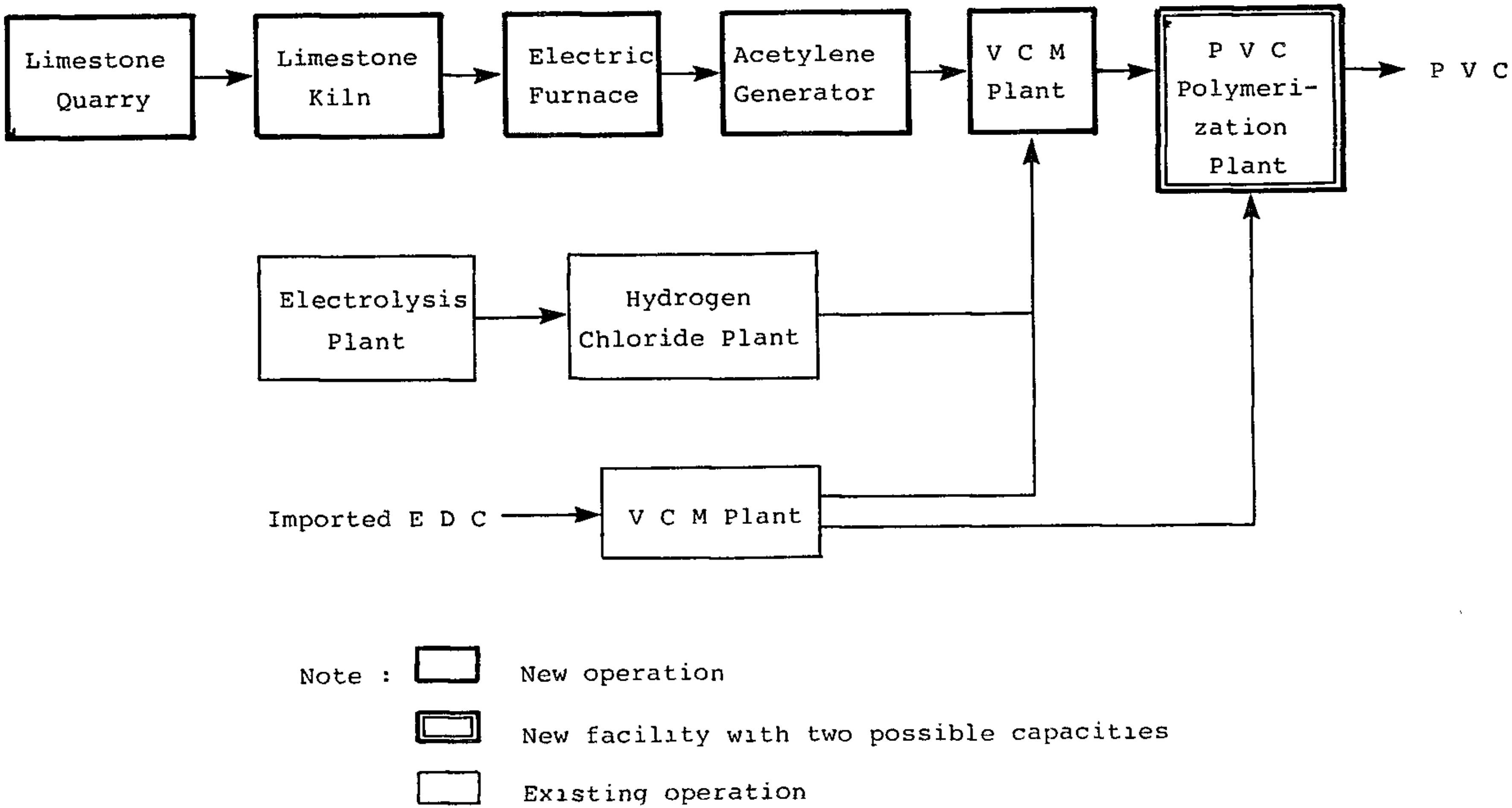


Figure 5-3 Project Scheme (3)

excess hydrogen chloride now being produced and disposed of in the sea by SPL amounts to 20,000 to 25,000 tons per year which corresponds to 33,000 to 42,000 tons per year of PVC. As was elaborated in CHAPTER 4, MARKET STUDY, the forecast demand of PVC does not permit the project capacity to largely exceed 25,000 tons per year. SPL and JICA have both agreed that Projec Scheme (3) is unrealistic and therefore should be dropped. Thus, Project Scheme (1) is the only project scheme that has survived these tests.

5.2 Factors Affecting Project Capacity

During the preliminary survey of January 1983, SPL and JICA preliminarily set the capacity as PVC at 24,500 tons per year. This was not meant to define the capacity of the project at 24,500 tons per year. The study team conducted of its own an intensive study on the question of project capacity.

Among the factors affecting the project capacity, forecast market situation is overhelmingly important. The availability of the raw materials does not practically act as a limiting factor. The availability of utilities such as electricity, industrial water, steam proves not to be a constraint within the range of the capacity being considered. The plant site prepared is wide enough.

Given that forecast market situation is the determining factor, the project capacity is studied from the viewpoint of the market potential. At the closing stage of the field survey the project capacity was determined to be 25,000 tons per year as PVC, subject to confirmation by further study in Japan. As are stated on Page 3-7 of Interim Report, rates of growth of the demand from 1982 to mid 1988, the year supposed for startup, have been calculated on three levels of assumed demand of 1988 together with running rates of a 25,000 tons per year plant as:

Table 5-1 PVC Demand and Growth Rate

1982 Demand	Rate of Growth,%	Demand in mid-1988	Running Rates,%
14,460	9.6	25,000	100
14,460	5.6	20,000	80
14,460	3.2	17,500	70

The study team figured from the information obtained that a growth rate around 5 to 6 percent would be realistic to which SPL also agreed. With a forecast demand of 20,000 tons per year, operation at 80 percent of the capacity could be expected at the initial year which seemed acceptable.

The above justification of the capacity is based on projection of the demand. Other approaches to the future demand developed in CHAPTER 4, MARKET STUDY, yield more or less similar results to the forecast based on projection. JICA, therefore, considers that 25,000 tons per year is an appropriate capacity. The technical and economic studies conducted in Japan do not give any reason for changing the project capacity.

With the project capacity set at 25,000 tons per year, the capacities of all the upstream operations or facilities are aligned to this capacity; namely:

Table 5-2 Intermediate Flows

	Tons per year unless otherwise stated
VCM plant	25,500
Acetylene generator *	9,945,000
Electric furnace, as carbide	35,000
Limestone kiln, as quick lime	32,200
Limestone quarry, as limestone	58,000

* Cubic meters per year at normal temperature and pressure

The stream day capacities must have allowances for plant shutdowns for maintenance and unexpected causes. The following stream day capacities are assigned to the plants:

Table 5-3 Stream-day Capacity

	Tons per year unless otherwise stated
PVC Polymerization plant	75
VCM plant	77
Acetylene generator *	28,743
Electric furnace, as carbide	101
Limestone kiln, as quicklime	93
Limestone quarry, as limestone	168

* Cubic meters per day at normal temperature and pressure

Peru does not have statutory regulations specifying frequencies and durations of plant shutdowns for reason of safety. For this project a 95 percent operation factor or 346 days operation a year is presumed.

Another important question about capacity concerns the capacity of PVC polymerization plant; in other words, which is better to keep the existing 7,000 tons per year unit operating and install an 18,000 tons per year plant or to suspend the operation of the existing plant and install a 25,000 tons per year plant. This is a question of economy and operating expediency. During the field survey JICA chose the latter alternative on the grounds that the incremental investment cost of a 25,000 tons per year unit over an 18,000 tons per year unit would be marginal and that disadvantages of operating two plants with a double manpower requirement and various operating inefficiencies for the entire project life would far outweigh the savings in the total investment cost.

This justification has been vindicated by the study in Japan. The estimated investment cost of the 25,000 tons per year PVC polymerization plant is 11.5 million US dollars. Assuming the investment cost to vary in proportion to 0.6 th power of the plant capacity, the investment cost of the 18,000 tons per year plant is calculated to be 9.5 million US dollars. The 25,000 tons per year unit is only 2 million dollars more expensive than the 18,000 tons per year unit which corresponds to about 3 percent of the total investment cost.

5.3 Factors Affecting Selection of Quarry

In selecting the quarry the conditions that the quarry should meet are:

1. The quarry contains sufficient reserves of limestone of required quality which are:

$CaCO_3$,%	98 minimum
SiO_2 ,%	1.5 maximum

   Retain sufficient strength after heating at 1300°C for 2 hours.

2. The distance of transportation is short.
3. Infrastructure such as road is adequate.

With close assistance of Mr. Figueroa, a geologist of SPL, JICA surveyed the following nine candidate quarries during the field survey:

Casma
Yautan
Tinta
Norca
Tarica
Pariahuanca
Tumac
Navas
Chacapalpa

(Refer to the map at the end of this chapter)

Based upon the conditions of the limestone deposits, conditions of the surroundings and the results of the laboratory tests on the samples obtained during the field survey, Pariahuanca was selected as the quarry and thus recorded in Interim Report. The results of the laboratory test on 52 samples conducted after the field survey further support this decision as shown on Table 6-1.

Casma quarry being located relatively close to Paramonga would be a good one but the samples failed the test. Yautan is now quarried on small scale but the quality is not adequate for a large electric furnace as this project.

Tinta, though at an altitude of 3,500 to 4,500 meters above the sea level, has a formation as thick as some 100 meters and, therefore, suited to large scale mining. The samples, however, showed too high silica contents and became fragile upon heating.

Norca is also being quarried by manual work on small scale to make quick lime. This limestone is pulverized upon heating. Tarica produces too soft a limestone and is unsuitable. Tumac produces only crystalized stone and is therefore not suitable. Navas deposit is too small in size. Chacapalpa is known to produce limestone. The formations of Chacapalpa are, however, so complicated that it is difficult to sort out limestone of desired quality.

Pariahuanca which JICA has finally selected is located about 20 kilometers north of Huaraz in the central region of Ancash. Limestone outcrops at two levels from 50 to 70 meters and also from 300 meters above the highway on both sides of the River Santa for a length of about one kilometer. The rock is hard enough which has been confirmed by field survey and the laboratory test. The limestone deposits lie just along a very good highway leading directly to Paramonga over a distance of some 200 kilometers. Therefore, the transportation of limestone to Paramonga will be easy. There is a small village nearby but it does not seem difficult to buy their land. It is also necessary to protect an electric cable and an agricultural canal that run along the deposit from possible damages. The owners of the quarry are identified as Comunidad Campesina de Shumay and an individual, Eduardo Navas.

5.4 Factors Affecting Decision on Site

Finding a good limestone quarry is a matter of vital importance to the viability of this projects. JICA was very much concerned about this question. At the time of the preliminary survey JICA had to consider possibility of developing a quarry in a remote area if one could not be found near Paramonga. In such a case it would make economic sense to install the limestone kiln and electric furnace near the quarry separate from the other facilities to be built at Paramonga. This possibility is mentioned in the Minutes of Meeting between Sociedad Paramonga Limitada and the Preliminary Japanese Survey Team dated February 2, 1983; quote The study shoud include the possibility that the carbide plant could be situated outside Paramonga. unquote.

By converting limestone into carbide the weight is reduced to about 57 percent. This would reduce the cost of transportation from the quarry to Paramonga. Conversely, coke weighing some 32 percent of the limestone has to be transported to the carbide plant site in the remote area. The real economic of locating the limestone kiln and carbide plant near the quarry in the remote area depends on many factors of which important ones are: (1) relative transportation costs of limestone to Paramonga, carbide to Paramonga, coke to the carbide plant, coke to Paramonga, (2) conditions of infrastructure around the quarry, (3) availability of electricity, (4) incremental construction and operation costs at the quarry as compared to those in Paramonga, and (5) managerial disadvantages associated with having the plants at two different places.

Pariahuanca having been identified as the quarry, this question can be studied in practical and concrete terms. The distance between Pariahuanca and Panamonga is relatively short connected by a very good highway. There is, therefore, no great motive to economize transportation cost of limestone. Regarding the transportation of coke, the port of import will be Chimbote. Shown below is a comperative study of transportation costs between these two cases.

Table 5-4 Comparative Study of Transportion Cost

	Quantity (tons/year)	Case 1	Case 2
Location of Limestone Kiln and carbide plant		Paramonga	Pariahuanca
Limestone	58,000		
From		Pariahuanca	
To		Paramonga	
Distance, km*		230	
Unit cost, Soles/ton		14,561	
Million Soles/year		844.5	
Carbide	35,000		
From			Pariahuanca
To			Paramonga
Distance, km*			230
Unit cost, Soles/ton			17,851
Million Soles/year			624.8
Coke	19,800		
From		Chimbote	Chimbote
To		Paramonga	Pariahuanca
Distance, km		230	240
Unit Cost, Soles/ton		14,876	18,407
Million Soles/year		294.5	364.5
Total Million Soles/year		1,139.0	989.3

* Actual traffic mileage on the road

The above comparative study shows a marginal difference, about 150 million soles or 97,400 US dollars per year, in favor of Pariahuanca. This amount may be considered negligible against such possible disadvantages of locating these plants at Pariahuanca with increased construction cost, managerial difficulties, incremental labor costs, etc. Under such conditions JICA recommends that all processing facilities be located in the Paramonga plant site.

As will be explained in CHAPTER 7, PLANT SITE, the Paramonga plant site may be considered to be the only ideal selection under the present circumstances for constructing and operating the plants.

5.5 Project Scheme

To summarize the foregoing discussions the project scheme is defined as below:

(1) Manufacturing flow scheme

The manufacturing flow scheme is basically as shown on Figure 5-1 Project Scheme (1) and the new PVC polymerization plant will have a full capacity of 25,000 tons per year, or as shown on Figure 5-4 Project Scheme (Final) on the next page.

(2) Capacity

	Calendar year capacity (tons/year)	Stream day capacity (tons/day)
PVC polymerization plant	25,000	75
VCM plant	25,500	77
Acetylene generator *	9,945,000	29,865
Electric furnace, as carbide	35,000	101
Limestone kiln, as quick lime	32,200	93
Limestone quarry, as limestone	58,000	168

* Calendar year capacity and stream day capacity are expressed in terms of cubic meters per year and per day, respectively, of acetylene at normal temperature and pressure.

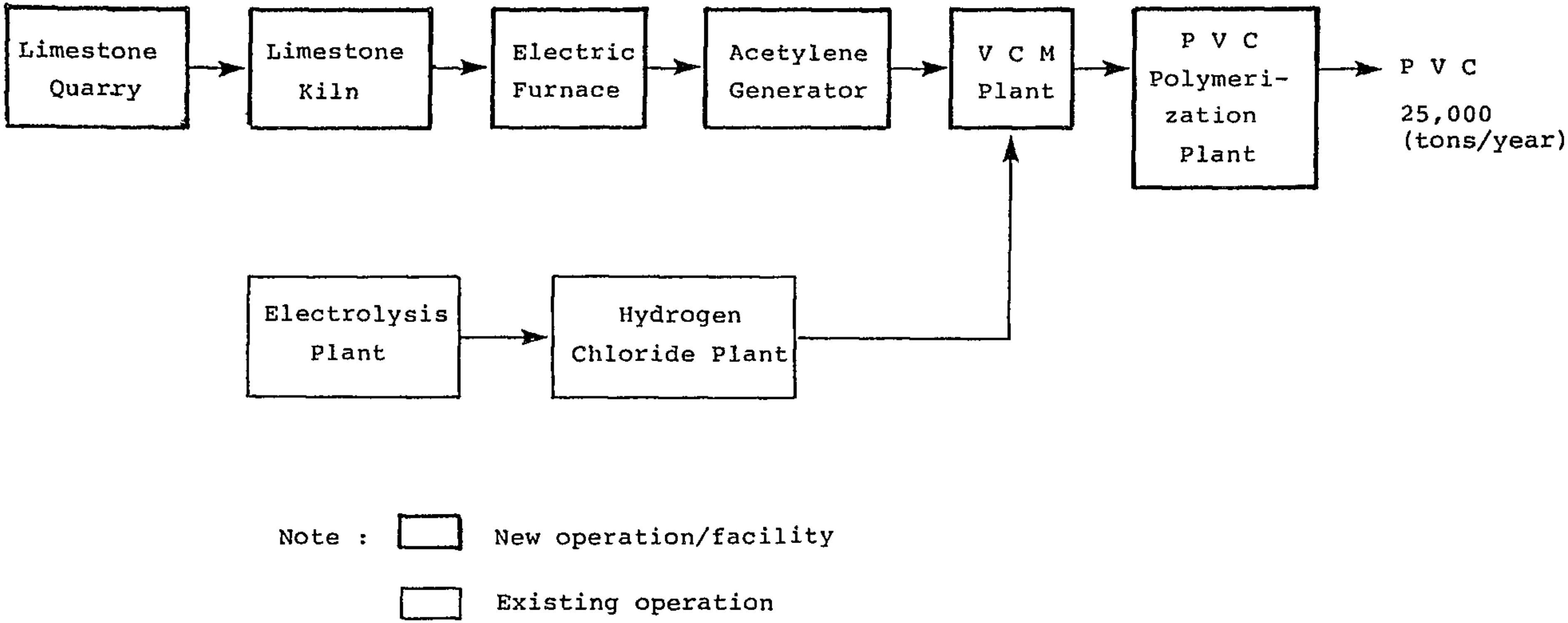


Figure 5-4 Project Scheme (Final)

(3) Limestone quarry

The limestone quarry is at Pariahuanca. The sized limestone will be transported to Paramonga plant site.

(4) Plant site

All the manufacturing facilities from the limestone kiln to PVC polymerization plant will be located at the Paramonga plant site.

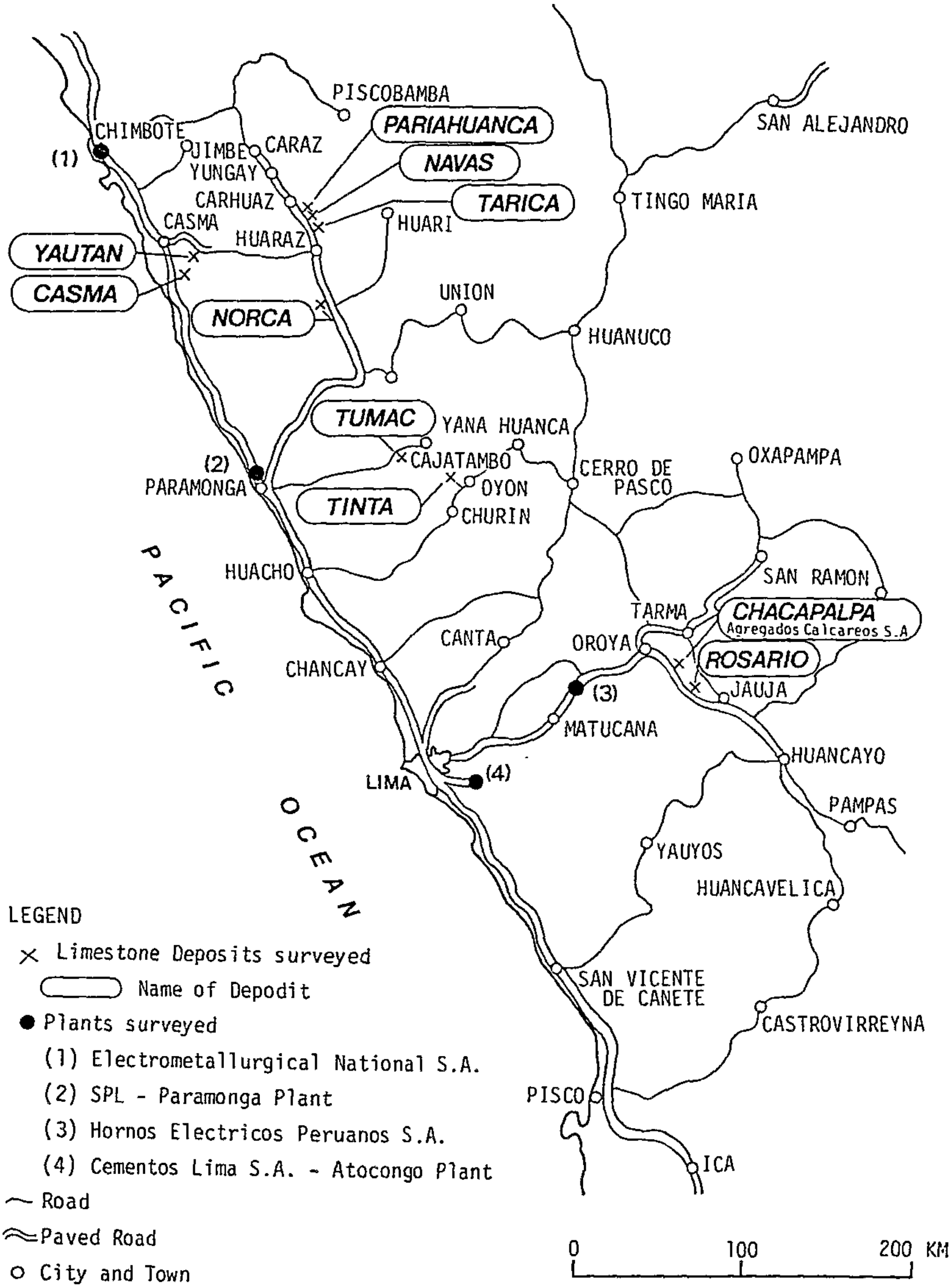


Figure 5-5 *Location Map of the Surveyed Limestone Deposits and Plants*

CHAPTER 6 LIMESTONE

Note: The geological terms used in this chapter are explained in Table 6-3, at the end of the chapter.

6.1 Overview

Pariahuanca deposit is located to the north of Paramonga on the east bank of the Santa River at 2,800 meters above sea level. From Paramonga Pariahuanca is accessed by travelling approximately 130 kilometers up the Fortaleza River to the Conococha Ridge, 4,190 meters above sea level, and travelling northwest approximately 100 kilometers down the Santa River to the deposit.

The limestone deposit of the Pariahuanca stratum belongs to the Albian group of the Mesozoic era's lower Cretaceous period. This stratum consists principally of grey to dark grey limestone and contains in its upper part muddy stones with dolostones and nodules, and also contains such fossilized extinct plants and animals as ammonites and brachiopoda.

The stratum runs in N20°-40°W direction, with a dip of 15°S—80°S, and below the stratum lie mudstone, red sandstone, and the Carhuaz stratum. The Carhuaz stratum consists of alternate layers of sandstone, shale, and mudstone, between which in the lower part are thin limestone, delostone and gypsum layers.

The two strata observable at an outcrop of the limestone deposit are considered to form a single continuation. The outcrop at the eastern end clearly shows an anticlinal rock structure.

6.2 Natural Conditions and Quarry Reserves

The Peruvian Andes is divided by the Santa River into eastern and western ranges. Pariahuanca is located at the foot of the eastern range, 2,800 to 3,300 meters above sea level at 9°20'S and 77°35'W. This site is 24 kilometers to the south of the Uascaran, the highest peak, 6,746 meters, of the Peruvian Andes. The topography of the site is mountaneous with a relatively gentle slope. The limestone outcrops horizontally and forms a 30 to 50 meter high walls.

The local flora is thin, consisting mainly of short thorny trees, cacti, and some xerophylic plants. Green leaved trees are found on the river sides and near the irrigation canals, and eucalyptus borders the roads around the villages. In winter, the temperature may drop to as low as 5° to 10°C at night, but rises to 25° to 30°c in the daytime.

Near the quarry is a farm, a farm house, roads, an irrigation canal and a power transmission line, and lime kilns. The irrigation canal is cut through the limestone deposit and; therefore, requires some protection from limestone excavation prior to development.

As there was no accurate information available regarding the boundaries of limestone with other rocks--rhyolite, acid clay, tuff, mudstone, shale and sandstone--that occur with the limestone, the quantity of deposits has not been accurately calculated. The lower deposits are estimated to contain 50 to 100 million tons of limestone per block; however, the upper deposits are considered far greater. It is recommended to ascertain the quantity of deposits before actually developing the quarry.

6.3 *Quality of Limestone*

The Pariahuanca deposit has upper and lower outcrops running intermittently in almost the same direction. The lower formation has three blocks all forming a wall facing the west. The samples were taken from four sections shown in Figure 6-1 designated as PA, PB, PC and PD. Samples PA and PD were taken from the lower deposit and PB and PC from the upper. The results of the analyses are shown in Table 6-1. In general, this stratum consists of grey and dark grey non-crystalline limestone and no ingression of igneous rock or crystalline limestone was found.

The limestone of the lower deposit is generally of acceptable quality though it contains white and pink-white mudstone at the middle and upper portions of the limestone layer. The analysis shows an average content of 1.01% SiO_2 in eight samples of PA2. Muddy limestone that contains 10% SiO_2 and 3% Al_2O_3 is easily discernible by sight for its white appearance and-softness. The chemical composition of PA and PD limestone samples from the lower deposit was approximately 1.0 to to 1.5% SiO_2; 0.6 Fe_2O_3/Al_2O_3 and 0.4 to 0.6% MgO.

In the upper deposit, the limestone represented by samples PB and PC occurs over several hundred meters along the ridge with a layer thickness of 100 to 150 meters. The quality varies considerably; dark grey limestone is found on the western side; brownish metallic limestone in the central portion; and pink-white soft limestone on the eastern side. Of these, the last is considered to be secondary products, including travertin. A metallic limestone also exists which is a dolostone containing 6% Fe_2O_3 and 16% MgO. The pink-white soft limestone contains dark grey limestone pebbles and is good in both chemical composition and thermal properties. Brown nodules of other minerals (37.9% SiO_2, 30.9% Fe_2O_3 and 14.3% CaO) spots the limestone layer and cause variations in the quality of the whole.

The results of the laboratory tests taken together, Pariahuanca limestone is considered to contain on an average approximately 3% impurities and 53% CaO. The thermal property is also regarded as acceptable on heating at 1,300°C for two hours. The results of the laboratory tests are shown on Table 6-1 on the next two pages.

6.4 Quarry Plan

A detailed geological survey, trial borings and calculation of accurate quantity of the limestone and formulation of the optimum method of quarrying must be accomplished before excavation can actually start. The mining should start both at the upper and lower deposits from the startup of the project to have greater production capacity and wider latitude to control the chemical composition.

The preliminary design calls for installation of the crushing plant at the foot of PA deposit on the slope between PA and PD deposit. Storage yards for the sized limestone (30-70 mm) and the fine particles (less than 30 mm) will be located on the flat area—partly cultivated—down the hill.

116,000 tons per year of limestone will be mined by what is known as bench-cut method. The rock face is drilled by a crawler drill followed by blasting by explosives. The bench is by standard eight meters with an average of 60 degree inclination.

For the transportation of blasted limestone the wheel-loader will carry them for not more than 200 meters beyond which dump trucks will take over.

Table 6-1 Analysis of Limestone Samples taken from Pariahuance Deposits (PA, PB, PC, PD) Unit: %

Sample No.	Sample Description	Ig-loss	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	P_2O_5	SO_3	Total	Thermal properties
PA-1	Pariahuanca limestone	42.41	2.10	0.25	0.36	54.06	0.36	0.018	0.03	99.59	Fair
3	Grey brown vein	43.38	0.87	0.19	0.26	54.68	0.30	0.009	0.06	99.75	Good
4	"	42.99	1.05	1.41	0.27	53.39	0.53	0.009	0.05	99.70	Good
5	"	43.00	1.54	0.28	0.34	53.90	0.41	0.032	0.09	99.59	Good
6	"	43.99	0.26	0.18	0.06	55.08	0.28	0.011	0.03	99.89	Good
7	Grey brown white vein	43.42	0.63	0.22	0.17	54.91	0.24	0.009	0.06	99.66	Good
8	"	43.49	0.94	0.16	0.28	54.28	0.45	0.009	0.07	99.68	Good
9	"	43.67	0.72	0.49	0.21	53.90	0.65	0.021	0.07	99.73	Good
Average	-	43.29	1.01	0.40	0.24	54.28	0.40	0.015	0.06	99.70	-
PA-2	Muddy limestone	37.81	10.12	1.32	3.04	46.34	0.65	0.116	0.10	99.45	Poor
PB-1	Grey brown spots	42.81	1.71	0.15	0.23	54.41	0.32	0.015	0.06	99.71	Fair
2	"	43.16	1.26	0.17	0.31	54.62	0.22	0.008	0.03	99.78	Good
3	Grey calcite vein	42.92	1.25	0.39	0.55	54.49	0.16	0.009	0.02	99.79	Good
6	Grey brown vein	41.76	2.12	1.65	0.52	52.65	1.07	0.014	0.04	99.82	Good
7	Grey calcite vein & brown spots	42.76	1.66	0.44	0.38	54.23	0.18	0.011	0.02	99.68	Fair
8	Limestone: pink-white	43.18	0.96	0.14	0.38	54.71	0.12	0.060	0.26	99.81	Good
Average	-	42.77	1.49	0.49	0.40	54.19	0.35	0.021	0.72	99.76	-
PB4	Dolostone	45.07	0.48	6.17	0.66	31.54	15.81	0.013	0.02	99.76	Good
5	Nodule	15.41	37.92	30.88	0.56	14.38	0.32	0.057	0.03	99.56	Good
PC-1	White with black pebbles	42.87	1.70	0.24	0.36	54.34	0.14	0.011	0.03	99.69	Good
2	Grey calcite vein	43.24	1.04	0.13	0.50	54.30	0.40	0.014	0.06	99.68	Good
3	Black & white	43.25	1.38	0.18	0.20	54.38	0.31	0.011	0.02	99.73	Good
4	Grey, white brown	43.39	1.49	0.18	0.19	54.20	0.20	0.019	0.02	99.69	Good
5	"	43.77	0.36	0.05	0.08	55.26	0.04	0.014	0.01	99.58	Good
Average	-	43.30	1.19	0.14	0.27	54.50	0.22	0.014	0.03	99.66	-
PD-1	Calcite	43.06	1.40	0.56	0.45	53.11	1.11	0.009	0.03	99.23	Poor
2	Limestone	42.99	1.75	0.21	0.45	54.01	0.33	0.022	0.06	99.82	Good
3	Grey calcite vein	43.08	1.22	0.28	0.25	54.32	0.49	0.023	0.01	99.67	Good
4	Blue-gray	43.19	1.40	0.15	0.17	54.46	0.36	0.027	0.07	99.83	Good
Average	-	43.08	1.44	0.30	0.33	53.98	0.57	0.020	0.04	99.76	-

Table 6-1 Analysis of Limestone Samples taken from Pariahuance Deposits (PE) and the other deposits

Sample No.	Sample Description	Ig-loss	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	P_2O_5	SO_3	Total	Thermal properties
PE-1	Grey calcite vein	42.73	1.82	0.34	0.78	53.56	0.24	0.030	0.04	99.54	Good
2	Black & brown	43.48	1.24	0.36	0.15	54.21	0.26	0.030	0.04	99.77	Good
3	Light gray	43.15	1.40	0.31	0.31	54.18	0.24	0.011	0.04	99.64	Good
Navas Quarry	Grey	43.42	0.79	0.30	0.20	54.44	0.44	0.016	0.08	99.69	Good
Huaraz Roadside	Dark grey	40.13	4.09	1.19	1.20	49.84	1.33	0.036	1.76	99.58	Good
Tarica Quarry	Acid clay	7.76	72.19	0.57	18.40	0.01	0.24	0.210	0.17	99.55	SiO_2 glass
Parco	Dolomitic limestone	43.52	2.00	0.30	0.13	49.51	4.15	0.007	0.01	99.63	Good
1	Chacapalpa Travertin	43.67	0.40	0.03	0.15	54.87	0.12	0.005	0.56	99.81	Good
2	"	43.98	0.74	0.08	0.08	54.46	0.20	0.007	0.22	99.77	Good
Average	-	43.83	0.57	0.06	0.12	54.67	0.16	0.006	0.34	99.76	-
Rosario	Travertin	43.29	0.15	0.01	0.03	54.38	0.10	0.003	1.79	99.75	Fair
1	Matucana Travertin	43.88	0.10	0.02	0.03	55.22	0.18	0.007	0.42	99.86	Poor
2	"	43.83	0.65	0.05	0.11	54.57	0.45	0.032	0.09	99.78	Fair
3	"	43.59	0.11	0.02	0.07	55.28	0.20	0.009	0.41	99.69	Poor
4	"	43.81	0.09	0.02	0.03	55.36	0.12	0.007	0.41	99.85	Poor
5	"	43.77	0.04	0.01	0.02	55.31	0.18	0.009	0.46	99.80	Poor
Average		43.78	0.20	0.05	0.05	55.15	0.23	0.013	0.36	99.80	-
Matucana	Quick lime	11.33	0.01	0.01	0.06	85.45	0.24	0.014	2.52	99.63	Good
1	Timbote Limestone	42.83	1.16	0.40	0.54	54.15	0.51	0.016	0.01	99.62	Fair
2	Gray	43.19	0.72	0.79	0.20	54.42	0.32	0.014	0.01	99.66	Good
3	Quick lime	5.12	2.24	0.56	0.74	90.16	0.51	0.025	0.23	99.59	Good
4	Quick lime	4.36	4.13	0.83	0.96	88.73	0.59	0.032	0.04	99.67	Good

The crusher process will consist of a scalping unit for primary screening, a jaw crusher, and a double-screen type screen for secondary screening to 70 mm and 30 mm size. Stones larger than 70 mm will be recycled to the crusher. By this arrangement stones from 30 to 70 mm may be obtained at 50 percent yield.

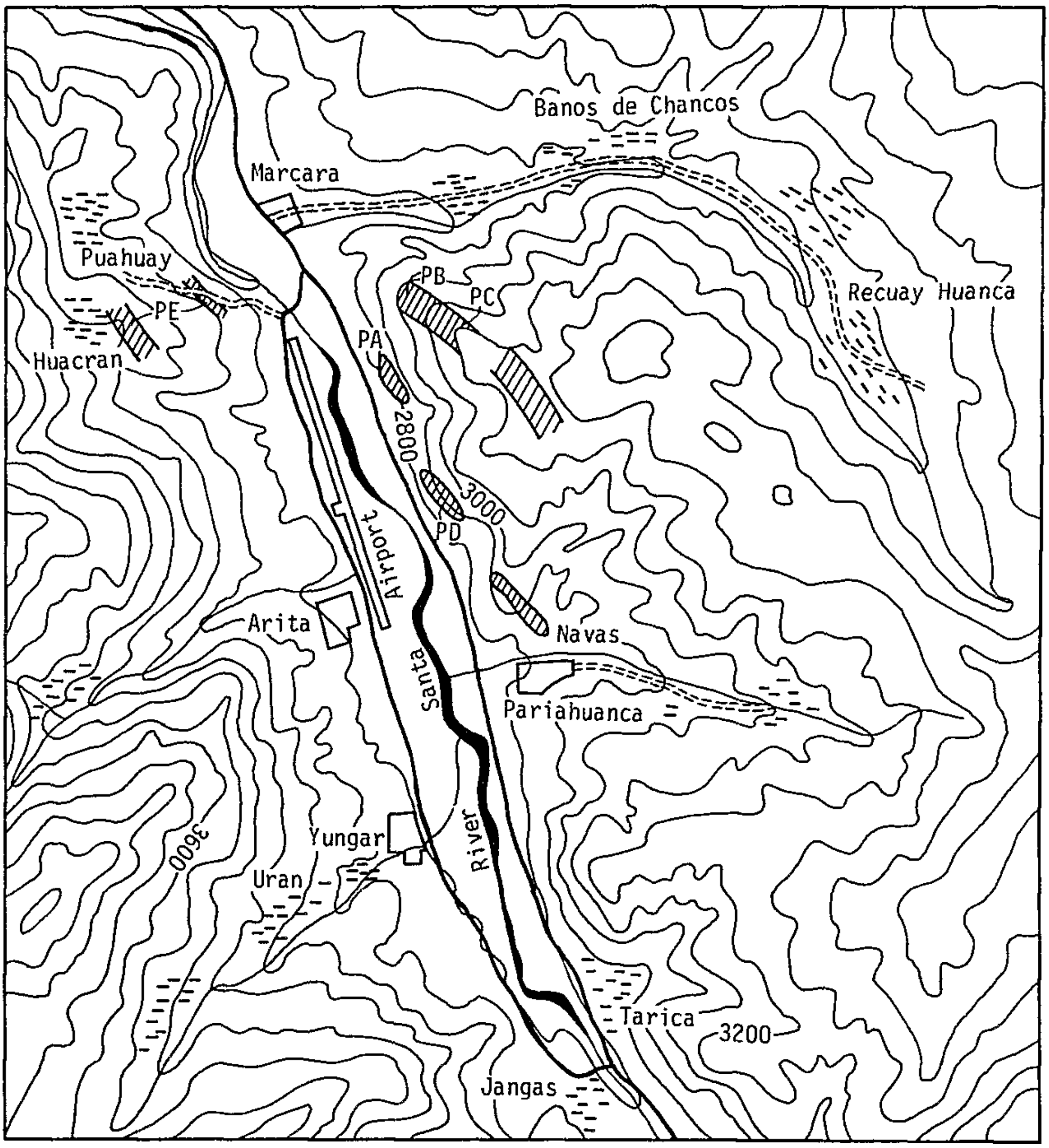
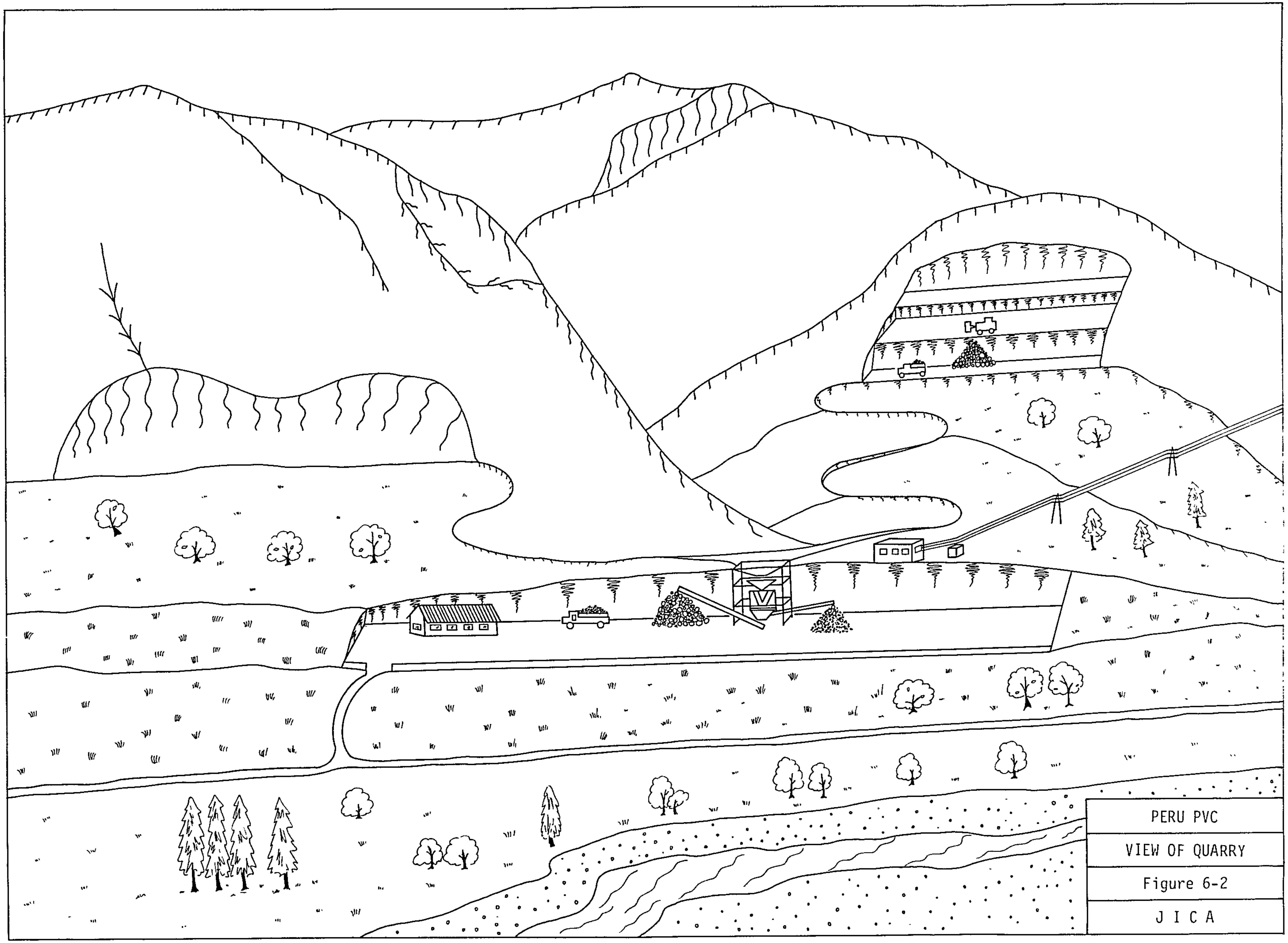


Figure 6-1 Topography of Pariahuanca Area

LEGEND

(hatched symbol)	Limestone deposit	(town symbol)	Town
PA–PE	Location of sampling	(village symbol)	Village
(solid line)	Asphalt road	(river symbol)	River
(dashed line)	Sand road		

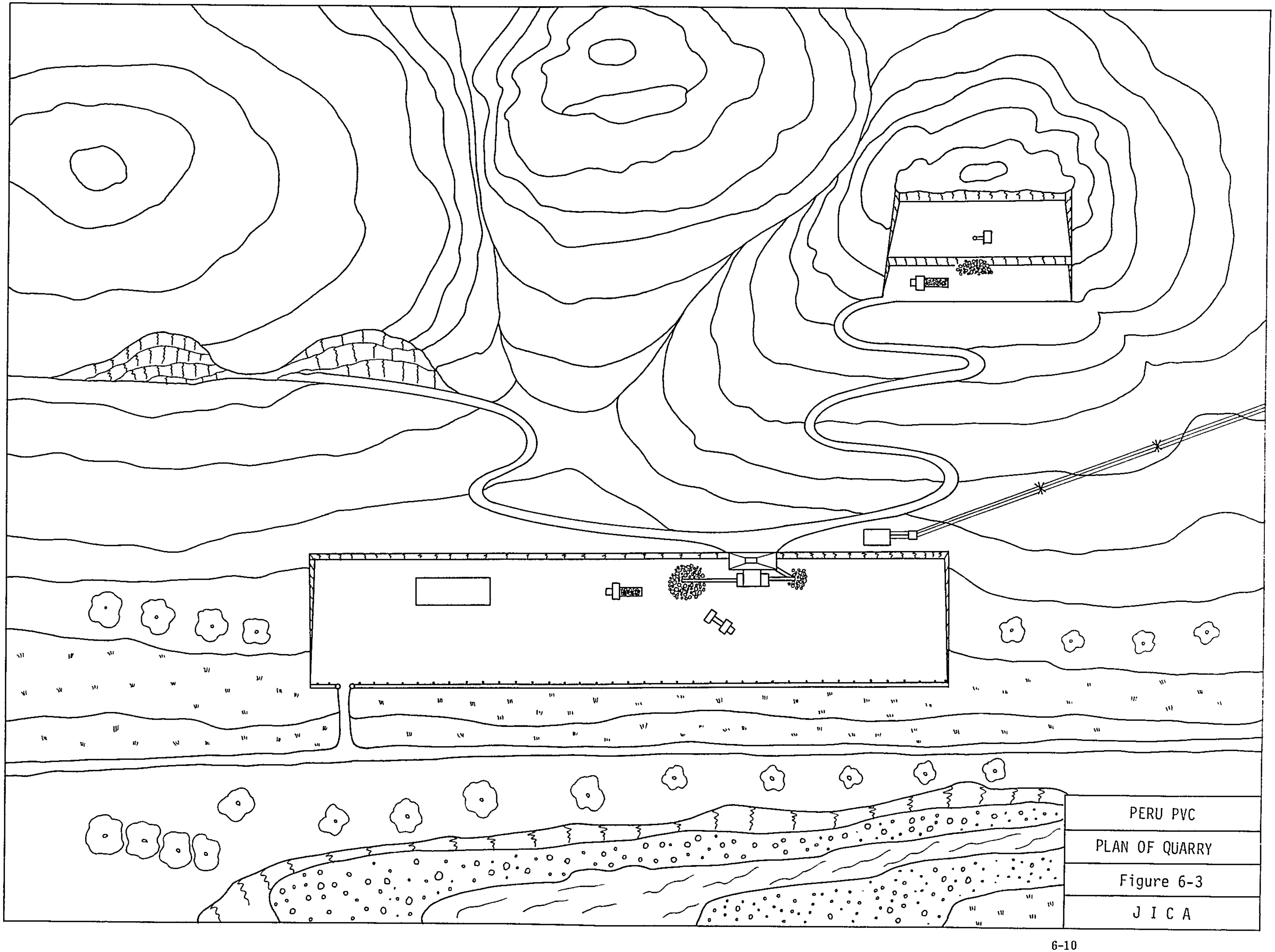


PERU PVC

VIEW OF QUARRY

Figure 6-2

J I C A

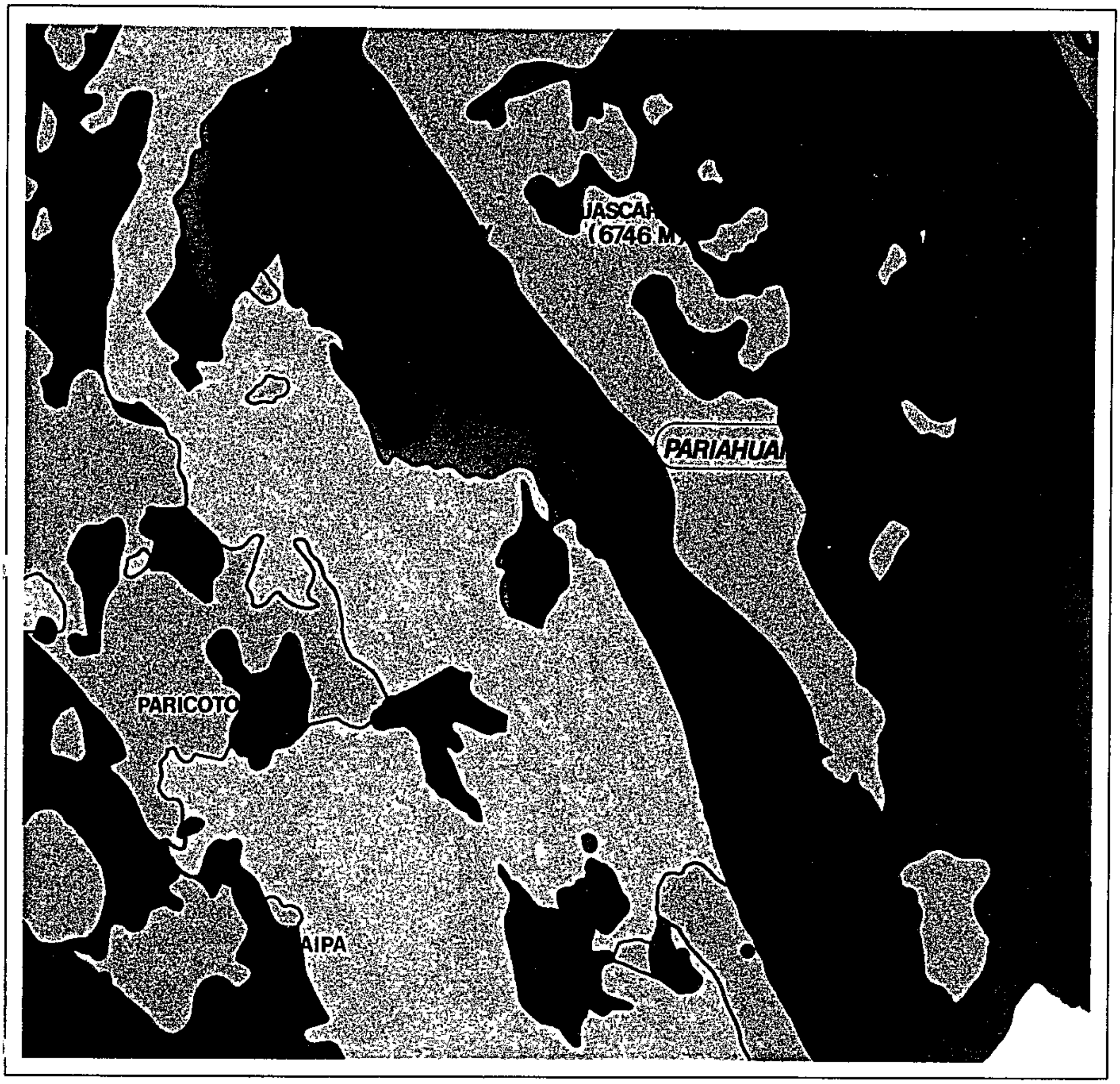


PERU PVC

PLAN OF QUARRY

Figure 6-3

J I C A



LEGEND

● Town
▲ Mountain

0 10 20 KM

Geological Classification

Age	Mark & Color	Formation or Rock
Quaternary	Q	Gracial deposit
Tertiary	KTi-a	Adamellite, Granite
	Ts-i	Ignimbrite
	KTi-t	Tonalite, Granodiorite
	KTi-vca	Calpuy form. Andesite Pyroclastic
	KTi-g	Gabbro, Diorite
Cretaceous	Ki-c	Casma form
	Ki-a	Pariahuanca form
	Ki-saca	Carhuaz form
	Ki-chim	Chimu form
Jurassic	Us-ch	Chicama form

Figure 6 - 4 Geological Map of Pariahuranca Area

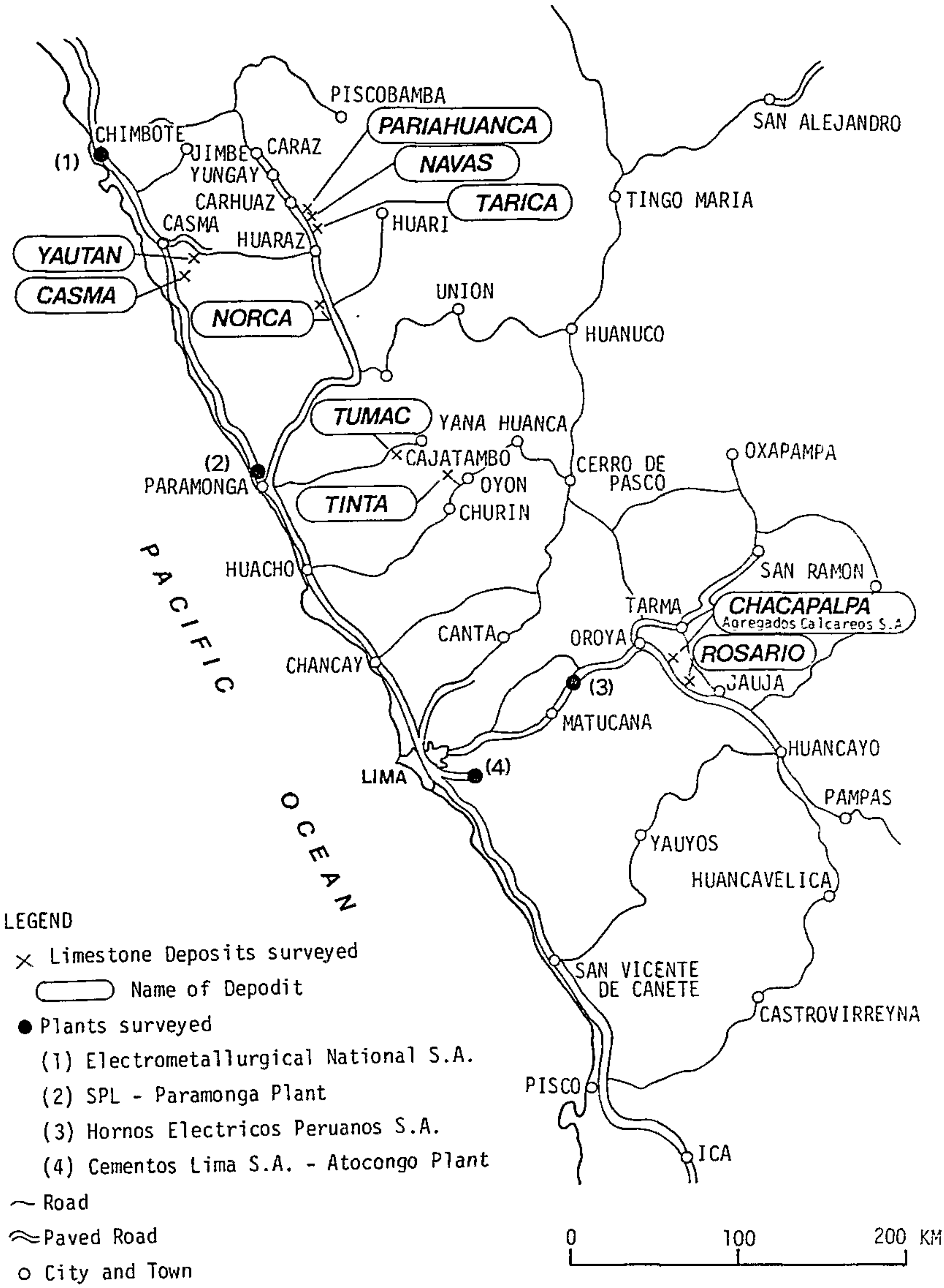


Figure 6-5 Location Map of the Surveyed Limestone Deposits and Plants

Stones smaller than 30 mm will be rejected. The sized limestones will be temporarily stored in the yard and then loaded by the wheel-loader to dump trucks which will carry the limestone to Paramonga Plant.

Table 6-2 Specifications of Mining and Crushing Equipment

Name of Machine	Qty.	Specification
Crawler drill	1	Rod length: 3m; bit gauge: 60 mm ϕ
Portable comperssor	1	17 m^3/min.
Bulldozer	1	20-ton class, with ripper
Wheel-loader	1	Bucket capacity: 3.1 m^3
Dump truck	12	11-ton capacity
Pneumatic hammer	1	Bit gauge: 30 mm ϕ
Scalping feeder	1	Mesh: 70 mm (vibrating or oscilating)
Crusher	1	Shinko Dyna-Jaw D-900, 220 kW
Screen	1	Double screen type; mesh: 70 mm and 30 mm
Conveyer belt	4	Width: 600 mm; 20 m x 2, 20 t/h x 2

The preliminary design calls for protection of the agricultural canal and power transmission line running parallel to the deposit and also purchase of the farm house.

6.5 Transporatation of Limestone

The route between Paramonga Plant and Pariahuanca is approximately 230 kilometers long. The maximum variation in altitude along the road is 4,200 meters. The road is paved with asphalt except for a short distance between Tarica and Pariahuanca which is gravel covered but would permit the passage of large-capacity turcks. At an assumed average speed of 50 km/h, a one-way trip requires approximately 4.5 hours; including loadings and restings, a round trip at the same speed requires approximately 10 hours. Since one truck can carry 16 tons, the transportation of 175 tons/day will require 11 dump trucks.

6.6 Environmental Conservation

Peru appears to have no specific laws regarding environmental conservations associated with mining and transportation of limestone. JICA, however, considers the following steps necessary to insure the safety and the protection of the environment. Therefore, these are included in this plan.

(1) Removal of private houses,

(2) Protection of irrigation canal and power transmission line,

(3) Measures to prevent stones from falling or flying,

(4) Measures to prevent dust, noise, and vibrations associated with use of explosives,

(5) Provisions for dumping surface soil,

(6) Prevention of surface water contamination in case of rain,

(7) The public authorities and the private sector must be consulted for an early resolution to these problems.

Table 6-3 Geological Terms

Geosyncline:	A crust that was folded by the orogeny and sank.
Mesozoic era (Jurassic and Cretaceous periods):	Geological ages may be broadly divided into the pre-cambrian, Paleozoic, Mesozoic era in turn is divided into the Triassic, Jurassic and Cretaceous periods (136 to 65 million years ago).
Cretaceous stratum:	Strata are chronologically divided the order of their sedimentation. Each layer is called by the name of the place in which it occurs. The strata that concern the present survey are from bottom to top, the Oyon, Chimu, Santa, Carhuaz, Farrat, Pariahuanca, Chulec, Pariatambo and Jumasha layers. The layers from the Pariahuanca layer to the lowerest Jumasha layer are called the Alibian group.
Casma:	A city located approximately 175 km northwest of Paramonga.
Pillow lava:	Globular mass of lava composed of basalt.
Chert:	Siliceous chemical sediment.
Pyroclastic rock:	Rock formed by volcanic clastic debris.
Subduction:	Movement of an ocean plate crawling under a continental plate (the cause of the Andes orogeny).
Cenozoic tertiary period:	The Cenozoic era is divided into the Tertiary (65 to 2 million years ago) and Quaternary (2 million years ago to the present) periods.

Tonalite:	A plutonic rock that consists mainly of labradorite (origoclase), neutral feldspar and biotite; a kind of diorite.
Contact metasomatic deposit:	Deposit produced under the influence of metasomatism caused by substances fed by magma, plus contact metamorphism; metal deposits tend to be produced and limestone or delostone from matrices.
Yautan, Pariahuanca, Ticapampa, Tumac, Tina, Chacapalpa:	See the Quarries Surveyed and Plant Map.
Travertin:	Limestone, spring sediment, stalactite grotto and onyx caused by chemical sedimentation; has a dense, striped structure.
Dolostone:	Sedimentary rock that consists of over 90% $MgCO_3$ and contains much dolomitic limestone.
Nodule:	Nodular or concretionary mass that is produced by the separation and concentration of the substances that form the binding within the sediment; in the case of limestone, modules are often caused by the sedimentation and silicification of mineral substances.
Rhyolite:	Acid volcanic rock; in the same category as liparite.
Acid clay:	Product of the weathering of rhyolite and tuff; contains such clay minerals as rhyolite and tuff.
Tuff:	Pyroclastic rock that was formed by the solidification of volcanic ash.

Bench-cut method:	Mineral mining method in which the deposit is cut in bench shape.
Face:	Surface on which mining is performed crushing the rock.
Load-and-carry process:	Loading and self-transport by means of a wheel-loader.

CHAPTER 7 PLANT SITE

7.1 Outline

Construction work will take place at two locations; one for limestone mining and processing facilities and the other for carbide and PVC manufacturing facilities.

The limestone mining and processing facilities will be located in Pariahuanca, at an altitude of approximately 3,500 meters in the Andes. A more detail of this site is given in Chapter 6.

This chapter concerns the SPL Paramonga Plant site where the carbide and PVC manufacturing facilities will be constructed.

7.2 Natural conditions of the candidate site

According to the official records covering the five year period from 1975 through 1980, Paramonga has the following natural conditions. Although located in the tropical zone, the climate is rather mild by the effect of the Antarctic cold current. Precipitation is very low and wind very gentle. Overall, the site has a very favorable weather conditions.

(1) Temperature, ^{o}C

	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
max.	32	32	27	27	25	24	24	20	22	22	23	27
min.	18	18	17	19	19	17	17	12	14	14	19	17
ave.	26	26	25	25	25	22	20	18	19	19	20	24

(2) Humidity, percent

	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
max.	95	95	95	100	100	100	92	94	99	99	99	95
min.	60	57	61	64	60	59	69	71	72	58	62	60
ave.	79	82	80	80	82	80	80	90	90	88	96	80

(3) Wind velocity, maximum 6 m/sec

(4) Prevailing wind direction: southwest

(5) Rainfall, maximum 10 mm/h

Rain is very rare on the Pacific coast. The entire coastal area except river basins, therefore, tends to be deserts.

(6) Earthquakes

According to tectonic geology Peru is subject to frequent earthquakes. A recent earthquake of July 7, 1977 damaged some of PVC pipes and brick walls at the Paramonga Plant, involving no injury or casualty.
Maximum seismic scale recording: Magnitude 6 to 7

(7) Thunderstorms and typhoons

Peru's coastal area is free from these disasters.

(8) Floods

As described in (5) above, there is very little rain on Peru's coastal area and consequently this area is generally not subject to floods. Last year, however, the abnormal weather conditions known as El Nino brought heavy rain to the Sierra zone which caused floods along the river basins on the Pacific coast.

7.3 Site Survey

The SPL Paramonga Plant site is located in Paramonga, a city some 200 kilometer north of Lima, the capital of Peru.

The construction site is a vacant lot immediately next to the north boundary of the existing Paramonga Plant's PVC plant.

The site is virtually flat and requires no special land grading. The area is 700 meters from east to west and 400 meters from north to south. The area is large enough to allow sufficient safety distances between facilities. Specifically, the electric furnace and lime kiln may be laid out sufficiently apart from the facilities which manufacture flammable and ignitable acetylene and VCM.

Geologically Paramonga area is an old river basin. Accordingly, the layer just below the surface is mainly of gravel with cobble stones and the lower formation is also believed to be of similar composition. In view of the soil bearing strength of 10 tons per square meter as indicated by the data furnished by the Paramonga Plant, it will be necessary to conduct a boring survey in order to determine the necessity for pile driving for foundations of large structures and heavy machines.

7.4 Utilities

(1) Water

Water is furnished to the plant via a 36-inch (900 mm) diameter underground pipeline from an intake weir situated approximately 3 kilometers southwest-by-west of the plant on a branch of Fortareza River that flows to the north of Paramonga city. The temperature is 22°C on average.

This pipeline normally takes 25,000 gallons per minute (5,677 tons per hour) of water which is distributed to individual plants after treatments with chemicals for clarification. The PVC plant takes at a rate of 2,000 gallons per minute (450 tons per hour) via an 8-inch (200 mm) diameter pipeline.

In addition to the supply from the river mentioned above, well water is available. Well water is, however, used only to a limited extent because the quality is inferior. The quality of river water is shown in Table 7-1.

Unit price of water is as follows:

River water, US$/1,000 m^3	0.097
Drinking water, US$/$m^3$	0.019

For cooling purpose Paramonga Plant recycles water through a cooling tower with a capacity of 2,500 gallons per minutes (500 tons per hour).

In association with the construction of the plant a cooling ith a capacity of 1,800 m^3 per hour will be built for recycling water back to the new plants. Normally, only 43 m^3 per hour of fresh make-up is required. There will therefore be sufficient water for cooling tower operations. A water softener will be employed for the treatment of the fresh make-up. A bypass will be provided around the cooling tower for emergency purpose.

Table 7-1 Analysis of River Water

(Unit PPM unless otherwise indicated) pH 7.4

pH	7.4
Total hardness (as $CaCO_3$)	194
Ca hardness (as $CaCO_3$)	155
Mg hardness (as $CaCO_3$)	40
Alkalinity (as $CaCO_3$)	65
SO_4	122.8
Chlorides (as Cl^-)	47.9
Total solid	438
Turbidity, degree max.	50
$KMnO_4$ Consumption, max.	10
SiO_2	10
SiO_2 Colloidal	Trace

(2) Electricity

1) Receiving facilities

As was described in Chapter 3, Paramonga Plant has a substation capable of receiving 42,000 kW branched out at 300 meters northwest of the Plant directly from Hidradina's power transmission line. A new receiving system will be installed to supply the additional requirement of the approximately 20,000 kW.

A breaker and a 138,000 V/13,800 V transformer will be installed in the existing substation.

A cable of 2 kilometers supported by 25 meters high steel towers will be installed from the substation to the site. Switchgears and transformers will be installed to all individual plants to supply power to all pieces of equipment.

2) Electric power rate (price)

Billing of electricity charge uses a two-tier system, basic charge and excess charge on top of the former. Both basic charge and the excess charges are the products of consumption and unit tariff in their respective categories. The total bill is the sum of the basic charge and the excess charge and 25 percent tax on the sum.

The average power rate at Paramonga Plant is US$ 0.035/kwh, as of June 1983.

(3) Steam

At present, Paramonga Plant has five boilers with a total capacity of 740,000 lb per hour (333 tons per hour) at a pressure of 450 psi (32 kg/cm^2). A 6-inch (150 mm) diameter pipeline runs from the boiler room to the existing PVC facilities for the supply of approximately 14,000 lb per hour (6.3 tons per hour).

The new plant will require approximately 10 tons per hour. Extension of the existing piping will suffice.

(4) Inert gas (nitrogen)

The existing PVC facilities are not equipped with inert gas generators and a bundle of high pressure cylinders are used for nitrogen supply.

The new plant will incorperate carbide crushing and storing processes which should be blanketed by flowing nitrogen gas. The acetylene and VCM facilities will also use nitrogen gas frequently for purging air from the system. Therefore, a PSI-type nitrogen generator will be installed in the new plant.

(5) Instrumentation air

Paramonga Plant has no special instrumentation air system but employs general-purpose air for instrumentation. Since this practice is not desirable for the proper maintenance of measuring instruments, an instrumentation air system including an oil-less compressor and a dryer will be installed with the new plants.

(6) General-purpose air

Because the capacity of the existing pneumatic air system is insufficient to support the new plants, new facilities will be installed.

(7) Brine

The existing PVC plant has a direct-cooling-type freon freezer. The new plant will require brine cooling at several points along the VCM manufacturing facilities, and two 60-Japanese-freezer-ton brine freezers (R-22) will be installed to accommodate this requirement. (One Japanese freezer ton equals 3,320 kcal per hour freezing capacity)

7.5 Municipal Infrastructure

(1) Paramonga city: See Figure 7-1 (map)

1) Population 30,000

2) Schools

Municipal primary school (six grades):
One boys' school and one girls' school with 2,000 pupils each

Minicipal middle school (five grades):
One co-educational school with 1,500 students

Private primary-middle school:

Two co-educational schools one with 1,000 and the other 400 students

3) Hospitals

One 90-bed general hospital with 12 physicians (2 surgeons; physicians, pediatricians, and obstetricians). A dentist and a heart specialist visit the hospital once a week. There are also several private practitioners.

4) Markets

There are three supermarkets, large and small, which sell general household commodities and food.

5) Hotels

There is no hotel in Paramonga City. There are two hotels in Barranca approximately 10 kilometers (15 minutes drive) to the south of Paramonga. The large one can accommodate 150 persons.

6) Restaurants

There are several restaurants in Paramonga.

7) Banks

Several Banks, including Banco de Credito

8) Other municipal facilities

Churches, a city hall, movie theatres, water supply authority, police station, and other usual municipal facilities.

9) Transportation facilities

The Peruvian railway system serves only in very limited areas and the Peruvians generally depend almost entirely on cars. Pan-Am Highway which runs along the

Pacific coast near Paramonga facilitates transportation to and from Paramonga. Bus services from the Central Terminal to neighboring Barranca City are available. The bus services are rather frequent in the morning and in the evening. Taxis are also available at the Central Terminal. Normally six passengers share the same car.

(2) Communication facilities

Paramonga Post Office provides both mail and telephone service. Overseas telephone takes too long. Normally one has to wait as long as two hours before connected. Paramonga Plant is provided with a telex.

(3) Roads

As Pan-Am Highway runs beside the city and the main roads of the city are 20 to 30 meters wide, transportation of construction machines and materials would not be restricted.

For transportation of the construction machines and materials from Lima there is a good road all the way; however, there is a dangerous 20 kilometer portion on the sand hills over the cliff if a bypass is used near Lima.

For land transportation of raw materials (coke) from Chimbote, a six meter high tunnel along the route must be taken into consideration.

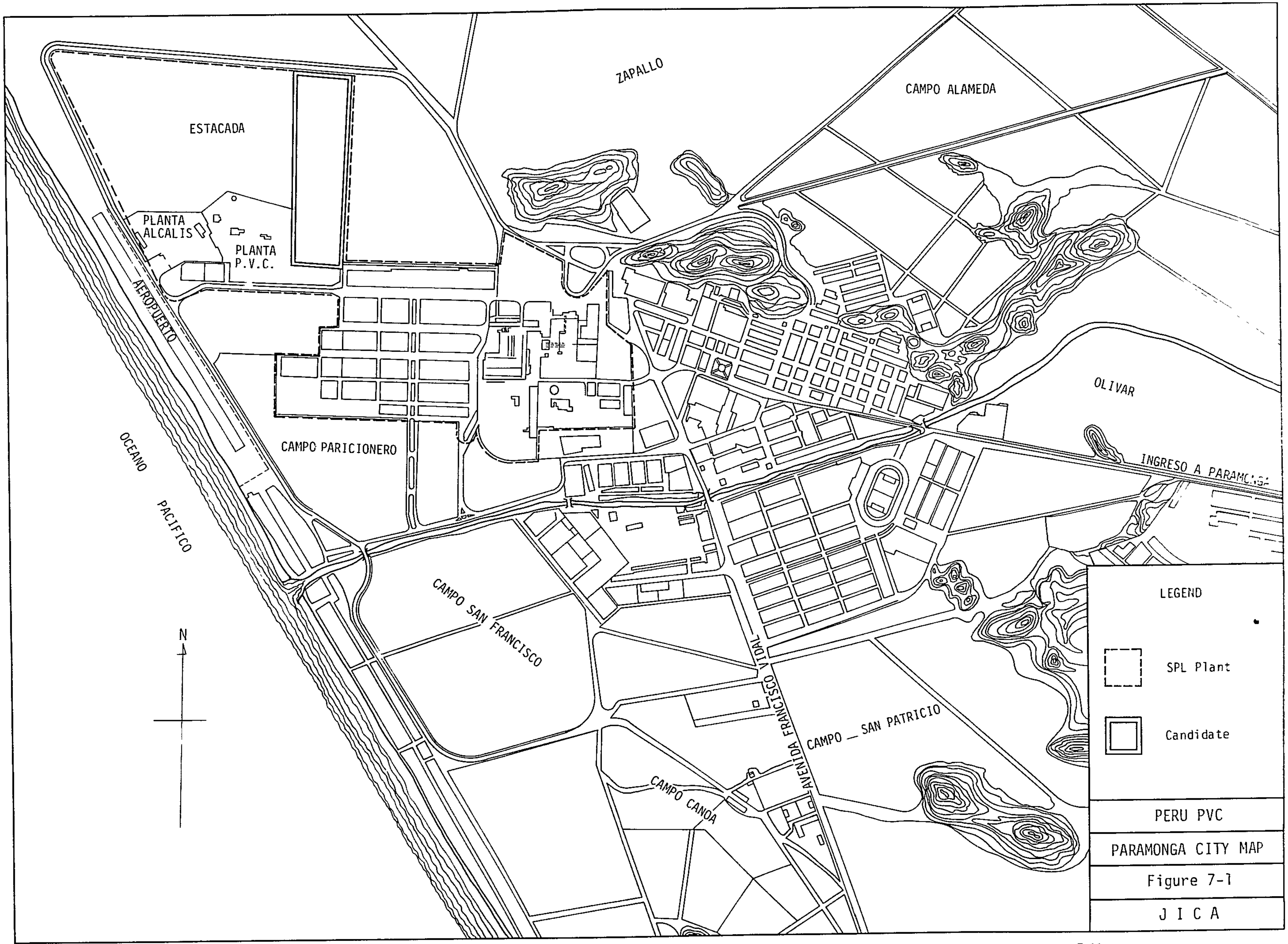
(4) Ports

Two ports are capable of receiving international ocean vessels; Callao Port near Lima, 200 km to the south of Paramonga and Chimbote Port, 220 km to the north.

Construction machines and materials can be unloaded at Callao Port, and raw material coke, at Chimbote Port.

(5) Neighboring cities

		Distance	Population
	Chimbote	220 km	500,000
North	Casma	170 km	15,000
	Paramonga	-	30,000
South	Barranca	10 km	40,000
	Huacho	50 km	50,000
	Lima	200 km	5,000,000


ZAPALLO
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ESTACADA
PLANTA ALCALIS
PLANTA P.V.C.
AEROPUERTO
OLIVAR
CAMPO PARICIONERO
OCEANO PACIFICO
INGRESO A PARAMONGA
CAMPO SAN FRANCISCO
N
AVENIDA FRANCISCO VIDAL
CAMPO SAN PATRICIO
CAMPO CANOA
LEGEND
SPL Plant
Candidate
PERU PVC
PARAMONGA CITY MAP
Figure 7-1
J I C A

CHAPTER 8 MANUFACTURING FACILITIES

8.1 Overview

This chapter concerns the conceptual design of the manufacturing processes and facilities applied to this feasibility study from the receipt of limestone all the way to the packing of PVC.

These processes are broadly divided into those dealing with inorganic processes and those dealing with organic processes. The inorganinc part includes such principal processes as receipt of limestone, manufacture of quick lime, manufacture of carbide, and crushing of carbide. The organic part consists mainly of such processes as generation of acetylene, manufacture of VCM and that of PVC.

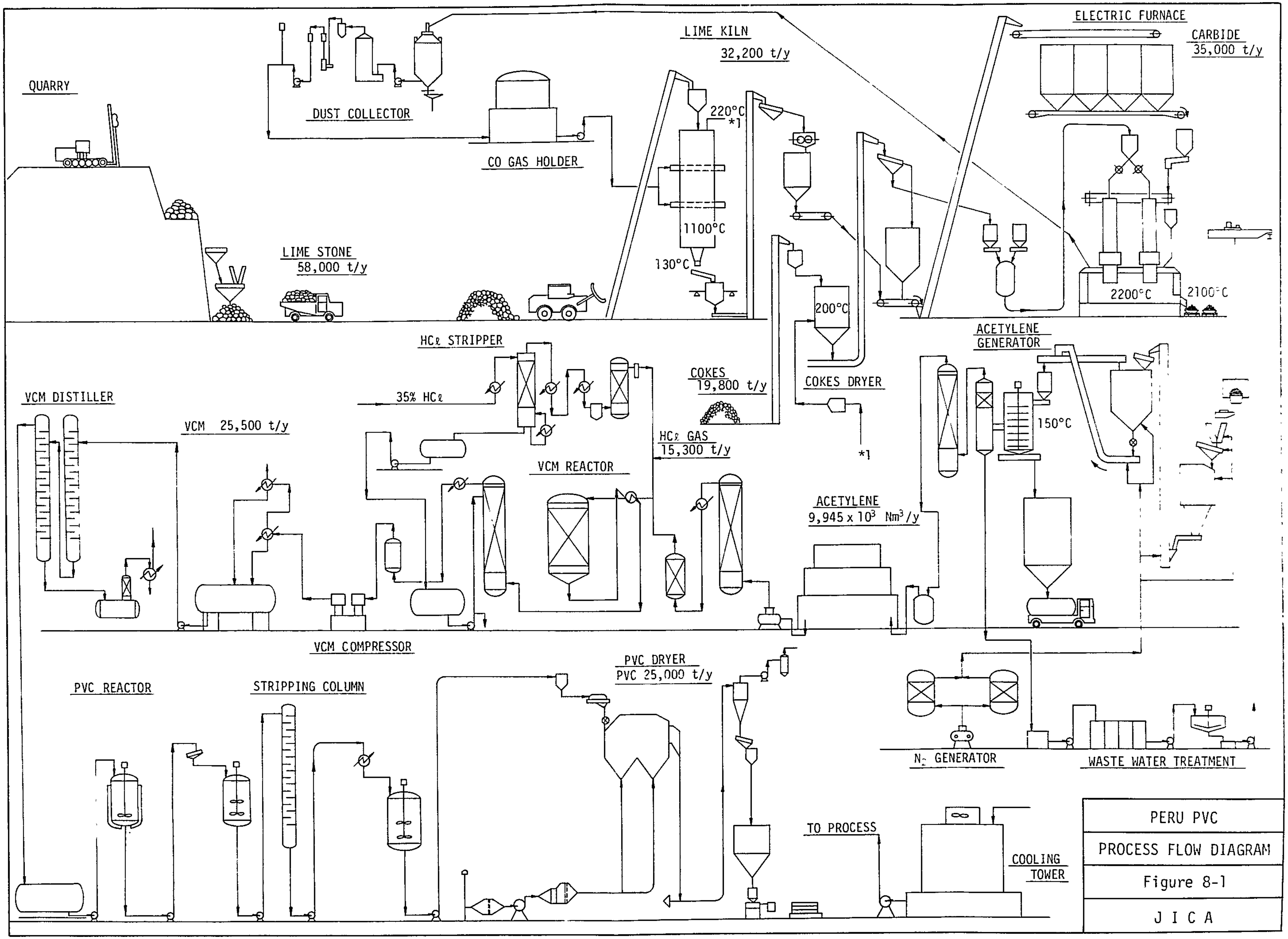
The recovery, briquetting and reuse of slaked lime, a by-product from the generation of acetylene, and the processes for such operations are dealt with as a case study in section 8.2 (5).

Figure 8-3 illustrates the principal manufacturing processes and facilities, including those of mining.

8.2 Quick Lime and Carbide

(1) Summary

This section outlines the facilities for drying carbon source, specifically coke in the case of this feasilibity study, and those for manufacturing quick lime, the electric furnace for manufacturing calcium carbide, the facilities for cooling, crushing and storing carbide, and related technical matters concerning the manufacturing processes and environmental control. Paragraph (5) is set up to answer the questions asked by SPL, namely, (a) the possiblity of briquetting slaked lime to be recycled to the electric furnace process, (b) possibility of using high-purity crystalline limestone in the electric furnace, and (c) the effect of voltage variations on the operations of other facilities during the startup or shutdown of the electric furnace, and measures to control it.



PERU PVC

PROCESS FLOW DIAGRAM

Figure 8-1

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(2) Process scheme for the conceptual design

1) Figure 8-1 shows process scheme of quick lime and calcium carbide manufacturing. Details of the individual processes are described in (3) Technology.

2) Tables 8-1, 8-2, and 8-3 show the design parameters and unit consumptions of the inputs and utilities for quick lime manufacturing, coke drying and calcium carbide manufacturing. The information obtained by the field survey is incorporated to the calculations of the figures.

3) Figures 8-2 and 8-3 show the insides of the lime kiln and electric furnace.

Table 8-1 Design Parameters and Unit Consumptions of Lime Kiln

	Specifications and consumptions
Limestone grade, %	$CaCO_3$>97, SiO_2<1.5, R_2O_3>1.5
Limestone size, mm	30 to 70
Quick lime grade, %	Total CaO>94 (Unburnt $CaCO_3$<5) SiO_2<2.9, R_2O_3<2.9
Quick lime size, mm	6 to 70
Limestone consumption, ton/ton-CaO	1.8 (167 ton/day)
Quick lime output, ton/day	93
Fuel consumption, $X10^4$ Kcal/ton-CaO	105
Power consumption, kWH/ton-CaO	70
Industrial water consumption, ton/ton-CaO	11
N_2, Nm^3/cycle	55
Compressed air consumption, Nm^3/ton-CaO	18

Table 8-2 Design Parameters and Unit Consumptions of Coke Dryer

	Specifications and consumptions
Required quantity of dry coke, ton/day	58
Drying time, hours	18 (operating rate: 75%)
Moisture in coke (before drying), %	10
Moisture in coke (after drying), %	1.5
Hot gas temperature (inlet), °C	200
Hot gas temperature (exit), °C	100
Required heat of hot gas, $\times 10^3$ Kcal/hour	485 (150×10^3 Kcal/ton-dry coke)
Thermal efficiency, %	40
Power (kWH/ton-dry coke)	28

Table 8-3 Design Parameters and Unit Consumptions of Electric Furnace

	Specifications and consumptions
Carbide production	101 ton/day,
Operating rate: 95 %	
Carbide (Grade)	295ℓ/kg
Operating consumptions (per ton-CaC_2)	
Electricity, kWH	3,200
Quick lime, ton	0.92
Carbon source, ton	0.565
Electrode paste, ton	0.020
Electrode case, ton	0.0013
Round steel bar, ton	0.0015
CO gas production, Nm^3	420 (2,700 Kcal/Nm^3)
Utility (per ton-CaC_2)	

Table 8-3 Design Parameters and Unit Consumptions of Electric Furnace (continued)

Power consumption, kWH (manufacturing and crushing)	106
Cooling water, ton	35.7 (150 m^3/hour)
Compressed air, Nm^3	106 (446 Nm^3/hour)
Gaseous nitrogen, Nm^3	90 (380 Nm^3/hour)

4) Main facilities

The manufacture of 25,000 ton per year of PVC requires 35,000 tons per year of calcium carbide. According to the design parameters shown in the preceding pages, the main facilities will have the following capacities:

Table 8-4 Capacity of Inorganic Plants

	Tons/year	Tons/day	Number
Lime kiln (quick lime)	32,200	93	1
Coke dryer	19,800	59	1
Electric furnace (carbide)	35,000	101	1

(3) Manufacturing technology

1) Quick lime manufacturing

a) Plant

The lime kiln is a vertical kiln that produces 93 tons per day of quick lime. Inside, it is fully lined with refractory bricks and is equipped at the top with a raw material measuring feeder. The kiln has three basic zones: the overhead portion which preheats raw materials; the middle portion which converts limestone into quick lime; and the bottom portion which cools quick lime and preheats the air flow to the middle portion.

To help discharge the gas, the kiln is equipped at the top with a blower and also a dust collector to remove dust from the exhaust gas.

Quick lime is discharged through the product measuring device at the bottom of the kiln, and then crushed by the crusher and screened. It is then transferred by a conveyor to the storage silo.

b) Raw material limestone

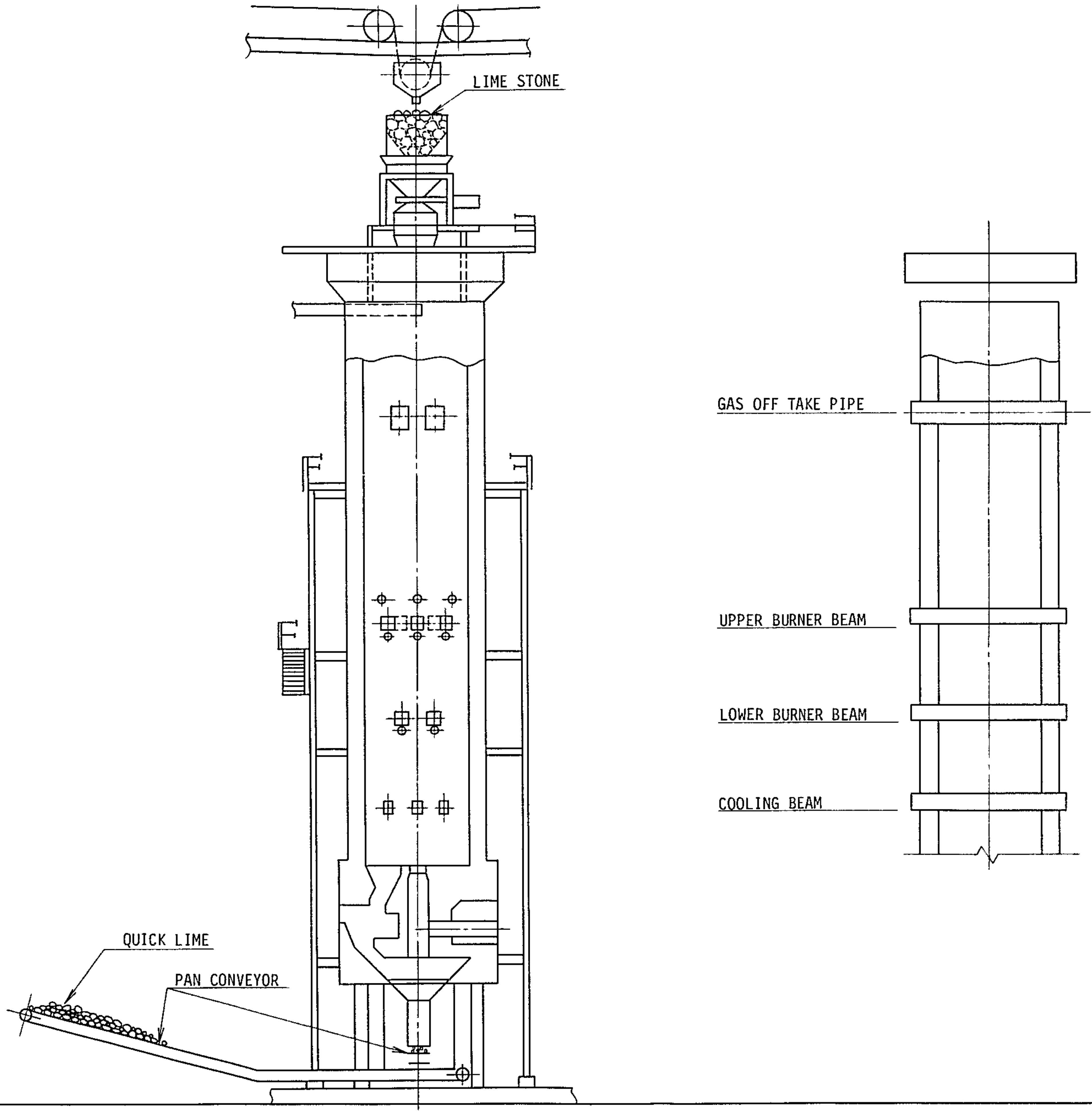
The grade of quick lime affects not only the consumption of various inputs but also the operating stability of the electric furnace. Limestone used to manufacture calcium carbide should be dense and rigid in structure and non-crystalline so that it will not break during the heating and cooling in the kiln. As described in CHAPTER 6, Pariahuanca limestone satisfies such requirements and is estimated to contain less than 1.5 percent of SiO_2.

If the size of the limestone is small, the reactions would be faster but it chokes the kiln and prevents the upward flow of air in the kiln. The preferred size of limestone for a 100 tons per day plant is from 30 to 70 mm in diameter.

c) Operation control

A shavel loader feeds the limestone sized between 30 to 70 mm to a weighing hopper then through which the feed is charged to a gas-sealed hopper at the top ot the kiln. It is necessary to maintain a constant level of raw materials in the upper zone of the kiln.

Reaction zone is equipped with gas burners arranged in upper and lower levels for burning CO gas. The hot air preheated through the bottom section of the kiln is used for combustion to achieve high thermal efficiency. The temperature of the reaction zone is automatically controlled at a fixed level by regulating the combustion according to the feed rate. Also the operation of the blower is



PERU PVC

LIME KILN

Figure 8-2

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controlled by variation of CO_2 and CO contents in the exhaust gas. The unreacted components in the product quick lime is checked and reflected in the determination of optimum heat input.

d) Auxiliary fuel

The lime kiln is designed to utilize as fuel byproduct CO gas from the carbide electric furnace. An auxiliary fuel will be required when the furnace is being started or when byproduct gas is not available due to operational upsets. The cheapest auxiliary fuel is coke charged mixed with limestone. The coke for the carbide manufacture is good for this purpose but the size should be in the same range as that of limestone, from 30 to 70 mm.

e) Fine particles

It is estimated that small particles less than 6 mm across will be generated to the extent of approximately 10 to 15 percent of the quick lime during the cooling, crushing and conveying processes that follow lime combustion. The fine particles are collected and mixed with fine particles of coke — less than 3mm — from the coke dryer and charged through the hollow of the hollow electrode to the electric furnace.

2) *Coke drying*

The moisture in the coke, if not removed previously, evaporates in the electric furnace, reacts with CaO, reacts with coke by what is known as water gas reaction thereby adversely affects power and coke consumption. Therefore, coke should be dried as much as practicable before use.

Imported coke usually contains more that 10 percent moisture. Precipitation is very low in Paramonga which allows outdoor storage of the coke. The outdoor storage will reduce the moisture content to approximately 10 percent. The dryer will further reduce the moisture content to less than 1.5 percent. The hot exhaust gas from the lime kiln, about 200°C, will be used as the heat source for drying during the normal operation. This hot gas is rid of dust and then introduced directly into the drying oven installed near the lime kiln. A standby heavy oil combustion unit will be installed to serve in case the temperature or amount of hot gas is not sufficient due to operational uspets of the lime kiln.

Dried coke will be conveyed through the transfer line to the electric furnace. Coke particles measuring less than 3 mm in diameter screened out after drying will normally amount to slightly more than 10 percent of the total. These particles will be charged through the hollow electrode as mentioned before.

c) Calcium carbide manufacturing

A mixture of coke and quick lime in the ratio given in Table 8-3 is heated in the electric furnace. When the temperature exceeds 1,800°C the following reactions take place to produce molten carbide and CO gas:

$$CaO + 3C = CaC_2 + CO - 114.5 \text{ Kcal}$$
$$CaO + C \text{ (solid)} \rightleftharpoons Ca \text{ (gas)} + CO$$
$$Ca \text{ (gas)} + 2C \text{ (solid)} \rightleftharpoons CaC_2 + 10.5 \text{ Kcal}$$

A closed-type electric furnace is adopted to allow total recovery of the product CO gas to use it as fuel. Quick lime and coke are weighed and mixed in a prescribed ratio and then stored in a holding tank placed above the electric furnace. The mixture is then distributed to nine service tanks directly leading to the inside of the electric furnace.

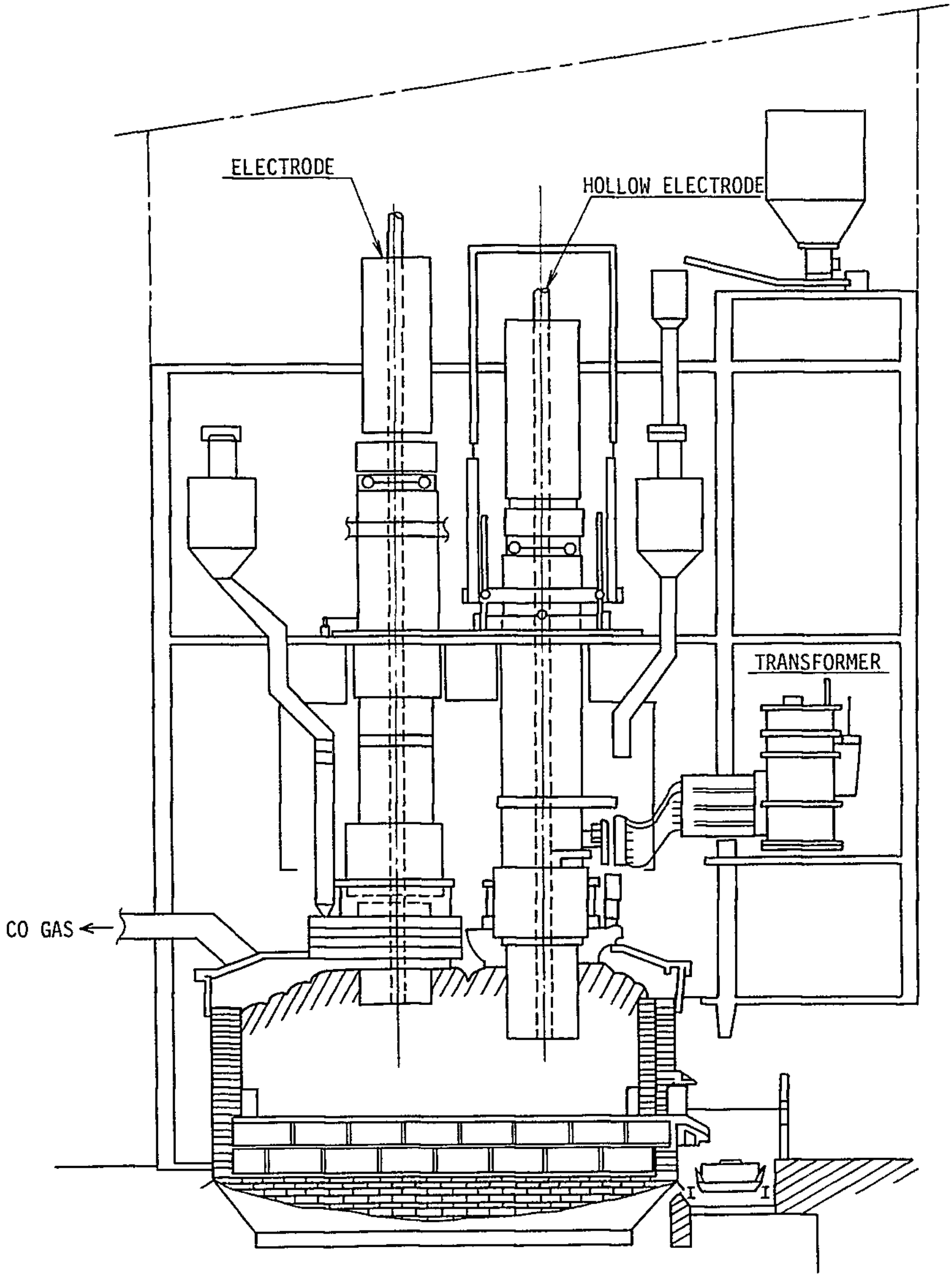
The service tanks are designed to allow by gravitation continuous flow of the raw material as reactions proceed and the content of the electric furnace is consumed. The content of the service tanks also serves to seal the electric furnace to keep CO gas gas from leaking. It is therefore important to closely control the level of the raw material in the service tanks.

The inner wall of the electric furnace is fully lined with refractory bricks or carbon. Three Soderverg-type electrodes are placed downward on the ceiling of the reactor and are surrounded by raw material chutes. The top of the furnace is completely covered with an electrically-insulated and water-cooled furnace lid to ensure gas-tightness of the reactor and to prevent byproduct CO gas leakage. Also important is to keep air from entering the reactor to form a dangerous explosive mixture. For this purpose the pressure of the electric furnace is maintained at ± 0 mm Aq as an operational standard for normal operation. The byproduct CO gas normally leaves the furnace at temperatures between 500 and 800°C and have a dust content of 8 to 100 g/Nm^3. A blower is used to send this gas to a gas-cleaner which removes essentially entire dust from the gas. The gas then goes through a CO gas holder to the lime kiln to be used as fuel. When the gas is in excess it may be used as fuel for the boilers. Futher excess is burned and released through an emergency stack installed near the electric furnace. There are two types of gas cleaners; the dry-type — bag filter — and wet-type — water scrubbing with a Venturi or a Teisen washer — gas cleaners. The former is adopted because it does not produce waste water that needs treatment and slurry disposal.

To ensure smooth operation of the closed-type furnace quick lime and coke are screened by 6 mm and 3 mm screens, respectively to remove fine particles. The fine particles obtained by screening amount to 10 to 15 percnet of the total and will be charged through the hollow electrode.

The molten carbide settles at the bottom of the furnace and is tapped at every 40 to 50 minutes through three tapholes provided at the bottom of the electric furnace. Molten carbide, 2,000 to 2,100°C, is received by cast-iron pans on wheels and moved by rail to the cooling bay where carbide stands for 12 to 13 hours to be cooled and solidified. The solid carbide, while the surface temperature is still around 200°C, is carried by a crane to the crusher where the carbide is crushed followed by milling and magnetic separation to remove iron. The carbide powder now measuring less than 3 mm across is weighed and transferred to the storage tank. This operation should always be blanketed with nitrogen gas of 99.9 percent or higher to avoid weathering of milled carbide.

The field survey confirmed that there is virtually no preferential price for night load of electricity; therefore, the electric furnace is designed assuming an equal load for night and day on 24 hours a day operation. The specifications for the electric furnace and associated facilities are summarized in Table 8-5.



PERU PVC
ELECTRIC FURNACE
Figure 8-3
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Table 8-5 Electric Furnace Facilities

	Specifications	Number
Transformer capacity, MVA	18	1
Electric furnace load, MW	Maximum 15	
	Agerage 13.5	
Electrodes, mm dia.	1,000	3
(hollow electrodes), in. dia.	5	3
Furnace proper, m		
Outside diameter	7.6	
Furnace height	3.6	
Lid	Made of iron	
Cooling	Water-cooled	
Raw materials handling facilities (including hollow electrode)		1 set
Tapping facilities		
Tapping transformer		1 set
Cast iron receiver		1 set
Wheels and rail		1 set
Product cooling system		
Cooling bay		1 set
Cooling bed		1 set
Crane 2.5 ton		1 set
Product crushing facilities		1 set
Dust collecting facilities		1 set
Carbide storage facitlities		1 set
Electrode case manufacturing facilities		1 set
Clay kneader		1 set

(4) Environmental conservation

Since there has not been established yet in Peru a comprehensive legislation regarding environmental conservation or pollution control, the relevant Japanese regulations are referred to in the design.

1) Lime kiln facilities

The Japanese Air Pollution Control Law limits the dust content in the exhaust gas below 0.30 g/Nm^3 (O_2: 15 percent). According to the design the entire exaust gas from the lime kiln passes through a cyclone ahead of the coke dryer and is released after dust removal. This practice will forestall air pollution problems by dust. No particular problem of water pollution or noise is anticipated.

2) Coke dryer

The Japanese Air Pollution Control Law requires for this kind of operations a dust concentration of less than 0.2 g/Nm^3 Waste gas from the dryer passes a bag-filter which reduces the dust content below such a level. This process does not cause any water pollution or noise.

3) Electric furnace

The design calls for a closed-type electric furnace which discharges virtually no fume. The fume released during the tapping operation is treated by a bag-filter. Collected dust from the exhaust gas — 4 to 5 tons per day — is buried on unused land around the plant. This dust may be used as a calcium silicate fertilizer or a raw material for cement. The wastes collected from the furnace during digout operation — removal of accumulates during the shutdown — do not contain heavy metals that can cause problems; therefore, they may be piled in a vacant place near the plant. Any leakage of gas containing CO represents a serious threat. Therefore, sensors and alarms will be installed at strategic points of the process and various safety measures will be taken. The electric furnace will have nothing to do with water pollution, nor will it cause noise problems.

(5) Others

This portion of the study was conducted as agreed with SPL and recorded in Interim Report.

1) Possibility of briquetting spent slaked lime from acetylene production to be used as electric furnace feed.

A study was made of technical and economic possibility of briquetting the slaked lime in order to convert it into a cost-effective raw material for electric furnace feed. Supposing a coke mixture consisting of 70 percent imported metallurgical coal and 30 percent petroleum coke is used with a limestone feed of which SiO_2 content is adjusted to 1.5 percent, the briquette produced from the slaked lime of this operation will contain 3.3 percent SiO_2. This calculation is based o the experience that about 65 percent of SiO_2 in the feed goes to the slaked lime. Quick lime produced from limestone containing 1.5 percent SiO_2 contains 2.7 percent SiO_2. Obviously recycling increases SiO_2 contents of quick lime. This calculation assumes 20 percent of recycled briquette on total feed.

As this calculation shows recycling of slaked lime is not recommendable from the viewpoint of SiO_2 accumulation. However, it is worth considering if it is cheaper than quick lime produced from limestone and also if low SiO_2 content limestone is available to mix with the briquette.

a) Briquette manufacturing process

A dry-type acetylene generator is adopted which discharges in sludge slaked lime, $Ca(OH)_2$, containing 6 to 7 percent moisture. The slaked lime is baked by a heavy-oil-burning-type rotary kiln at about 900°C to be converted into quick lime by the following reaction:

$$Ca(OH)_2 = CaO + H_2O$$

The quick lime thus obtained is pelletized by a pelletizer followed by screening to remove fine particles. The pellets are mixed with quick lime from the kiln and fed to the electric furnace.

b) Facilities for briquetting

The following table lists the facilities needed for this operation.

Table 8-6 Slaked Lime Briquetting Facilities

	Specification	Number
Raw materials feeding facilities		1 set
Rotary kiln facilities		1 set
Heavy-oil-burning facilities		1 set
Dust-collecting facilities		1 set
Briquetting machine facilities	800 kg/h	1 set
Briquette transporting facilities		1 set
Total equipment cost	US$ 992 x 10^3	

c) Consumptions

The following table indicates the necessary inputs for this operation.

Table 8-7 Inputs for Briquetting Operation

Power, kWH/ton briquette	80
Fuel (heavy oil), kg/ton briquette	100
Operating personnel, worker/shift	1

2) Use of high-purity crystalline limestone

The physical strength of limestone is as important as chemical composition. Limestone that breaks easily during burning cannont be charged to the lime kiln. If limestone breaks up it blocks the gas flow and consequently lowers the product quality and reduces the capacity of the kiln. The dust of limestone may be blown off the kiln. Theoretically, it is possible to directly charge it to the electric furnace without calcinating it in the lime kiln. However, the following reaction takes place which consumes 33 percent more carbon than with CaO, generates excessive CO gas, and seriously reduces the capacity of the furnace to produce carbide. Power consumption also increases by 1,100 kWH/ton-CaC_2. Therefore the design does not adopt this practice.

$$CaCO_3 + 4C = CaC_2 = 3CO$$

3) Effect of voltage variations of electric furnace on other facilities

The electric furnace generates heat by electric resistance and; therefore, voltage does not change very much during the operation. The voltage changes the most when the furnace starts after power failures. The following measures are recommended both on design and operation and are incorporated in the conceptual design:

a) Device to delay trip switch

Normally an electric switch trips the moment the voltage falls. A device that delays trips for 0.5 second at 80 percnet of the normal voltage will be installed at supply side of the alkali plant. This device will hold trip even longer if the decline of voltage is smaller.

b) Installation of delayed relays

Delayed relays will be installed to important electric motors which suspend trip for 0.5 second at 65 percent normal voltage.

c) Operational measures

1. The transformer to the electric furnace is equipped with a tap changer to allow tap selection. To start electricity the medium point tap is used and then switched to the lowest tap. Gradually the switch is shifted to higher taps.

2. The electrode should be lifted 150 to 200 mm immediately before electricity is started.

d) Transformer specification

The transformer is designed to allow tap selection and for high magnetic flux density although it is a little costlier.

8.3 Acetylene, VCM, and PVC

(1) Summary

This section decribes the manufacture of acetylene, calcium carbide and that of VCM and PVC from acetylene and hydrochloric acid. The latter is supplied by the existing electrolysis/hydrochloric acid synthesis plants.

(2) Existing facilities

1) Common salt electrolysis and hydrochloric acid synthesis

At Paramonga Plant SPL operates common salt electrolysis and hydrochloric acid synthesis plants and manufactures PVC with imported EDC as raw material. The capacity is about 7,000 tons per year. Figure 8-4 shows the capacities of the existing plants and raw material/product material balance.

The capacity of the electrolysis/hydrochloric acid synthesis plants is 42,000 tons per year of caustic soda and 37,275 tons per year of chlorine. SPL produces 40,000 tons per year of caustic soda and corresponding amount of chlorine of which only about 12,000 to 17,000 tons per year of chlorine or hydrochloric acid is used on the premises, meaning that about 20,000 to 25,000 tons per year is discharged to the sea after dilution with water. This excess hydrochloric acid now discharged to the sea is therefore available to the manufacture of VCM by this project.

2) Ethylene and EDC

SPL formerly manufactured ethylene by dehydrating alcohol from molasses and converted it to EDC. However, this operation was discontinued in November 1981. Since then SPL has been importing EDC.

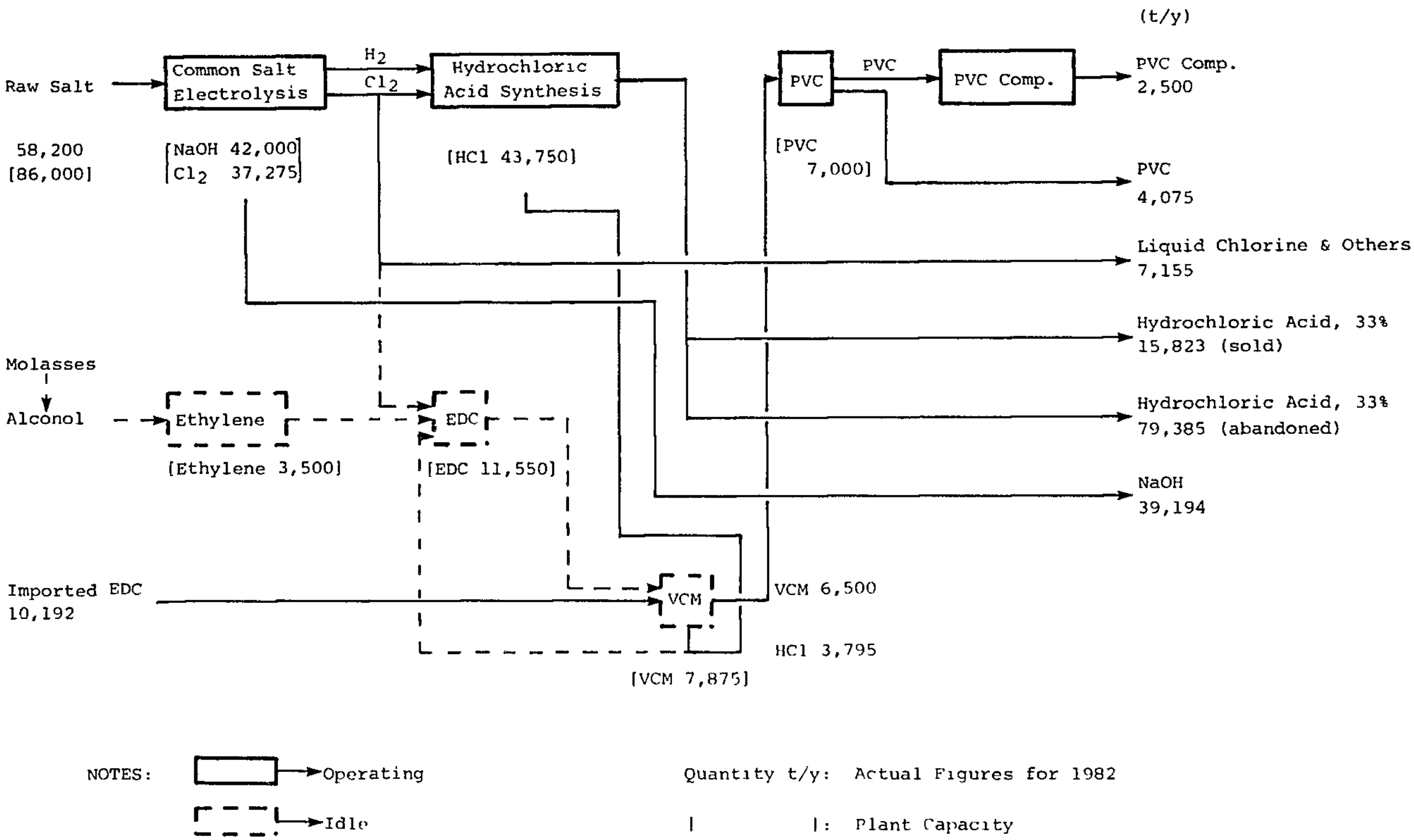


Figure 8-4 Capacity and Material Balance of Existing Plant

The EDC plant has a hydrochloric acid stripper unit with a capacity of 14 tons per day hydrogen chloride (4,900 tons per year). This unit has not been operated for nearly two years and is seriously corroded. The design calls for installation of a new unit.

3) VCM

SPL imports about 10,000 tons per year of EDC from which manufactures about 6,500 tons per year of VCM by the VCM plant (EDC cracker). This operation generate approximately 3,800 tons per year of hydrochloric acid as byproduct which is discharged to the sea.

4) PVC

The plant has three glass-lined 15 m^3 polymerization autoclaves, one rotary dryer and associated facilities and produces 6,000 to 7,000 tons per year of suspension polymerization/straight and vinyl acetate copolymer.

The unit consumptions of VCM, cooling water, steam, and power are relatively large. The productivity of polymerization is rather low.

Although the PVC facilities — polymerization, dehydration, drying, bagging, etc — are still serviceable, they have only one third the planned capacity of the present project. Use of the existing facilities along with the new ones would save equipment costs only slightly but would involve possible opertional difficulties and inefficiencies. Operation of two PVC platns requires more raw materials, auxiliary materials, utilities, and personnel. Therefore, this project decides to suspend the operation of the existing plant.

(3) Schematic flow diagram

1) Figure 8-1 is a schematic flow diagram of the manufacturing processes from carbide milling throuh acetylene generation and VCM synthesis to the manufacture of PVC.

2) Basis of design

Production capacities and consumptions of inputs are shown for the individual facilities in Tables 8-8, 8-9, and 8-10.

Table 8-8 Production Capacity and Unit Consumptions of Acetylene Generating Plant

Production capacity: (25,500) (390 m^3/ton-VCM)
= 9,945 x 10^3 Nm^3/year

Unit consumptions: per 10^3 Nm^3, C_2H_2

	Unit Consumption	Note
CaC_2, ton	3.5	96.3%
NaOH, kg	15	97%, for H_2S removal
Acetic acid, kg	1.3	99%, for adjusting PH of bleaching solution
Bleaching solution, kg	55	Equivalent to 8 percent chlorine, for PH_3 removal
Power, kWH	175	
Water, ton	40	30°C
N_2, m^3	55	Steam-tracing

Table 8-9 Production Capacity and Unit Consumptions of VCM Manufacturing Facilities

Required production: (25,000) (1.02)
= 25,500 tons per year

Operating consumptions: per ton-VCM

	Unit Consumption	Note
C_2H_2, m^3	390	
HCl, ton	0.60	100%
Catalyst, kg	1.0	
Sulfuric acid, kg	2.5	98%
Silica gel, kg	0.2	
Cooling water, ton	250	25°C
Steam, ton	1.3	
Power, kWH	350	7 $kg/cm^2 \cdot G$
N_2, m^3	20	
Instrument air , m^3	47	7 $kg/cm^2 \cdot G$
Utility air, m^3	16	7 $kg/cm^2 \cdot G$
Freezer, JRT	38	Brine -5 to 0°C
Pure water, ton	0.5	

Table 8-10 Production Capacity and Unit Consumptions of PVC Manufacturing Facilities

Required production: 25,000 ton per year

Operating consumptions: per ton-PVC, unless otherwise stated

	Unit Consumption	Note
VCM	1.02	
Pure water	3.5	
Catalyst	0.35	
Dispersant	0.75	
Cooling water	100	25°C
Steam	1.5	7 $kg/cm^2 \cdot G$
Power, kWH	200	
Instrument air, m^3	48	7 $kg/cm^2 \cdot G$
Air for miscellaneous uses, m^3	8	7 $kg/cm^2 \cdot G$

3) Design specifications of main faicilities

The major design specifications of the acetylene generator, VCM plant and PVC plant are shown in Tables 8-11, 8-12, and 8-13 respectively.

Table 8-11 Specifications of Acetylene Generator

	Specifications	Number
Carbide milling machine	10 tons/hour	1 line
Acetylene generator	750 m^3/hour	2 units
Acetylene gas holder	1500 m^3	1 unit
Acetylene scrubber	1500 m^3/hour	1 line
Waste water treating system	70 m^3/hour	1 line

Table 8-12 Specifications of VCM Facilities

	Specifications	Number
HC releasing tower	30 ton/day	2 units
VCM reaction vessels		5 units
Catalyst manufacturing facilities	150 kg/day	1 line
VCM compressor	450 m^3/hour 10 kg/cm^2.G	4 units
VCM distillation column	4 ton/hour (double-tower type)	1 line
VCM recovery gas holder	1500 m^3	1 unit

Table 8-13 Specifications of PVC Facilities

	Specifications	Number
PVC polymerization vessel	$50m^3$.GL, $11kg/cm^2$.G	3 units
VCM removal facilities	4 ton/hour	1 unit
PVC dehydrator	2 ton/hour centrifugal	3 units
PVC dryer	4 ton/hour horizontal	1 unit
PVC bagging machine	3 ton/hour	4 units

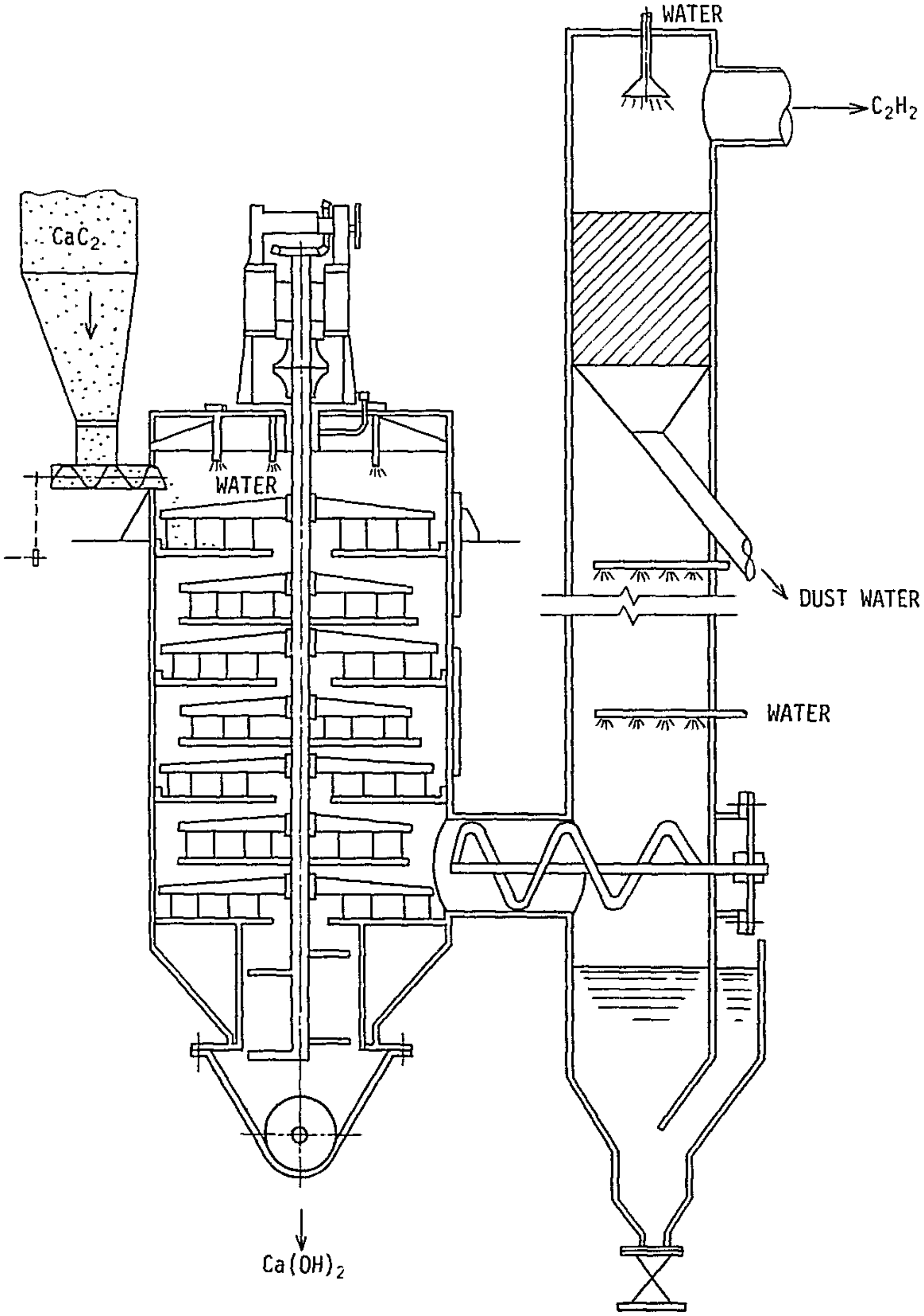
(4) Technology

1) Acetylene generation

Calcium carbide milled to smaller than 3 mm is introduced into the acetylene generator where it reacts with water to generate acetylene gas and gives byproduct slaked lime. To keep the temperature of this exothermic reactions between 110 and 120°C, water three time as much as the stoichiometric quantity is introduced to the generator. After leaving the generator, acetylene gas is scrubbed with water and caustic soda solution to eliminate H_2S and is then sent to the gas holder for storage. On leaving the holder, acetylene gas is washed in three consecutive steps first with bleaching solution for removing PH_3, with caustic soda solution to eliminate residual bleaching solution and finally with water to remove residual caustic soda. Slaked lime in powder form is extracted from the generator and rejected. A waste water treatment unit is provided for the treatment of NaSH and $Ca(SH)_2$ contained in the waste water from the dust removal and desulfurization, respectively. Automatic detectors/analyzer are installed where necessary to watch any acetylene leakage from the process. Figure 8-5 shows cross section of acetylene generator.

2) VCM synthesis

Acetylene should be completely dehydrated before entering the reactor to prevent undesirable side reactions and corrosion of the facilities.



PERU PVC
ACETYLENE GENERATOR
Figure 8-5
J I C A

Hydrochloric acid, 33 to 35 percent, from the existing hydrochloric acid synthesis plant is separated into hydrogen chloride gas and 20 percent hydrochloric acid the hydrochloric acid stripper. Hydrogen chloride gas from the top of the stripper is first cooled with water and brine then dehydrated in the sulfuric acid tower. To prevent corrosion, resin-impregnated carbon lining is employed in this process.

Dehydrated acetylene is mixed with dehydrated hydrogen chloride in a molar ratio of slight hydrogen chloride excess. And, the mixture is sent to the VCM reactor. The mixing ratio of the two gases is accurately controlled by an automatic regulator to minimize the production of byproducts and unreacted feeds. The reactor is of multi-tubular type filled with a catalyst with cooling water jacket on the outside to remove reaction heat. Activated carbon with adsorbed metal salt (mercury chloride type) is normally employed as catalyst. A precious-metal-type catalyst under development may be used althoush it has not been used on a commercial scale. The same facilities can be used for both types of catalysts. The reaction temperature is controlled by an automatic regulating system to keep the activity of the caltalyst constant during the operating cycle.

VCM gas leaving the reactor contains unreacted hydrogen chloride, acetylene and byproducts. With a mercury-type catalyst the gas leaving the reactor contains a trace of mercury and is first passed through an activated carbon adsorber to remove mercury and then treated with 20 percent hydrochloric acid and water to remove unreacted hydrogen chloride. Recovered hydrogen chloride is returned to the hydrochloric acid synthesis process.

After dehydration with molecular sieves VCM is liquefied by compression and cooling. Liquid VCM at this stage contains acetylene and other substances which are removed by the subsequent two-stage distillation.

The distillation columns are compact and operate under high pressures. The first column eliminates uncondensed gas (C_2H_2) which is recycled back to the reactor. The liquid VCM withdrawn from the bottom of the first column enters the second column where high-boiling substances are removed.

The distillation columns use bubble caps. The principal operating variables are feed rate, temperature, pressure, and reflux rate and are all automatically controlled to ensure stable and efficient operations. The raw VCM and refined VCM are stored in tanks equipped with water-cooling jackets. The refined VCM is sent to the PVC polymerization process.

3) PVC polymerization

Pure water, dispersant, catalyst and additives are fed to the polymerization vessel and the manhole is closed. Then VCM is weighed and fed and then hot water is passed through the jacket to heat the content to the prescribed polymerization temperature. When the prescribed polymerization temperature is reached, hot water to the jacket is switched over to cooling water to accurately control the temperature of this exothermic reaction. When the pressure drops to a set value the polymerization is terminated and unreacted monomer is purged first by its own pressure and later by a vacuum pump through the separator to the recovered VCM gas holder.

The recovered VCM is returned to the VCM gas-refining process of the VCM synthesis line to go through the dehydration, cooling, and liquefaction processed again to be reused for polymerization.

The polymer is in a form of slurry which is withdrawn from the polymerization vessel and is fed to the VCM stripping tower to eliminate residual monomer.

After removal of residual monomer, the slurry is sent to the slurry tank where it is dehydrated by a centrifugal seperator and is dried by a fluid dryer to a moisture content of 0.1 to 0.5 percent. The dried product is sent to the screen for separation of coarse particles, and is then sent to the product silo for bagging by a packer (bagging machine).

(5) Environmental conservation

Possible environmental problems and measures to control them are described below for each process.

1) Acetylene generation

NaSH and $Ca(SH)_2$ contained in the waste water from dust removal and desulfurization are converted into $Na_2S_2O_3$, CaS_2O_3 by hypo-conversion in the waste-water treatment facilities consisting of an aeration tank, thickener, etc. The waste water is then neutralized and discharged. The solid precipitate is dehydrated by a filter press and buried.

Slaked lime discharged by the acetylene generator may be dumped on a remote unused land.

2) VCM synthesis

With the mercury-type catalyst, VCM gas from the reactor is passed through the activated carbon adsorber to completely remove even the last trace of mercury contained in the VCM gas.

The spent catalyst from the reactor and the spent activated-carbon from the adsorber are treated for mercury recovery if this operation is possible under the circumstances. When recovery is not possible, these wastes are sealed in concrete and are kept in protective storage. Waste sulfuric acid discharged from the hydrogen chloride gas dehydration tower is neutralized with alkali and is discharged.

3) PVC polymerization

Residual VCM contained in the PVC polymerization slurry is recovered by the VCM stripper to reduce the residual VCM content in the PVC product to less than 10 ppm. This will also help minimize the discharge of VCM from the polymerization, slurry dehydration and drying processes.

8.4 Material, Utility, and Fuel Balances

(1) Material balance

This section deals with material and utility balances of importance only. The auxiliary inputs are treated in Sections 8.2 and 8.3. Water required for the organic processes is included in the utility balance. The major raw materials used in these manufacturing processes are limestone, carbon source and hydrochloric acid. Limestone, carbide, acetylene, and VCM manufactured in the complex are, in principle, totally consumed within the complex.

The substances that go outside the battery limit without being utilized are explained in Sections 6.6, 8.2, (4), and 8.3 (5), particularly their treamtnets. Carbon monoxide produced by the electric furnace is used as fuel for the lime kiln and the dryer of the coke as described in Section 8.3 (2); a small amount of the excess is burned. The overall material balance is given in Figure 8-6 on the previous page.

(2) Utility and fuel balances

Electricity used by the electric furnace may be considered as one of the raw materials of carbide manufacturing but it is treated as a utility. The fuel balances are based on the unit consumptions given in CHAPTER 6 and Section 8.2 and 8.3. For both organic and inorganic processes electricity and water balances are calculated on an assumed load of 80 percent.

8.5 Related Facilities

(1) Auxiliary facilities for quarry

Auxiliary facilities at the quarry include an operators' quarter, a heavy machinery shop, a powder magazine, a warehouse for parts and fuel, pickups, jeeps, tools and jigs, and water supply facilities. For these purposes, a buildings with a floor area of approximately 200 m^2 is required.

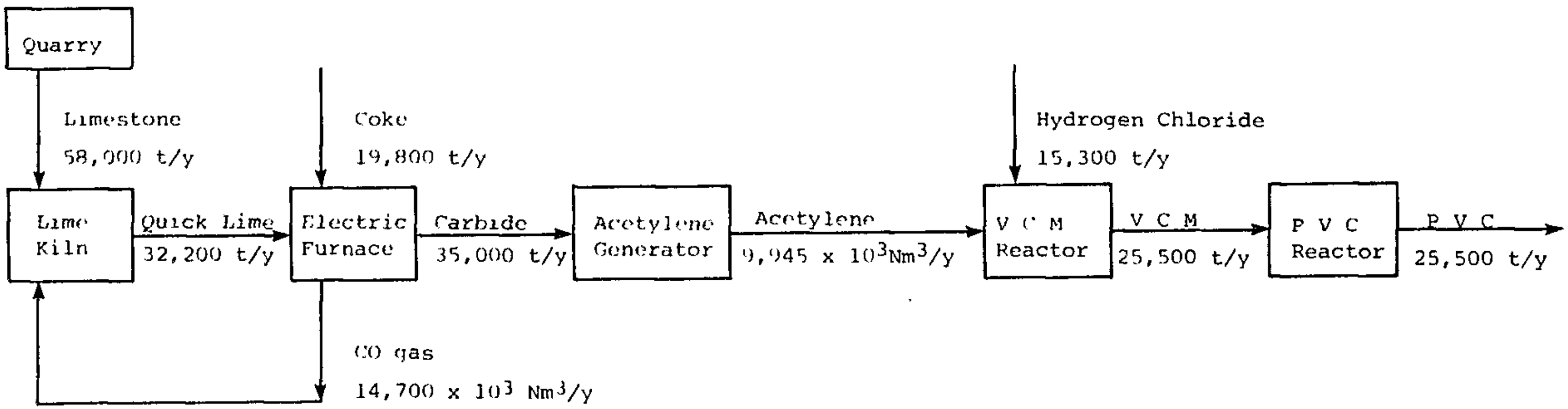


Figure 8-6 Overall Material Balance

Table 8-14 Utility and Fuel Balance (25,000 ton PVC)

(Unit: per year)

	Electricity (10^3kWH)	Fuel (10^6Kcal)	Steam (ton)	DMW (ton)	CW (10^3ton)	Notes	
Quarry	122	-	-	-	-	Limestone	58,000 ton
Limestone Kiln	2,254	33,810	-	-	8	Quick Lime	32,200 ton
Coke Dryer	554	2,970	-	-	-	Coke	19,800 ton
Electric Furnace	115,710	-39,690	-	-	30	Carbide	35,000 ton
Acetylene Generator	1,740	-	-	-	398	Acetylene	$9,945 \times 10^3 Nm^3$
VCM Reactor	8,925	-	33,150	12,750	153	VCM	25,500 ton
PVC Reactor	5,000	-	37,500	87,500	60	PVC	25,000 ton
Common	5,120	-	-	-	9	Compressors, Cooling Tower, Office, etc.	
Plant Total	139,425	-2,910	70,650	100,250	658		

(2) Electrode case manufacturing facilities

The electrode cases are consumed continuously during the operation, at a rate of 2.6 cases in two days. Machines and devices that are required for the manufacture of electrode cases are shown in Table 8-15.

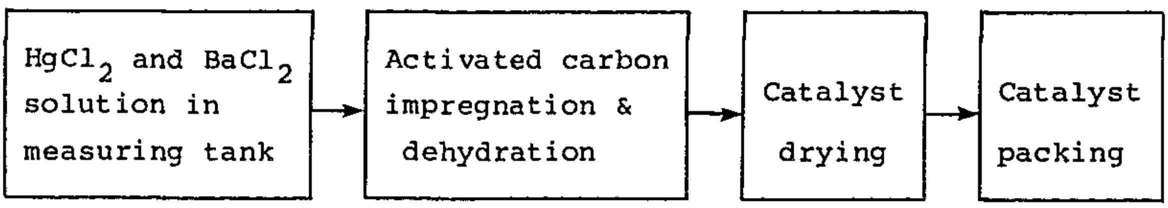
Table 8-15 Facilities for Manufacture of Electrode Case

Item	Specification	Number
Steel sheet cutter	3.2 mm	1
Stamping press machine	3.2 mm	1
Folding machine	1.2 m	1
Bending roll machine	2.0 m	1
Seam welding machine	arm length of 1.2 m	1
	thickness of 2.3 m	1
Welding machine		1

(3) VCM synthesis catalysis manufacturing facilities

Activated carbon impregnated with mercuric chloride and barium chloride will be employed as catalyst. The outline of the manufacturing facilities of this catalysit is as follows:

1) Flow



2) Principal machines and devices are given in Table 8-16.

Table 8-16 Catalyst Manufacturing Facitlity

Item	Specification	Number
Measuring tank	1 m^3	1
Impregnation tank	100 m^3	3
Discharge blower	20m^3/min x 25 mm aq	1
Catalyst hopper	500	1
Drying pan		1

(4) Waste water treatment facilities:

The acetylene, VCM, and PVC processes require facilities as given in Table 8-17.

Table 8-17 Waste Water Treating Facilities for Acetylene Generator, VCM and PVC Plants

Item	Specification	Number
Acetylene generator		
aeration tank		1
thickner		1
neutralizing tank		1
filter press	30 tons/hour	1
waste bleaching vessel	Solution 15 tons/hour	1
waste de-sulfurizing vessel	Solution 1 tons/hour	1
VCM plant		
sulfuric acid neutralizer	8 tons/month	1
PVC plant		
waste water slurry settler	13 tons/hour	

(5) Inspection facilities:

The facilities required for laboratory testing of raw materials, intermediate and final products are shown in Table 8-18.

Table 8-18 Facilities for Laboratory Testing

Item	Specification	Number
Laboratory	200 m^2	1
Facilities for inorganic testing		
Milling machine	medium	1
	small	1
	fine	1
Dryers	hot-air circulating type	1
	fixed temperature dryer	1
Sieves	plate-type	1
	screen-type	1
Cube machine	Jis-type	2
Electric furnaces	box-type	2
	cylindrical-type	2
Spectrophotometer	wave length range: 195-850 mm	1
Facilities for organic testing		
Gas chromatography	acetylene and VCM	2
Chemical analysis apparatus	analysis of waste water, for example	1 set
Gear age tester		1
Tensile tester		1

(6) Maintenance shop

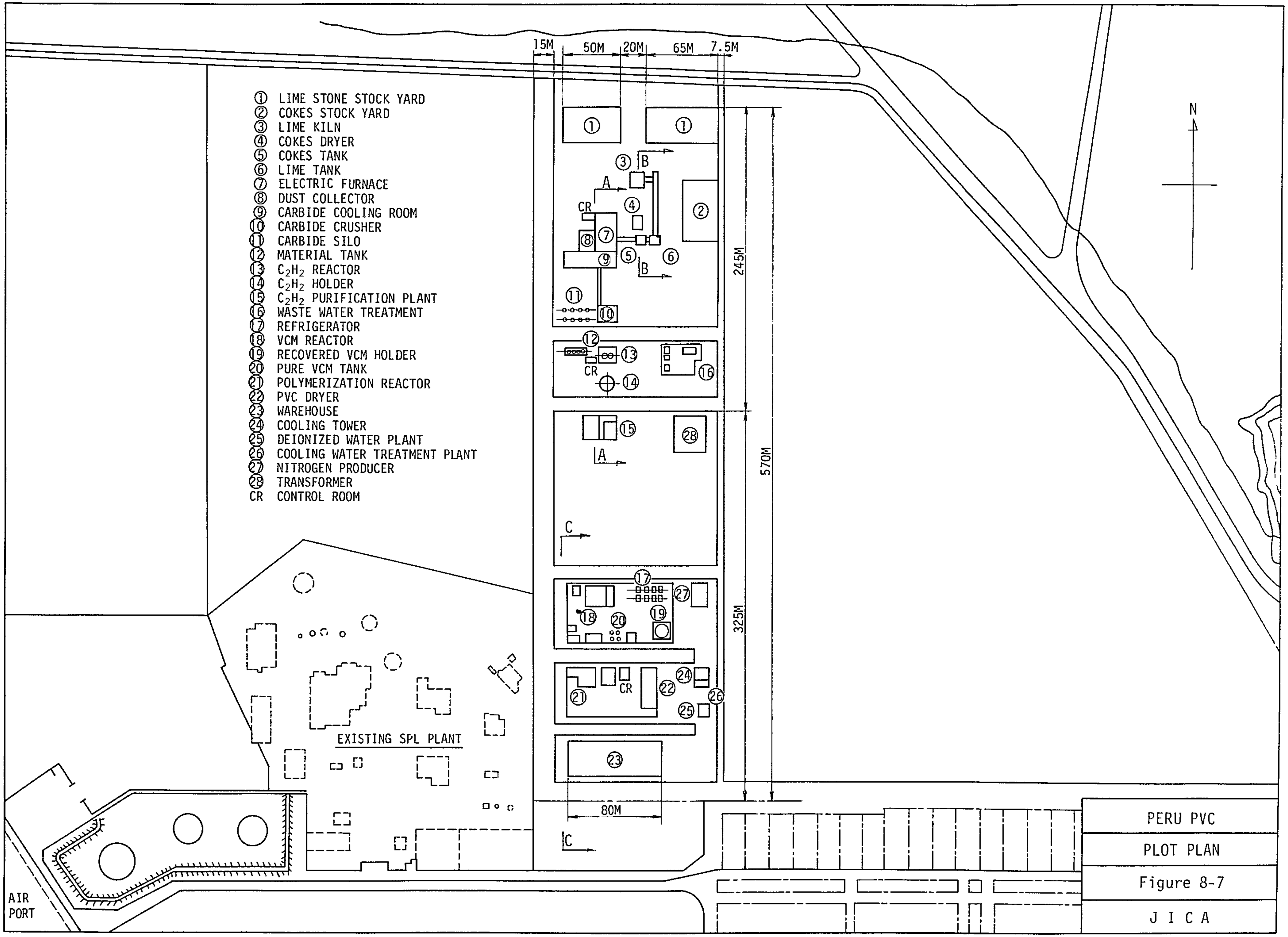
Table 8-19 lists machines and equipment required for the maintenance ship.

Table 8-19 Maintenance Shop Supply

Item	Specification	Number
Lathe	1,800 mm (length)	1
Grooving lathe	standard type	1
Drilling machine	large	1
	Medium	1
	small	1
Shaper	standard type	1
High-speed cutter	450 mm ϕ	1
Automatic threading machine	standard type	1
Bending roller machine	standard type	1
Plasma cutter/welder	standard type	1

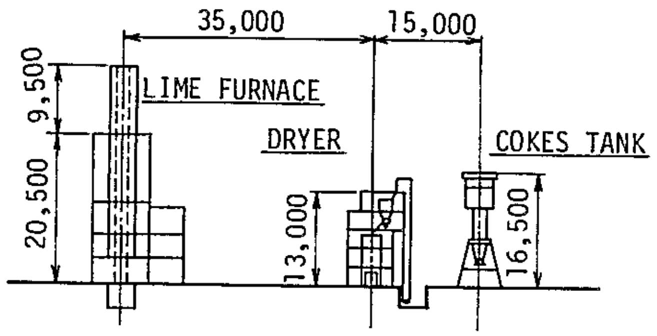
8.6 Plot Plan

As described in CHAPTER 7, the construction site is located next to the existing plant and sufficient safety distance should be allowed between the inorganic plants and organic plants. Figures 8-7 and 8-8 show plot plan and selected elevation views, respectively.

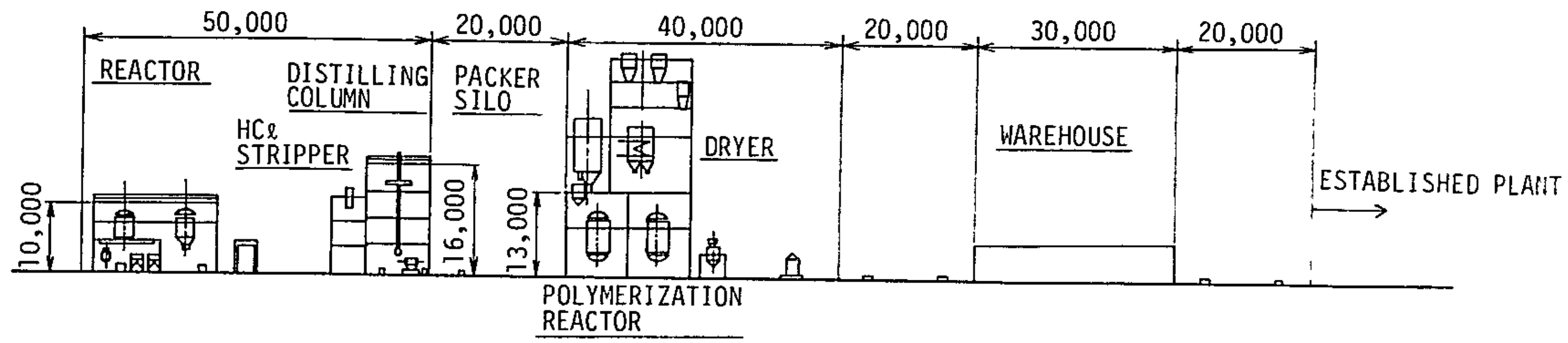


15M
50M
20M
65M
7.5M
① LIME STONE STOCK YARD
② COKES STOCK YARD
③ LIME KILN
④ COKES DRYER
⑤ COKES TANK
⑥ LIME TANK
⑦ ELECTRIC FURNACE
⑧ DUST COLLECTOR
⑨ CARBIDE COOLING ROOM
⑩ CARBIDE CRUSHER
⑪ CARBIDE SILO
⑫ MATERIAL TANK
⑬ C_2H_2 REACTOR
⑭ C_2H_2 HOLDER
⑮ C_2H_2 PURIFICATION PLANT
⑯ WASTE WATER TREATMENT
⑰ REFRIGERATOR
⑱ VCM REACTOR
⑲ RECOVERED VCM HOLDER
⑳ PURE VCM TANK
㉑ POLYMERIZATION REACTOR
㉒ PVC DRYER
㉓ WAREHOUSE
㉔ COOLING TOWER
㉕ DEIONIZED WATER PLANT
㉖ COOLING WATER TREATMENT PLANT
㉗ NITROGEN PRODUCER
㉘ TRANSFORMER
CR CONTROL ROOM
N
245M
570M
325M
80M
EXISTING SPL PLANT
AIR PORT
PERU PVC
PLOT PLAN
Figure 8-7
J I C A

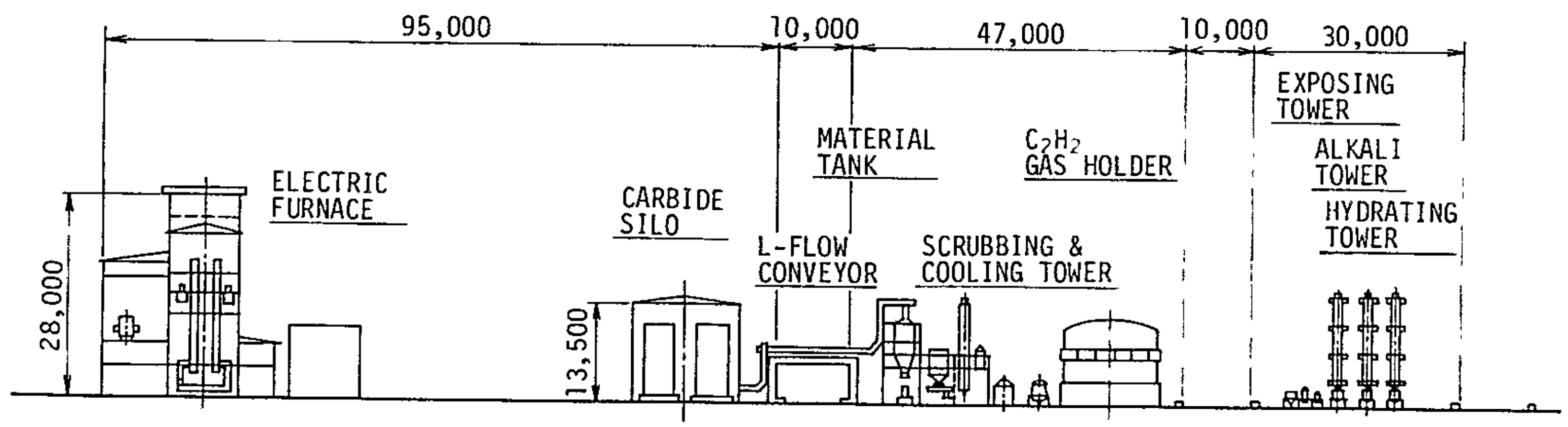
SCALE 1/1000



VIEW - B~B



VIEW - C~C



VIEW - A~A

PERU PVC
ELEVATION VIEW
Figure 8-8
J I C A

8.7 Organization, Management of Plant Operation

(1) General

The organization plan presented here is formulated on the assumption that the new complex is independent of the existing plants as through this were a grass-roots project.

(2) Plant organization

The Plant organization consists of six departments; Mining, Inorganic processes, Organic processes, Technical, Maintenance, and General Affairs Departments. The plant general manager and the assistant general manager will manage these departments. Figure 8-9 shows the overall organization chart including sections under each department.

(3) Department functions and personnel

This section describes the function of each department and presents manning plan to each department. The manning plans assume four teams for three shifts without standby personnel for absence of operators.

The personnel required for the entire complex is shown in Table 8-18. The responsibilities of plant general manager, assistant general manager, and each department are as follows:

1) Plant general manager and assistant general manager

The plant general manager is responsible for the entire complex, manages the six departments and makes important decisions. The assistant general manager assists the general manager. One secretary is assigned to the general manager and assistant general manager.

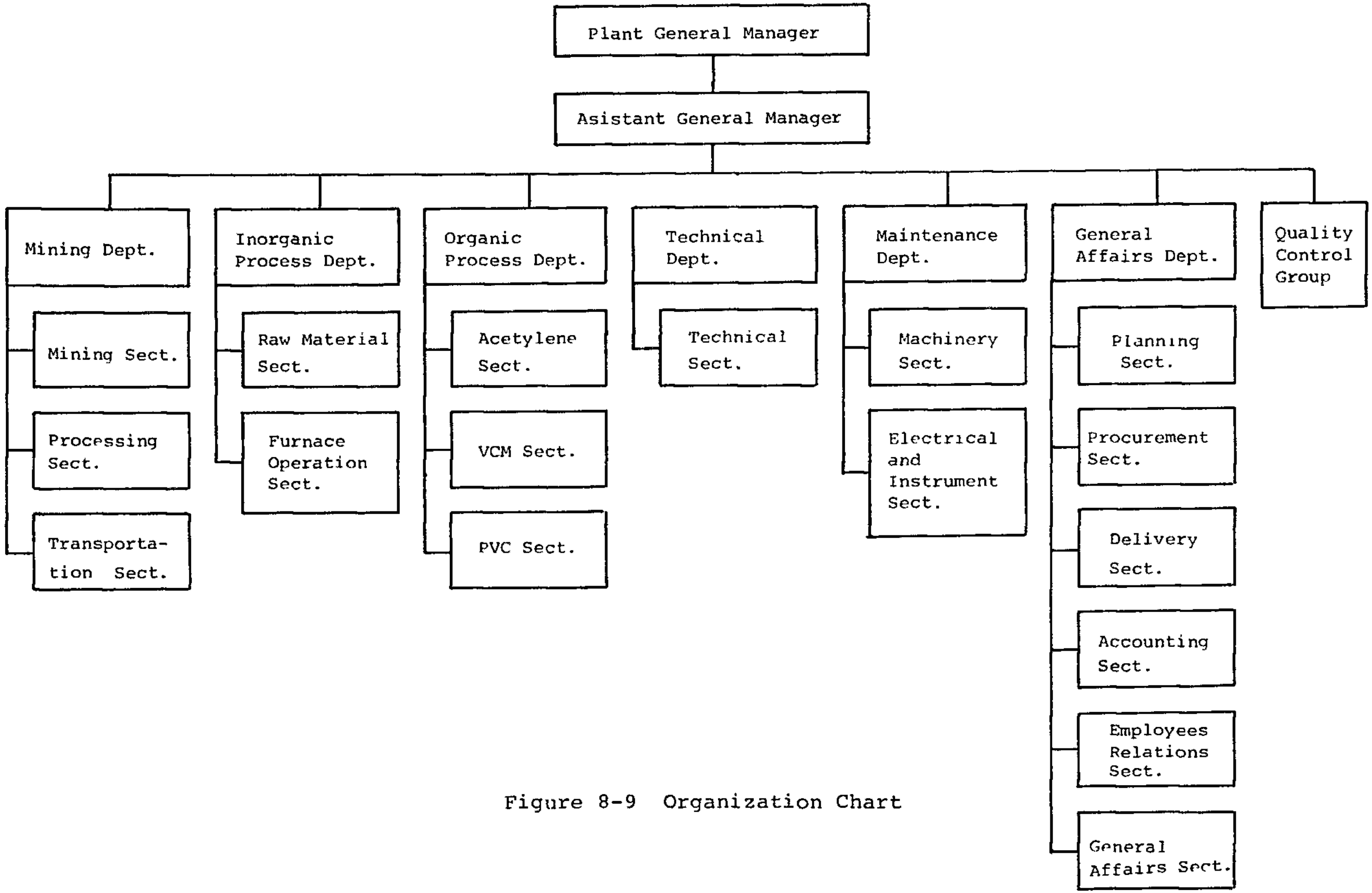


Figure 8-9 Organization Chart

2) Mining department

This department is responsible for rock mining, associated operations and transportation of limestone to the complex. Manning plan is shown, by work category, in Table 8-19.

3) Inorganic processes department

This department is responsible for the operation of the lime kiln and the electric furnace. Manning plan is shown, by work category, in Table 8-20.

4) Organic processes department

This department is responsible for the operation of the acetylene generator, VCM plant and PVC plant. Manning plan is shown, by work category, in Table 8-21.

5) Technical Department

This department has Technical Section under the department manager. Technical Section is responsible for studies and solutions of technical problems that arise from day-to-day operations and for the preventive or corrective measures that are to be taken against such problems.

6) Maintenance department

This department is composed of Machinery Section and Electrical and Instrumentation Section. Machinery Section is responsible for the maintenence of the complex as a whole, including such works as maintenence, inspection, and welding of plant machines.

Electrical and Instrumentation Section is responsible for the maintenence and inspection of the instruments and the electric system.

Maintenence Department manning plan is shown in Table 8-23.

7) General affairs department

This department consists of six sections; Planning, Procurement, Delivery, Accounting, Employees Relations, and General Administration.

Planning Section is responsible for the preparation of production plans and monitoring of the performance.

Procurement Section is responsible for the purchase of raw materials, auxiliary materials, and machine parts.

Delivery Section is responsible for the shipment of products.

Accounting Section is responsible for accounting.

Employees Relations Section is responsible for all matters that concern employee's relations.

General Administration Section is responsible for all general affairs of the complex.

Manning plan is shown in Table 8-24.

8) Quality control group

This group is responsible for quality control including laboratory testing of the raw materials, finished and intermediate products. This group also conducts test of effluents to watch possible pollutions. This group reports directly to Assistant General Manager and has authority to stop shipment of the products failing to meet the specifications.

Table 8-20 Required Plant Personnel

Position	Daytime
Plant General Manager	1
Assistant General Manager	1
Secretary	1
Mining Dpt.	26
Inorganic Process Dept.	94
Organic Process Dept.	59
Technical Dept.	7
Maintenance Dept.	31
Genenal Affairs Dept.	18
Quality Control Group	12
Total	250

Table 8-21 Manning Plan for Mining Dept.

	Daytime
Manager	1
Clerk	1
Mining	
Supervisor	1
Foreman	1
Worker	5
Maintenance Worker	2
Processing	
Supervisor	1
Foreman	1
Worker	1
Transportation	
Supervisor	1
Driver	11
Total	26

Table 8-22 Manning Plan for Inorganic Process Dept.

		Daytime	Shift
Manager		1	
Clerk		1	
Technical Staff		1	
Raw Material			
Supervisor		1	
Coke dryer	Foreman		1
	Operator		2
Lime Kiln	Foreman		1
	Operator		3
Furnace Operation			
Supervisor		1	
Operation	Engineer	1	
	Foreman		1
	Operator		7
Product Treatment	Foreman		1
	Operator		3
Miscellaneous	Foreman	1	
	Operator	7	
Inspection	Operator		1
Total		14	80 (20 x 4)

Table 8-23 Manning Plan for Organic Process Dept.

	Daytime	Shift
Manager	1	
Clerk	1	
Acetylene Generator		
Supervisor	1	
Foreman		1
Operator		4
VCM		
Supervisor	1	
Foreman		1
Operator		2
PVC		
Supervisor	1	
Foreman		1
Operator		3
Packaging Operator	6	
Total	11	48 (12 x 4)

Table 8-24 Manning Plan for Technical Dept.

	Daytime
Manager	1
Technical	
Chief	1
Staff Geologist	1
Metallurgist	1
Chemist	3
Total	7

Table 8-25 Manning Plan for Maintenance Dept.

	Daytime
Manager	1
Clerk	1
Machinery	
Chief	1
Engineer	2
Foreman	2
Technician	6
Worker	10
Electrical and Instrument	8
Total	31

Table 8-26 Manning Plan for General Affairs Dept.

	Daytime
Manager	1
Planning	
Chief	1
Clerk	1
Procurement	
Chief	1
Clerk	2
Delivery	
Chief	1
Clerk	2
Accounting	
Chief	1
Clerk	2
Employees Relations	
Chief	1
Clerk	2
General Affairs	
Chief	1
Clerk	2
Total	18

Table 8-27 Manning Plan for Quality Control Group

	Daytime
Analysis	
Chief	1
Staff (Chemist)	1
Foreman	1
Operator	9
Total	12

Table 8-28 List of Main Equipment

Name	Qty.	Specification	Material
Limestone Mining and Crushing			
Crawler drill	1	CD-6 Type	ss
Portable compressor	1	17Nm^3/min, 7kg/cm^{2}G	sc
Bulldozer	1	182PS.	ss
Wheel-loader	1	3.1m^3	ss
Dump truck	12	11-ton capacity	ss, sc
Pneumatic hammer	1	Bit gauge:30mmø	ss
Scalping unit	1	Mesh:70mm	ss
Crusher	1	Jaw type, 130t/h	sc
Screen	1	Mesh:70mm and 30mm	ss
Conveyor belt	4	Width:600mm	ss
Lime Kiln			
Shovel loader	1	0.6m^3,Tire type	ss
Skip hoist	1	14t/h,32mH	ss
Lime kiln	1	4t/h,Vertical type	ss
Conveyor	2	6t/h	ss
Vibratory screen	1	6t/h	ss
Roll crusher	1	6t/h	ss
Quick lime tank	2	30tons	ss

Name	Qty.	Specification	Material
Coke Dryer			
Bucket elevator	1	6t/h	ss
Coke dryer	1	3t/h	ss
Vertical elevator	1	3t/h,20mH	ss
Vibratory screen	1	3t/h	ss
Dry coke tank	2	50tons	ss
Electric Furnace			
Steel belt conveyor	1	50t/h, c-c8m	ss
Raw material tank	4	Quick lime 20m^{3}x2. Coke 25m^{3}x2	ss
Belt conveyor	2	10t/h	ss
Compound tank	1	6m^3	ss
Electromagnetic feeder	1	10t/h	ss
Circular pan conveyor	1	7mø,30t/h	ss
Charging bin	9	1.2mø x 1.8mH,2m^3	ss
Electric furnace	1	15,000kw. Carbide 4.5t/h	ss Brick carbon
Dust collector	1	inlet gas 2,200Nm^3/h	ss
CO·Gas holder	1	300m^3 Waterseal	ss
Trasformer	1	18,000KVA	ss
Pneumatic conveyer	1	1.0t/h	ss
Ladle	185	0.6t Charge	F.C
Ladle car	24	760mm Gauge	ss
Overhead crane	1	2.5t, Lift 10m, Span 12m	ss
Fine Powder Tank	2	Quick lime 4m^{3}x 1, Coke 5m^{3}x 1	ss ss

Name	Qty.	Specification	Material
Carbide Crusher			
Crushing bench	1	$20m^2$	ss
Apron conveyor	1	25t/h	ss
Jaw crusher	1	30t/h	ss
Backet elevator	1	25t/h, 17mH	ss
Magnetic separator	1	20t/h	ss
Impeller breaker	1	20t/h	ss
Backet elevator	1	20t/h	ss
Vibratory screen	2	10t/h	ss
Carbide Storage tank	8	200 tons x 8, 5.7mø x 9mH	ss

Name	Qty.	Specification	Material
Acetylene Generator			
Flow conveyor	1	10t/h	ss
Pulverized carbide tank	1	$15m^3$, 2500mmø x 3500mmH	ss
Flow conveyor	2	6t/h, Ltype x 1	ss
Seal tank	2	$3m^3$, 1500mmø x 1700mmH	ss
Acetylene generator	2	$750Nm^3/h$	ss
Scrubbing & cooling tower	2	1200mmø x 13000mmH	ss
Desulphurizer	2	960mmø x 6120mmH	ss
Water sealed safety bottle	2	Packed tower, 1600mmø x 1400mmH	ss
Acetylene gas holder	1	$1,500m^3$	ss
Slaked lime discharging device	2	5t/h, Screw feed back system	ss
Bucket elevator	1	8t/h, 20mH	ss
Slaked lime tank	4	$100m^3$x4, 5500mmø x 5000mmH	ss
Acetylene gas blower	2	Roots blower, $1300Nm^3/h$ x 9000mmAq	ss
Gas washing tower	3	Packed tower, 800mmø x 18000mmH	ss HRL
Cooler	2	$20m^2$, Vertical poly tube type	ss
Acetylene Dryer	2	Silica gel column, 1500mmø x 3000mmH	ss
Waste water treatment system	1	$50m^3/h$	ss concrete

Name	Qty.	Specification	Material
VCM Production			
HCl Stripping system	2	30t/day x 2	carbon
20 HCl Liq.tank	2	$10m^3$, Horizontal	ss HRL
HCl Dryer	2	Packed tower, 1250mmø x 5000mmH	ss GLL
Sulfuric acid tank	2	$5m^3$, 1600mmø x 2600mmL	ss PVCL
Mist separator	2	1000mmø x 2000mmH	ss PVCL
Heat exchanger	1	$20m^2$, Poly tube type	ss
VCM Reactor	5	Multi-tube type, 2200mmø x 3800mmH	ss
Dehydrochloric-acid tower	2	Packed tower, 1200mmø x 10000mmH	ss HRL
22% HCl Tank	2	$5m^3$, Horizontal	ss HRL
Water washing tower	1	Packed tower, 1200mmø x 16000mmH	ss HRL
Water tank	1	$5m^3$, Horizontal	ss HRL
VCM Gas Dryer	2	$3m^3$, Silica gel column	ss
VCM Compressor	5	$450Nm^3/h$ x $10kg/cm^2G$	FC
Water condensor	2	$80m^2$, Horizontal multi-tube	ss sus
Brine condensor	2	$10m^2$, Horizontal multi-tube	ss sus
Crude VCM Tank	1	$50m^3$, Horizontal multi-tube	ss sus

Name	Qty.	Specification	Material
Distillation column	1	4t/h,cap tower	ss sus
Pure VCM Tank	1	$30m^3$,Horizontal	sus
High boiler system	1	$2m^3$, $2m^2$	ss
Recovery VCM Gas holder	1	$1500m^3$, water seal type	ss

PVC Production

PVC Reactor	3	$50m^3$	sc GLL
Slurry Screen	1	4t/h	sus
Feed tank	1	$50m^3$,Vertical	sus
Stripping column	1	4t/h, 1100mmø x 15500 mmH	sus
Slurry tank	2	$80m^3$,Vertical	ss HRL
Decanter	3	2t/h	sus
PVC Dryer	1	4t/h	sus
PVC Silo	2	$150m^3$	sus
Packer	4	1t/h	sus

Name	Qty.	Specification	Material
Utility & Common Facilities			
Cooling tower	1	1800m^3/h, 32°C/25°C	ss slate
N_2 Generator	1	550Nm^3/h, 99.7%	ss
DMW System	1	18m^3/h	ss
Refrigerator	2	60JRT	SS FC SC
Air compressor	2	300Nm^3/h	FC
Diesel engine	1	1000KVA	FC SC

Note:

SS	Carbon steel
SUS	Stainless steel
SC	Cast steel
FC	Cast iron
HRL	Hard rubber lining
GLL	Glass lining
PVCL	PVC lining

CHAPTER 9 CONSTRUCTION

9.1 Summary

The construction work has two objectives: to provide facilities which mine and process limestone at Pariahuanca, and to construct plant facilities on the plant site.

Capacities of the operations are:

	(Unit tons per year)
Limestone mining and processing	58,000
Lime calcination	32,200
Calcium carbide manufacture	35,000
VCM manufacture	25,500
PVC manuacture	25,000
Utilities for the above	full set

9.2 Quarry Development

Before actually starting development detailed geological surveys, boring tests, estimation of reserves and the preparation of a quarry development plan should be carried out by professionals.

The following works are required for the development of the quarry:

(1) Construction of the access road to quarry site from the existing road running near Pariahuanca limestone quarry (Refer to Section 6.2).

(2) Construction of benches and preparation of processing plant site (300m x 150m) and surface soil dumping site (200m x 100m).
Construction of roads between benches.

(3) Construction of auxiliary facilities such as offices, operators' quarter and stock-houses within the processing plant site

(4) Protection of the irrigation canal and power transmission line and other environmental conservation work as descrebed in the Section 6.6.

9.3 Plant Construction

Presented here are general rules and variations to them are possible as needed to fit the prevailing circumstances.

The plant shall be constructed by generally accepted construction methods on the basis of an international tender and award of contract.

The owner shall provide requisite know-how and basic engineering, and the prime contractor, on a full turn-key basis, shall design, procure equipment and machinery, and perform construction on the site.

This feasibility study discovered that almost all equipment and machinery required for this project have to be imported. This study also found out that, among the construction materials required at the site, only cement, aggregate, general-purpose rolled steel products, and general-purpose electric wires can be procured in Peru.

Construction works at the site will be carried out by domestic subcontractors as long as they are competitive in cost and skill. However, availability of machine and materials, ability to employ skilled labor and experiences in properly controlling sequences of works during construction at the site should be checked before employing domestic subcontractors to avoid any serious deleys.

For this reason, steel frames and large-diameter piping materials will be fabricated to the extent possible in the countries of export to reduce the works at site. In other words, the works on site should desirably be limited to assembling operations only in order to achieve the quality of work and maintain the schedule of construction.

9.4 Construction Equipment and Machinery

Plant and machines that are manufactured and assembled at the manufacturers' plants will be subjected to careful inspection and testing and will then be transported by sea to Callao Port. Imported machines, after customes clearance, will be transported by land to the site via Pan-Am Highway and will then be carefully unloaded at prescribed and prepared locations at the site.

9.5 Civil Engineering

(1) Preliminary work

As described in Paragraph 7.3, a boring survey will be conducted. Based upon the results of this survey, pile foundations will be constructed for heavy structure. Reinforced concrete piles will be driven at the site. Standard foundations for light structures will be constructed on the solid soil after the surface layer is removed.

(2) Buildings

Because Paramonga has only slight rainfall and wind, only those buildings relating to the manufacture of carbide and control rooms will be roofed and side walled; other building will be, wherever possible, of simplified structure without roof or side walls.

Structures for supporting or housing the electric furnace, lime kiln, acetylene generator, VCM reaction vessel, PVC polymerization vessel and other heavy machines will be constructed with reinforced concrete or heavy-steel frames. Other structures will be constructed with light steel frames.

A seismic force with a horizontal coefficient of 0.2 is considered to be the potential external force; consideration of wind velocity is unnecessary.

Roofs and side walls will be of slate, with the exception of the roofs of control rooms which will be reinforced concrete and brick. The VCM and PVC control rooms will be internally pressurized and double-doored.

9.6 Plant Construction

The construction of related buildings and foundations for machines should be completed prior to the installation of machines at the site. The construction machines, vehicles, materials and supplies for such installation should all be ready for work at the site.

After pre-fabrication operations such as cutting, bending and drilling have been finished in the countries of export, steel members for the electric furnace, lime kiln, gas holder and large storage tanks will be imported. Operations at the site include welding, assembling, brick-laying, insulating, and painting.

Smaller devices, towers and tanks will be imported as completed. Large-diameter steel pipes and stainless steel pipes will be fabricated to the extent possible in the coutries of export. Domestically manufactured small-diameter pipes are expensive; therefore, importation will reduce the cost of these items.

Principal electrical equipment and instruments must be imported. Some electrical wires and communication lines are domestically available, but importation may reduce the cost of these items.

A considerable labor force, including skilled and unskilled workers, will be required during the construction at site. If a sufficient number of skilled workers are not available, it will be necessary to use foreign skilled workers.

If facilities for lodging workers at the site are insufficient, a camp shall be prepared near the site.

Manufacturers of important unit equipment and facilities like gas holders that require assemblying at the site will be requested to dispatch installation and test operation supervisors to insure satisfactory operation.

9.7 Construction Schedule

The construction schedule shall cover the period from the award of contract to the prime contractor to the start of actual production.

Operations which are to be conducted during this period include the execution of the contract agreement, the basic design, detailed design, procurement of machines, civil engineering and construction work, and installation and piping. The test operation will be conducted upon the completion of construction. When the prime contractor guarantees the work and the owner accepts it, the project will be considered to have been satisfactorily completed.

As shown in Figure 9-1, the estimated plant construction schedule covers a period of 36 months, from the execution of the contract to the completion of construction. Two additional months will be required for test operation.

The construction period includes the time required for the training of engineers and operators and for the purchase of raw materials, chemicals, and miscellaneous items.

9.8 Construction Management

Preliminary activities which are required before the execution of the present project include:

(1) Preparation of bid specifications.

A detailed site survey will be conducted to determine actual site conditions which will also be specified in the bid documents.

(2) Evaluation of bids.

Criteria for the evaluation of bids will be prepared and invitations to bid will be issued.

(3) Award of contract.

A prime contractor will be selected by the owner in accordance with bid evaluation criteria. This prime contractor shall subcontract, as required, both foreign and domestic works, including all necessary work at the site and shall observe the construction schedule shown in Paragraph 9-7. Further, this prime contractor shall cooperate with the owner's representatives and shall satisfy all contract requirements including the guarantee of all works, prior to the completion of the project.

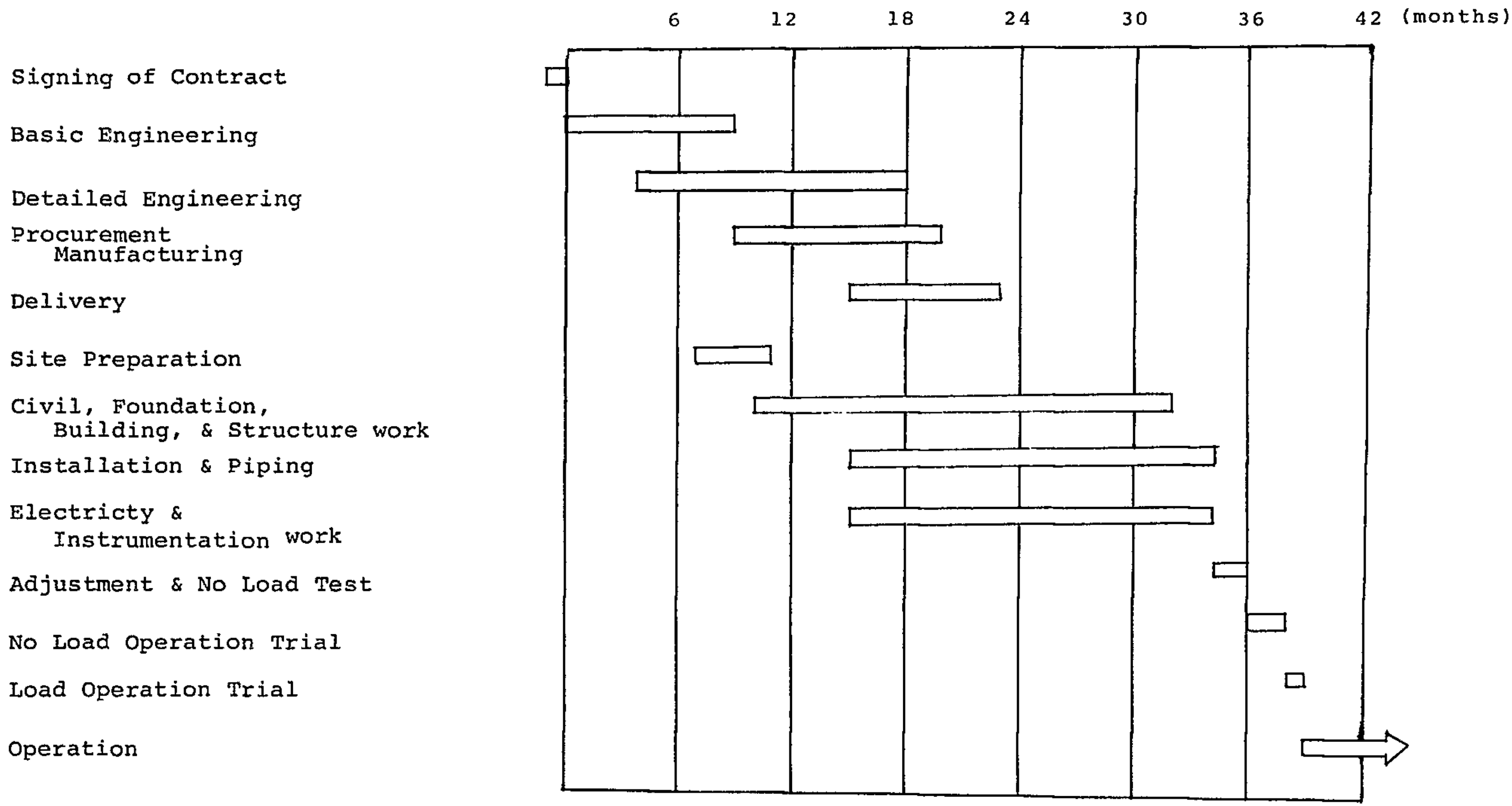


Figure 9-1 Estimated Plant Construction Schedule

CHAPTER 10 TOTAL CAPITAL REQUIREMENT

The total capital requirement for the development of quarry, installation of the carbide and PVC plants and associated expenses and fees, are summarized in this chapter. The basic premises for the Calculation of total capital requirement are as follows:

(1) Base of price (1983 constant price base)

The costs and expenses are fixed at 1983 price. This means the effect of escalation on the costs and expenses is excluded in the calculation of the total capital requirement.

(2) Exchange rate

The prices are expressed in US$, to which both Peruvian currency (sol) and Japanese currency (yen) portions are converted using the exchange rates as shown below:

1 US$ = 1536.65 sol
1 US$ = 242.00 yen

(3) Plant cost

The plant cost has been estimated based on the information and data collected during the field survey and on the concepts developed for the construction work explained in CHAPTER 9. The estimation is built up from the unit Costs of important pieces of equipment of which specifications were developed as part of the conceptual design. The estimation assumes a full turn key lumpsum contract. The duty on the imported items is also obtained.

10.1 Summary of Total Capital Requirement

The total capital requirement shown in this chapter is the total cost invested by the time the project starts commercial operation. The following table gives the summary of total capital requirement. This project requires reinvestment after the operation starts which will be treated in CHAPTER 11.

Table 10-1 Fixed Capital Requirement

(Unit: 1,000 US$)

	Foreign Currency Portion	Domestic Currency Portion		Total
		Domestic Works	Duty	
Construction cost				
Construction of mine	1,918	1,499	1,257	4,674
Construction of plant				
Site preparation	0	579	0	579
Equipment and machinery	22,953	0	12,135	35,088
Inland transportation	0	82	0	82
Erection works	0	7,197	0	7,197
Civil works	2,235	3,372	992	6,599
Engineering fee	5,165	0	0	5,165
Contingency	1,756	0	0	1,756
Construction expenses	5,165	0	0	5,165
Sub-total	39,192	12,729	14,384	66,305
Pre-operating expense	278	1,540	96	1,914
Initial working capital	566	1,896	378	2,840
Interest during construction				
Without duty (const.)	3,170	0	0	3,170
With duty	4,013	0	0	4,013
Total capital requirement				
Without duty (const.)	43,206	16,165	474	59,845
With duty	44,049	16,165	14,858	75,072

10.2 Quarry Development and Limestone Transportation Cost

The investment in this section consists of the cost of machinery, their inland transportation cost, erection works, construction of access road to the quarry, civil works and construction of buildings. The costs are shown in the following table.

Table 10-2 Quarry Development Cost

(Unit: 1,000 US$)

	Foreign Currency Portion	Domestic Currency Portion		Total
		Domestic Works	Duty	
Mining machinery	1,881	0	1,230	3,111
Inland transportation	0	17	0	17
Construction works	0	579	0	579
Land preparation	0	186	0	186
Access road	0	653	0	653
Others (Civil & buildings)	37	64	27	128
Total	1,918	1,499	1,257	4,674

Note: The "access road" is the cost for the construction of a 1,000 m road from the existing highway.

The foreign portion inludes 219,000 US$ for transportation of quarry machinery.

10.3 Plant Construction Cost

(1) Land and site preparation cost; 579 thousand US$

(2) Equipment cost

Table 10-3 gives cost of the equipment for process and offsite facilities at Paramonga. The estimation assumes importation of all pieces of equipment except those made of 9 mm or thinner carbon steel.

Table 10-3 Plant Equipment Cost

(Unit: 1,000 US$)

	Foreign		Domestic	
	FOB	Freights Insurance	Duty	Total
Lime kiln sect.	1,179	238	704	2,121
Coke drying sect.	344	118	260	722
Electric furnace sect.	5,500	1,280	3,136	9,916
Carbide crushing sect.	679	184	523	1,386
Acetylene generation sect.	1,589	216	931	2,736
VCM sect.	3,335	208	2,133	5,676
PVC sect.	3,550	436	2,220	6,206
Utilities sect.	3,805	292	2,228	6,325
Total	19,981	2,972	12,135	35,088

(3) Inland transportation cost; 82 thousand US$

This is the cost of transportation of the imported equipment and materials from the port of Callao to the Paramonga plant site.

(4) Plant erection cost; 7,197 thousand US$

This consists of plant installation, erection, and assembly at the plant site, and the costs of the equipment and materials necessary for the field works.

(5) Civil work and building cost; 6,599 thousand US$

The costs of land preparation, construction of buildings, foundation, concrete work, and housings are counted as civil work and building cost.

(6) Engineering and supervision fee; 5,165 thousand US$

This is the cost for the works of engineering, construction supervision, etc.

(7) Contingency; 1,756 thousand US dollars

The contingency is approximately 5 percent of the sum of plant constrution cost excluding the costs of contingency, freight and import duty.

(8) Expense for construction; 5,165 thousand US$

This expense includes the general expenses associated with the field construction work, and miscellaneous costs.

10.4 Construction Cost of Quarry and Plant

The total costs for quarry development and plant construction are as shown in the next Table 10-4 Construction Cost.

Table 10-4 Construction Cost

(Unit: 1,000 US$)

	Foreign Currency Portion	Domestic Currency Portion		Total
		Domestic Works	Duty	
Mining				
Mining machinery	1,881	0	1,230	3,111
Inland transportation	0	17	0	17
Construction work	0	579	0	579
Land preparation	0	186	0	186
Access road	0	653	0	653
Others (Civil & Building)	37	64	27	128
Sub-total	1,918	1,499	1,257	4,674
Plant				
Land & site preparation	0	579	0	579
Equipment & machinery	22,953	0	12,135	35,088
Inland transportation	0	82	0	82
Erection works	0	7,197	0	7,197
Civil works	151	991	65	1,207
Building	2,084	2,381	927	5,392
Engineering fee	5,165	0	0	5,165
Contingency	1,756	0	0	1,756
Construction expenses	5,165	0	0	5,165
Sub-total	37,274	11,230	13,127	61,631
Total	39,192	12,729	14,384	66,305

10.5 Land Acquisition

The land needed for quarry site and access road is purchased; however, the land cost is nil. The land acquisition for the plant site is not needed because SPL already owns it.

10.6 Pre-Operating Expense

Pre-operating expense in the case of this project consists of training expenses, administration cost, materials for test run, and quarry licence. The breakdown is shown in Table 10-5.

(1) Training expense; 275 thousand US dollars

Training expense incurs for a period of one year before the startup. It is estimated that 24 foremen will be trained in Peru for one year during which period they will also have two months -- 50 men-month — training in Japan. The salaries, living expenses for overseas stay and travels paid to them are counted.

(2) Administration cost; 495 thousand US$

Managers, engineers and supervisors will be employed before the startup on the following schedule:

	Number	Period before startup, year
Manager	3	3
Engineer	5	3
Supervisor	10	1

The salaries paid to them and associated indirect expenses are calculated as administration cost.

(3) Materials for test run; 1,088 thousand US$

The expense required for the test run is estimated to cover the cost of raw materials, utilities, auxiliary materials required for the test run period. The test run without production requires 2 months and the utilities consumption is 30 percent of full load. The period of test run producing PVC is 1 month. However, the production of PVC is 1,042 ton (1/2 month of PVC production). The raw material consumption is 0.5 month of full load; however, the utilities requires 1 month of full load.

	Utilities	Raw Materials	Total
Raw material	0	240	240
Utilities	318	530	848
Total	318	770	1,088

(4) Quarry licence; 2 thousand US$

The quarry development licence of 2 thousand US$ is required in the year before commercial operation.

Table 10-5 Pre-Operating Expense

(Unit: 1,000 US$)

	Year			
	- 3	- 2	- 1	Total
Training expense	0	0	329	329
Administration cost	121	121	253	495
Material for test run	0	0	1,088	1,088
Licence fee	0	0	2	2
Total	121	121	1,672	1,914

10.7 Working Capital

The initial working capital means the funds required for an enterprise to continue its daily business activities. In this study, the working Capital is defined as a total of raw materials and product inventories, operating cash and account receivable minus account payable. Breakdown of the initial working capital is shown in Table 10-6. As the balance of account receivable minus account payable increases in proportion to increase in operating rate, the increases are counted as increases in the working capitals for these years.

Table 10-6 Initial Working Capital

(Unit: 1,000 US$)

	Period of Inventory	Inventory	Price	Total
Raw material				
Coke	3 month	4,950 t	187 US$/t	926
Consumable				
Explosive	1 month	1,450 kg	2.58 US$/kg	4
Fuel	10 days	20 kl	201 US$/kl	4
Tools				10
Products*	1 month	0.5 month of operating cost		661
Operating cash	1 month of labor expense and plant overhead			180
Sub-Total				1,785
Account receivable	1 month of PVC and slaked lime			1,863
Account payable	1 month of variable cost			-808
Total				2,840

Note* The products manufactured during the test run is stocked as inventory which is equivalent to 0.5 month of production.

10.8 Financial Source and Terms and Conditions of Long-Term Loan

The sources for the capital have not been fixed yet. However, the following financing conditions for a long-term loan are assumed.

Conditions for long-term loan:

Long-term loan	:	60 % on the total capital requirement
Interest rate	:	13.5 % per annum (11% + 2.5% of guarantee)
Debt repayment	:	10 installments/10 years equal annual payment 3 years' grace period after the commencement of commercial operation.

10.9 Disbursement Schedule

The disbursement schedule of total capital requirement for investment is shown in Table 10-7.

Table 10-7 Disbursement Schedule

(Unit: 1,000 US$)

	Year - 3	Year - 2	Year - 1	Total
Without duty case				
Construction cost	5,550	27,219	19,152	51,921
Pre-operating expense	121	121	1,672	1,914
Initial working capital	0	0	2,840	2,840
Interest during const.	0	459	2,711	3,170
Total	5,671	27,799	26,375	59,845
With duty case				
Construction cost	5,550	37,621	23,134	66,305
Pre-operating expense	121	121	1,672	1,914
Initial working capital	0	0	2,840	2,840
Interest during const.	0	459	3,554	4,013
Total	5,671	38,209	31,200	75,072

CHAPTER 11 OPERATING COST

11.1 General

The operating cost is divided into direct cost and fixed cost, the former covering the costs of the raw materials, auxiliary materials and utilities, the latter those not relating to the operating rate of the plant. All the plants are aligned to the production of PVC only and the sale of the intermediate products is not attempted; therefore, the financial analysis is done on the complex, not on any individual plants. Accordingly, the operating cost to produce the intermediated products are not discussed here.

11.2 Limestone Production and Transportation Costs

The limestone is not purchased but produced as a part of this project. By applying the above principle, the economics of the quarry per se is not studied but is treated as an integral part of the entire project. The direct and transportation costs incurred to the quarry only are shown. To produce 58,000 per year of sized limestone, twice as much or 116,000 tons per year of limestone is excavated. The costs of consumables for mining and transportation are shown in Table 11-1. Just for the purpose of reference the cost of limestone is calculated and given in APPENDIX.

Table 11-1 Cost of Consumables for Mining and Transportation

	Annual Consumption	Unit Price	Annual Cost ($\times 10^3$US$)	Cost per 1 ton of PVC (US$)
Mining				
Fuel	58,000 l	0.201 $/l	12	0.48
Explosive	17,400 kg	2.58 $/kg	45	1.80
Transportation				
Fuel	664,000 l	0.201 $/l	133	5.32
Tire	320 Units	103.3 $/Unit	33	1.32
Total			223	8.92

The annual payment to the mining right is 55 US$.

11.3 Raw Material Cost

(1) Coke

The imported coke is used.

(2) Hydrogen chloride

Hydrogen chloride which currently disposed of, is planned to be supplied to the VCM Section. The following two cases are studied.

- Hydrogen chloride cost is Zero
- Hydrogen chloride cost is 101 US$ per ton

Table 11-2 Raw Material Cost

	Annual Consumption (ton)	Price (US$/t)	Annual Cost (x 10^3 US$)		Cost per 1 ton of PVC (US$)
			A	B	
Coke	19,800	187	3,703	3,703	148.12
Hydrogen chloride	15,300	0	0	-	0
Hydrogen chloride	15,300	101	-	1,545	61.80
Total			3,703	-	148.12
Total			-	5,248	209.92

Note A: Hydrogen chloride priced zero
B: Hydrogen chloride priced at 101 US$ per ton

11.4 Auxiliary Material Cost

The auxiliary material costs for mining and transportation, inorganic and organic sections are shown in the next page.

Table 11-3 Auxiliary Material Cost

	Annual Cost ($x10^3$US$)	Cost per 1 ton of PVC (US$)
Mining and transportation section	223	8.92
Inorganic section		
Electrode paste	868	34.72
Electrode case	42	1.68
Others	157	6.28
Sub-total	1,067	42.68
Organic section		
VCM catalyst	537	21.48
PVC catalyst	69	2.76
PVC dispersant	62	2.48
Others	93	3.72
Sub-total	761	30.44
Total	2,051	82.04

11.5 Utility Cost

The utility cost for the production of PVC is as follows:

Table 11-4 Utility Cost

	Annual Consumption	Unit Price (US$/t)	Annual Cost ($x10^3$US$)	Cost per 1 ton of PVC (US$)
Electricity ($x10^3$kwh)	139,425	35*	4,880	195.20
Steam (ton)	70,650	21	1,484	59.36
CW ($x10^3$ ton)	654	0.097	nil	nil
Total			6,364	254.56

* Unit US cent/KWH

11.6 Labor Cost

The required number of labor and personnel for the plant operation is discussed in CHAPTER 8. They are divided as follows:

	Number
- Direct personnel	198
- Indirect personnel	52

The direct personnel are the workers below foreman class in the production department.

Since the indirect personnel expense is included in the plant overhead, only the personnel expense for the direct personnel will be discussed here. The personnel expense includes social security costs such as health insurance, welfare pension insurance, and these costs are assumed to be 56 percent of the paid wage and salary.

The direct personnel expense is shown below.

Table 11-5 Personnel Expense

(Unit: 1,000 US$)

Salary and Wage	650
Social Security	364
Total	1,014

Table 11-6 Labor Cost Breakdown

Grade	Mining	I.O.	O	Tech	Maint	G.A.	Q.C.	Total	
(US$/year, head)									
a) Director Manager (22,420)	1	1	1	1	1	3		8	Gen.Manager, Ass.Manager, Secretary
b) Professional (10,860)		2		3			3	8	Staff, Chemist, Geologist
c) Office clerk (6,920)	1	1	1		1	12		16	
d) Technics (13,240)	3	2	3	2	4	6		20	Supervisor, Chief
e) W.Q. (8,130)	2	17	12	1	11			43	Foreman, Technician
f) W.N.Q. (4,290)	19	71	42		14		9	155	Worker, Operator
Total	26	94	59	7	31	21	12	250	

Note: 1. The indicated expenses include social security expense

2. e) + f) Direct Labor Cost (1,014,540 US$)

3. a), b), c), D) Indirect Labor Cost Counted in Plant Overhead

11.7 Plant Overhead

(1) Indirect personnel expense

This expense consists of personnel expense for the indirect personnel and the social security expense assumed to be 56 percent of the personnel expense. The indirect personnel are those classified as a) b) c) and d) in Table 11-4. The number of the indirect personnel is 52. Annual indirect personnel expense is calculated here in the same way as in the previous section.

	(Unit: 1,000 US$/year)
Personnel Expense	412
Social Security	230
Total	642

(2) Office expense

This expense is management expenses such as cost of stationery, communication, travel, etc.

(3) Other expense

Maintenance of recreation facilities, houses, club house, etc. are counted in the other expense.

(4) Total plant overhead cost

The total plant overhead cost is as follows:

Table 11-7 Plant Overhead

	(Unit: 1,000 US$/year)
Personnel expense	642
Office expense and others	500
Total	1,142

11.8 Maintenance

The cost for maintenance is 1,240 thousand US$ consisting of the costs of material and the parts.

11.9 Cost for Insurance

The cost for insurance is calculated to be 0.5 percent of construction cost. The cost amounts to 332 thousand US$ per year.

11.10 Local Tax

The local tax is a cost for production which is 24 thousand US$ per year.

11.11 Summary of Operating Cost

Table 11-8 shows the summary of operating cost.

Table 11-8 Operating Cost Summary

(25,000 ton/year PVC)

	Annual Consumption	Unit Price (US$/*)	Annual Cost ($x10^3$US$) A	Annual Cost ($x10^3$US$) B	Cost per 1 ton of PVC (US$)
Variable Costs (*)					
Coke (ton)	19,800	187	3,703	3,703	148.12
Hydrogen chloride (ton)	15,300	0	0	-	0
Hydrogen chloride (ton)	15,300	101	-	1,545	61.80
Auxiliary materials			2,051	2,051	82.04
Electricity($x10^3$kwh)	139,425	35	4,880	4,880	195.20
Steam (ton)	70,650	21	1,484	1,484	59.36
Sub-total			12,118	-	484.72
Sub-total			-	13,663	546.52
Fixed Costs					
Labor expense			1,014	1,014	40.56
Plant overhead			1,142	1,142	45.68
Maintenance			1,240	1,240	49.60
Insurance			332	332	13.28
Local tax			24	24	0.96
Sub-Total			3,752	3,752	150.08
Total			15,870	-	634.80
Total			-	17,415	696.60

Note A: Hydrogen chloride priced zero

B: Hydrogen chloride priced at 101 US$ per ton

11.12 Reinvestment

The quarry machinery, VCM synthesis section, hydrogen chloride treating unit and electric furnace require reinvestment to replace important machinery and equipment. The followings are the costs required for the reinvestment.

Table 11-9 Reinvestment

(Unit: 1,000 US$)

	8	10	13	15	Total
Mining machinery	2,171	0	0	2,171	4,342
Plant equipment	0	2,406	2,597	0	5,003
Total	2,171	2,406	2,597	2,171	9,345

CHAPTER 12 FINANCIAL ANALYSIS

12.1 General

This chapter conducts financial analysis of this project. Sections 12.2 to 12.6 define the conditions and data to be input to the analysis. Section 12.7 explains the method of analysis and the meanings of the indices of profitability obtained as a result of the calculation. Sections 12.9 and 12.10 discuss the result obtained and pass judgement as to the financial profitability of this project.

Analysis is made on the assumption that this project is implemented by an independent business entity, SPL in this case. This means that financial profitability is as important to SPL as national benefit to the nation. Income statements and cash flow tables are developed in a manner generally employed by operating businesses, although simplification of the calculation processes is done when appropriate because the operation here is not an exact accounting for tax purpose but project evaluation.

12.2 Premise for Financial Analysis

(For Base Case)

(1) Project life

Construction period	:	3 years
Commercial operation period	:	20 years

(2) Exchange rate

1 U.S. Dollar (US$) = 1,536.65 Sol

1 U.S. Dollar (US$) = 242.00 Yen

(3) Price basis

The 1983 fixed prices are used in this financial analysis. That is, all prices and costs are calculated at 1983 fixed price and excalation and inflation are not incorporated in the calculation.

(4) Plant capacity

The capacities of the plants are given in CHAPTER 8. The production of PVC at full capacity is 25,000 tons per year.

(5) Operation rate

First year	:	80 %
Second year	:	90 %
Third year and after	:	100 %

(6) Short term loan

The total capital required for this project is explained in CHAPTER 10. The financing conditions for the short-term loan that may be borrowed in case this project runs short of cash during the commercial operation period are as described below:

Conditions of short-term loan

Interest rate	:	16 percent p.a.
Debt repayment	:	All debt is to be paid back in the earliest possible year after borrowing

(7) Depreciation and amortization

The conditions for the calculation of depreciation and amortization are set as follows as a result of the discussions with the concerned authorities.

Table 12-1 Depreciation and Amortization

	Depreciation Method	Salvage Value (%)
Machinery and equipment for quarry, vehicle	5 yr straight line	0
Machinery and equipment for plant	10 yr straight line	0
Civil and building	30 yr straight line	0
Pre-operating cost and interest during construction	10 yr straight line	0

(8) Industrial community and taxes

Also as a result of the discussions with the concerned authorities, the followings are applied to income tax calculation.

1) Industrial community

Twenty seven percent of profit before tax is taken as an industrial community.

2) Tax

a) Income tax (Corporate tax)

Progressive tax rates as shown on the next page are employed:

Table 12-2 Industrial Community and Income Tax

(Unit: %)

Profit Before Tax (1,000 US$)	Industry Community	Tax Rate	Total
Less than 107	27	30	48.90
From 107 to 1,074	27	40	56.20
From 1,074 to 2,148	27	50	63.50
More than 2,148	27	55	67.15

Note: Total = Profit before tax (100 - 27) x tax rate.

b) Local Tax

The local tax for the existing plants is 45 thousand US$ per year with 37.5 thousand US$ per year as Paramonga city tax and 7.5 thousand US$ per year as licence fee. However, the following local tax is applied to the new project.

Local city tax	20	thousand US$/year
Licence fee	4	" "
Total	24	" "

(9) Incentives incorporated to the calculation of financial analysis

1) Loss carry forward

The loss carry forward for 5 years is applied to the calculation.

2) Income tax credit for reinvestment

Income tax is reduced based on the income tax credit shown by the following equation.

Net profit X	X	
Industrial community, 27%	0.27X	
Income tax, Y%	0.73XY/100	(a)
Profit before reinvestment	X - 0.27X - 0.73XY/100	
Credit additional	0.146 XY/100	(b)
Credit reinvestment	Y/100 x (X - 0.73XY/100)	(c)
Tax amount		
Tax	0.27 Y/100	(a)
Credit additional	0.146 XY/100	(b)
Credit reinvestment	Y/100 x (X - 0.73XY/100)	(c)
Net tax	(a) - (b) - (c)	

Note: Maximum reinvestment is limited the value shown below X - 0.27X - 0.73X Y/100

The result of calculation on industrial community and income tax is as follows;

(Unit: %)

Profit Before Tax (1,000 US$)	Without Reinvestment			With Reinvestment		
	Industrial Community	Income Tax	Total	Industrial Community	Income Tax	Total
Less than 107	27	30	48.90	27	2.19	29.19
From 107 to 1,074	27	40	56.20	27	5.84	32.84
From 1,074 to 2,148	27	50	63.50	27	10.95	37.95
More than 2,148	27	55	67.15	27	14.052	41.052

3) Internal tax refund

Sixteen percent of gross revenue is refunded until the total of refund reaches the value of internal tax paid for the import of equipment and machinery. Internal tax is calculated based on the information listed on the next page.

1) FOB
+ Freight
+ Insurance

CIF	=	Taxable value

2) Duty
3) D.L.N'22342 1% of 1)
4) Internal tax 16% of 1) + 2) + 3)

12.3 Disbursement Schedule of Total Capital Requirement

Disbursement schedule of the total capital requirement is discussed in CHAPTER 10 summarized in Table 12-3.

Table 12-3 Disbursement Schedule of Total Capital Requirement
- Without duty Case -

(Unit: %)

	Year		
	- 3	- 2	- 1
Construction cost	10.7	52.4	36.9
Pre-operating expense	6.3	6.3	87.4
Working capital	0	0	100.0
Interest during construction	0	14.5	85.5

Note: (-) in year indicates constructon period.

The base case assumes that 40 percent of the total capital requirement is paid by own capital fund and, the balance, 60 percent of the requirement is borrowed.

12.4 Sales Plan

Sales volumes and revenues of PVC and slaked lime are shown in Table 12-4.

Table 12-4 Sales Volume and Revenue of PVC

(Unit: 1,000 US$)

		Year 1	Year 2	Year 3 - 20
Sales volume, t/y	PVC	20,000	22,500	25,000
	Slaked lime	7,200	8,100	9,000
Unit price, US$/t	PVC	1,100	1,100	1,100
	Slaked lime	50	50	50
Revenue, 1,000 US$/yr		22,360	25,155	27,950

(1) Production plan

The plan for PVC production is the same as described in 12.2.(5).

(2) Sales volume

The entire product is assumed to be sold.

(3) Prices of products

Based on the results of market survey, prices of PVC and slaked lime are 1,100 and 50 US$ per ton respectivily and these figures are applied to the calculation of revenue.

12.5 Production Cost

The production cost consists of operating costs, depreciation and interest to the loan. The result of calculation for production cost is summarized in Table 12.9.

12.6 Method of Financial Analysis

Based on the study results and premise presented in CHAPTERS 10, 11 and preceding sections of this chapter. The followings financial tables have been prepared.

- Profit and loss statement
- Cash flow statement
- Income Statement

As a criterion of profitability, Financial Internal Rate of Return (FIRR) is used.

(1) FIRR on I (Financial Internal Rate of Return on Investment)

"FIRR" on I stands for Internal Rate of Return (IRR) on Investment. The calculation is done as if the total investment were covered by own funds. "FIRR on I" essentially indicates the profitability of a project itself, and financing conditions such as debt and equity ratio, loan conditions, etc., do not affect the result.

(2) FIRR on E (Financial Internal Rate of Return on Equity)

"FIRR on E" stands for IRR on Equity (own fund invested), and FIRR on E indicates the profitability of own capital invested.

(3) Equation applied to the calculation of FIRR

The equation applied to the calculation of "FIRR on I" and "FIRR on E" is given on the next page.

Table 12-5 Equation of FIRR

$$\sum_{i=0}^{N} \frac{(CFE) \text{ of } i}{(I + R)^{i}} + \frac{S + W}{(I + R)^{n}} = 0$$

(CFE) Represents cash flow element of each year.

FIRR ON I		FIRR ON E	
(CFE) =	- Investment	(CFE) =	- Equity
	+ Revenue		+ Revenue
	- Operating Costs		- Operating Costs
	- Income Tax		- Income Tax
	+ Depreciation		- Repayment of Debt
			+ Depreciation

R: Rate of return

i: ith Year

N: Years from initial cash outlay to end of project

S: Salvage value

W: Working capital plus non-depreciable investment

12.7 Case Study-Change in Import Duty for Quarry and Plant Equipment and Machinery

This section sees the effect of import duties on imported machinery and equipment on project viability by arbitrarily setting up two extreme cases each representing imposition of 0 and 100 percent duty on equipment.

(1) Cases

The following two cases are established:

Case A: Total exemption of import duty
Case B: Import duty fully imposed

Principal differences in the investment and total capital requirement between cases are summarized below.

Table 12-6 Investment Cost and Total Capital Requirement

(Unit: 1,000 US$)

	A	B
Import duties	0	14,384
Investment cost excluding duty	51,921	51,921
Sub-total	51,921	66,305
Pre-operating expence	1,914	1,914
Initial working capital	2,840	2,840
Interest during construction	3,170	4,013
Total capital requirement	59,845	75,072

Note: Import duties are calculated based on the information listed below:

1) FOB
+ Freight
+ Insurance
CIF = Taxable value

2) Duty

3) D.L.N'22342 1% of 1)

4) Internal tax 16%
Applied on the bases of 1) + 2) + 3)

5) D.L.N'22448 (10% in maritime freight)

6) Custom agents' commision and expenses:
10% of 2) + 3) + 4) + 5)

7) Import duty or duties referred to in this financial analysis mean (2) total of 2) to 6).

(2) Summary of case study

Calculated FIRR's on I and E before and after tax are summarized in Table 12-7.

Table 12-7 Financial Analysis Results (Case Study)

(Unit: %)

	A	B
FIRR on I (before tax)	16.8	14.1
FIRR on I (after tax)	11.9	10.3
FIRR on E (before tax)	19.7	14.7
FIRR on E (after tax)	15.5	11.5

It is not always right to judge project or commercial viability from the viewpoint of return on investment or equity being over a certain standard, which is, depending upon the circumstances, 10, 15, or 20 percent. If a project could obtain a very favorable financing ROI considerably lower than 10 percent could be commercially viable. Looking at the results of the case study shown here, exemption of the import duty to this project would be regareded as one of desired, not necessarily mandatory, conditions for project viability. For this reason Case A is treated as the base case on which further analysis is conducted.

12.8 Results of Financial Analysis

(1) Summary of calculation

The principal results of the calculation are shown in the next page.

Table 12-8 Summary of Calculation

	FIRR on I	FIRR on E
Total capital requirement		
Finance		
Equity	56,675	23,938
Dept	-	35,907
Total	56,675	59,845
Annual revenue		
Revenue, 1,000 US$	27,950	27,950
Net production cost		
Annual, 1,000 US$	21,026	25,706
Cost, US$/ton PVC	841.04	1,028.24
Profit before tax		
Annual, 1,000 US$	6,924	2,244
Profit, US$/ton PVC	276.96	89.76
Taxes		
Annual, 1,000 US$	2,842	921
US$/ton PVC	113.68	36.84
Profit after tax		
Annual, 1,000 US$	4,082	1,323
US$/ton PVC	163.28	52.92
Cash flow		
Annual before tax, 1,000 US$	12,080	4,126
after tax, 1,000 US$	9,238	3,205
FIRR (before tax), %	16.8	19.7
FIRR (after tax), %	11.9	15.5
Payout period, year	6.5	5.4

Note: Revenue, cost, profit, tax and cash flow shown in the table are those for the fifth year after the startup of the operation.
HCl cost is zero in the calculation of net production cost.

(2) Production cost summary

The production cost consists of operating cost, depreciation and interest to the loan. The production cost obtained is summarized in Table 12-9. The variable cost occupies a substantial portion of the production cost due to the high cost of electricity. The effect of electricity is even higher than that of limestone.

Table 12-9 Production Cost Summary

(Unit: 1,000 US$)

Year	Operating cost Variable cost	Fixed cost	Total	Depreciation	Interest	Total	Unit* Cost
1	9,694	3,752	13,446	5,473	4,878	23,797	1,190
2	10,906	3,752	14,658	5,473	4,878	25,009	1,112
3	12,118	3,752	15,870	5,473	4,878	26,221	1,049
4	12,118	3,752	15,870	5,473	4,878	26,221	1,049
5	12,118	3,752	15,870	5,473	4,363	25,706	1,028
6	12,118	3,752	15,870	4,978	3,878	24,726	989
7	12,118	3,752	15,870	4,978	3,393	24,241	970
8	12,118	3,752	15,870	4,978	2,909	23,757	950
9	12,118	3,752	15,870	5,412	2,474	23,756	950
10	12,118	3,752	15,870	5,412	1,939	23,221	929
11	12,118	3,752	15,870	912	1,454	18,236	729
12	12,118	3,752	15,870	912	970	17,752	710
13	12,118	3,752	15,870	912	485	17,267	691
14	12,118	3,752	15,870	738	0	16,608	664
15	12,118	3,752	15,870	738	0	16,608	664
16	12,118	3,752	15,870	1,172	0	17,042	681
17	12,118	3,752	15,870	1,172	0	17,042	681
18	12,118	3,752	15,870	1,172	0	17,042	681
19	12,118	3,752	15,870	1,172	0	17,042	681
20	12,118	3,752	15,870	1,172	0	17,042	681

Note: * US$ per ton of PVC

The break down of cost counted as depreciation and amortization is as follows:

Table 12-10 Depreciation and Amortization

	Depreciable Cost (1,000 US$)	Depreciation Method	Salvage value	Depreciation (1,000 US$)
Vehicle and Quarry equipment	2,477	5 yr straight line	0	495
Machinery and equipment (Plant)	42,318	10 yr straight line	0	4,232
Buildings and civil work	7,126	30 yr straight line	0	238
Pre-operating expense and interest during construction	5,084	10 yr straight line	0	508
Vehicle and Quarry equipment for reinvestment		5 yr straight line	0	
Machinery and equipment for reinvestment		10 straight line	0	

(3) Cash position (Capital balance)

As shown in Table 12-11, the yearly cash in hand after commercial operation always shows surplus position. This means that the borrowing of short term loan to cover the deficit of cash is not required.

Table 12-11 Cash Flow

(Unit: 1,000 US$)

Year	Increase working capital	Reinvest-ment	Profit after taxes	Repay-ment	Depre-ciation	Cash Flow
1	-132	0	-1,407	0	5,473	3,934
2	-132	0	176	0	5,473	5,517
3	0	0	1,586	0	5,473	7,059
4	0	0	1,092	-3,591	5,473	2,974
5	0	0	1,323	-3,591	5,473	3,205
6	0	0	1,901	-3,591	4,978	3,288
7	0	0	2,186	-3,591	4,978	3,573
8	0	-2,171	2,472	-3,591	4,978	1,688
9	0	0	2,502	-3,591	5,412	4,323
10	0	-2,406	2,788	-3,591	5,412	2,203
11	0	0	5,726	-3,591	912	3,047
12	0	0	6,012	-3,591	912	3,333
13	0	-2,597	6,297	-3,591	912	1,022
14	0	0	6,686	0	738	7,424
15	0	-2,171	6,686	0	738	5,253
16	0	0	6,430	0	1,172	7,602
17	0	0	6,430	0	1,172	7,602
18	0	0	6,430	0	1,172	7,602
19	0	0	6,430	0	1,172	7,602
20	0	0	6,430	0	1,172	13,861

(4) Profitability

FIRR's on I and E obtained for the base case are shown on Table 12-12.

Table 12-12 FIRR for Base Case

	FIRR on I	FIRR on E
Before tax, %	16.8	19.7
After tax, %	11.9	15.5
Payout period, year (After tax)	6.5	5.4

The obtained FIRR on I (before tax) and (after tax), 16.8 and 11.9 percent may be taken to show borderline profitability. The FIRR on E (after tax) of 15.5 percent also represents a borderline profitability that exceeds the interest rate of debt by only 2 percent.

(5) Major financial indicators

Major financial indicators, profit after tax on equity, debt service coverage ratio and breakeven point of capacity utilization are shown on Table 12-13. These indicators are calculated by the formula shown below.

- Profit after tax on equity
  (Profit after tax/equity)

- Debt service coverage ratio

(Net income after tax + Depreciation + Interest)/(Repayment + Interest)

(6) Profit B.E.P. (Breakeven Point) - capacity utilization

$$\frac{f}{(r_0 - V_0)}$$

f : Fixed Op. Cost + Depreciation + Interest

r_0 : Sales revenue at full capacity

v_0 : Variable Op. Cost at full capacity

Table 12-13 Major Financial Index

Year	Profit after tax on equity	Debt service coverage ratio	Breakeven point (Capacity utilization)
1	-5.9 %	1.8	88.9
2	0.7	2.2	88.9
3	6.6	2.5	88.9
4	4.6	1.4	88.9
5	5.5	1.4	85.8
6	7.9	1.4	79.6
7	9.1	1.5	76.6
8	10.3	1.6	73.5
9	10.5	1.7	73.2
10	11.6	1.8	70.1
11	23.9	1.6	38.6
12	25.1	1.7	35.6
13	26.3	1.9	32.5
14	27.9	-	28.4
15	27.9	-	28.4
16	26.9	-	31.1
17	26.9	-	31.1
18	26.9	-	31.1
19	26.9	-	31.1
20	26.9	-	31.1