CHAPTER VI RAW MATERIAL

6.1 Electricity

6.1.1 Power Service Network

ANDE, the public electric power company in Paraguay, is implementing numerous projects designed to expand the nation's power service network. In the north central area, a 66 kV cable linking Pedro Juan Caballero to the Holfeta transformer station has been completed, which will bring electric power into Amanbai District, Conception District and San Pedro District.

In the south, a similar 66 kV cable has been completed between San Pedro del Parana City and the Trinidad transformer station. In addition, the 220 kV cable supplying Ajolas transformer station is in the process of being expanded.

Figure 6-1-1 maps the existing and planned cable network for delivering electric power in Paraguay. The power which ANDE supplies to the consumer is generated at existing power stations owned by ANDE, and purchased from Itaipu.* Cable voltage is rated at 220 kV, 66 kV, 23 kV, 13 kV, 6 kV, 380 V and 220 V. In 1984, a total of 877 km of cable was constructed, and ANDE supplied over 1,000 GWh of power.

* *Itaipu is a public company established on April 26, 1973 by an agreement between Paraguay and Brazil. Equity ratio is 50:50, and the company has constructed Itaipu Dam, with 4 power generators now in operation and expansion work in progress.*

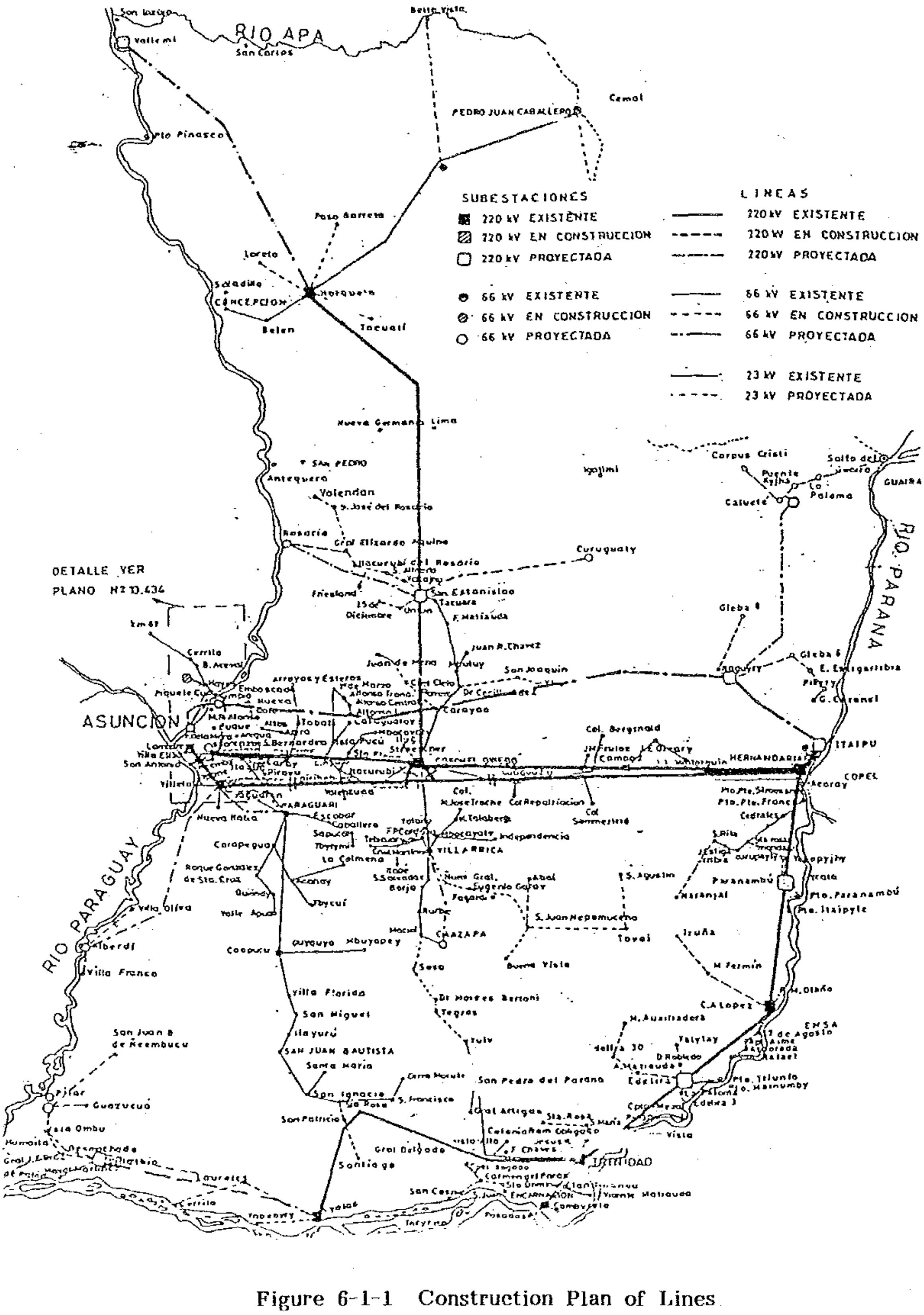


Figure 6-1-1 Construction Plan of Lines

6.1.2 Supply of Electricity

The growth of energy consumption over the past ten years is shown in Table 6-1-1.

Table 6-1-1 Generated Energy for National Consumption

Year	kWh	Growth (%)
1975	331,780,943	14.2
1976	374.325,983	12.8
1977	453,936,706	21.3
1978	502,910,557	10.8
1979	590,326,265	17.3
1980	700,310,011	18.6
1981	822,308,746	17.4
1982	915,977,684	11.4
1983	995,213,313	8.7
1984	1,090,351,005	9.6

99.2% of the energy generated in Paraguay is hydroelectric, and the remaining 0.8% is thermal. As can be seen in Table 6-1-2, 79.8% of the hydroelectric energy is generated at the Acaray Station in 1984, where two 47,000 kW and two 50,000 kW generators provide a total power output of 194,000 kW.

Table 6-1-2 Energy Balance (1984)

	Generated Energy gross kWh	Own Consumption kWh	Generated Energy net kWh
Original of Energy			
Hydraulic			
Acaray	885,482,430	2,180,381	883,302,049
Itaipu	161,644,530	-	161,644,530
Import	61,980,051	177,349	61,802,702
Hydraulic Total	1,109,107,011	2,357,730	1,106,749,281
Thermal			
San Lorenzo	173,140	116,760	56,380
Pietro Sajonra	221,900	138,000	83,900
Pedro Juan Caballero	131,720	1,315	130,405
Concepcion	5,409,342	28,063	5,381,279
Others	2,959,829	88,795	2,871,034
Thermal Total	8,895,931	372,933	8,522,998
Totals	1,118,002,942	2,730,663	1,115,272,279
Purpose of Energy National Consumption			
Hydraulic	1,081,455,074	2,301,338	1,079,153,736
Thermal	8,895,931	372,933	8,522,998
Total	1,090,351,005	2,674,271	1,087,676,734
Electric Company			
Hydraulic	27,651,937	56,392	27,595,545
Thermal	-	-	-
Total	27,651,937	56,392	27,595,545
Totals	1,118,002,942	2,730,663	1,115,272,279

Table 6-1-3 shows the distribution of power consumption according to sector. Residential use accounted for the largest percentage (59.6%) in 1984, with the industrial sector second at 31.5%. As is evident from Table 6-1-4, power consumption in the industrial sector has increased dramatically in recent years, rising 47.4% between 1980 and 1984.

Table 6-1-3 Total National Consumption

	kWh	
	1983	1984
Category		
Residential	492,189,732	540,703,223
Industrial	260,162,503	286,111,405
Fiscal	28,263,074	28,083,797
Municipal	4,310,009	5,042,382
Traction	381,292	376,568
Public Lighting	41,918,075	47,009,352
Total	827,224,685	907,326,727

Table 6-1-4 Industrial Consumption

Year	Industrial Consumption kWh	Growth (%) based on 1980
1980	194,150,819	-
1981	234,282,091	20.7
1982	241,264,244	24.3
1983	260,162,503	34.0
1984	286,111,405	47.4

6.1.3 Outlook for Electric Power Demand

At present, plans to expand the electric power distribution network are being advanced by ANDE, and a substantial increase in power demand is expected over the next few years. According to Table 6-1-5, the projected demand for 1990 will be 450 MW (2,335 GWh). This demand is expected to be met by Acaray Station's 194 MW and power purchased from Itaipu.

Table 6-1-5 Demand Forecast for Power and Energy

Year	Potential MW	Energy GWh
1986	285	1,370
1987	350	1,695
1988	380	1,935
1989	415	2,130
1990	450	2,335

Itaipu power station, when completed, will have 18 generators capable of 700 MW each, for a total output of 12,600 MW. Four of these have been completed to date, and construction is expected to be finished by early 1990s.

As Paraguay holds the right to receive 50% of this power, in 1986 ANDE will be able to supply 1,400 MW. As can be seen in Table 6-1-5, however, the national demand for this year is only 285 MW. This gap between potential supply and demand will be even greater when the Itaipu Power Station is completed in 1990, with Paraguay eligible to receive 6,300 MW but only able to use 450 MW. Thus the Itaipu Power Station alone will be able to easily meet Paraguay's entire domestic demand for electric power, and even given the growth of energy consuming industries, there is no likelihood of an energy shortage.

The Itaipu Power Station is a bi-national project with Brazil. In addition, two huge dam building projects are now underway with Argentina. One of these is the Yacyreta Project, the agreement for which was signed in 1973 and calls for 50/50 equity. The objectives of this project are:

* hydroelectric power
* improvement of ship transportation below Yacyreta Island on Rio Parana
* flood control measures

At present, construction for this project is going on in the vicinity of Yacyreta, on the Rio Parana below Itaipu Dam. The electric power plant of Yacyreta expects to begin operation in 1992, but the projected power output of 4,500 MW is yet to be confirmed and this project will be postponed.

The other joint project with Argentina is the Corpus Project, which will involve constructing a dam somewhere below Yacyreta. At the moment, this project is in the feasibility study stage, and neither the precise location nor the projected output have been determined.

As can be seen, Paraguay's capacity to supply electric power will be increased substatially in the future.

6.1.4 Tariff for Electric Power

Tariff for electric power differ according to usage, voltage required, and level of power use. Table 6-1-6 illustrates an example of fees for industrial use of high voltage, while Table 6-1-7 shows fees for commercial use. As can be seen, fees for commercial use are higher, and industrial use is granted a favored position. At present, there are no separate rates for the summer peak, or for day time and night time use.

Table 6-1-6 Tariff System for Industrial Use

Tension (V)	23,000 or 6,000
Maximum Potential (kW)	6,000
Minimum Potential (kW)	2,000
Price of Reserved Potential (Gs/kW month)	1,538
Price of Excess of Demand (Gs/kW month)	1,845
Price of Actual Energy (Gs/kWh)	3.58

Table 6-1-7 Tariff System for Commercial Use

Tension (V)	23,000 or 6,000
Maximum Potential (kW)	6,000
Minimum Potential (kW)	2,000
Price of Reserved Potential (Gs/kW month)	1,999
Price of Excess of Demand (Gs/kW month)	2,398
Price of Actual Energy (Gs/kWh)	4.65

6.1.5 Electric Supply and Price for Designated Project

The fertilizer plant project under consideration if implemented, would be a heavy user of electric power by Paraguayan standards, requiring 25,000-30,000 kW. As can be seen from Fig. 6-1-2, however, all proposed sites would be favorably located with respect to sources of electric power. Furthermore, proximity to the dam would assure a convenient supply of water for industrial use.

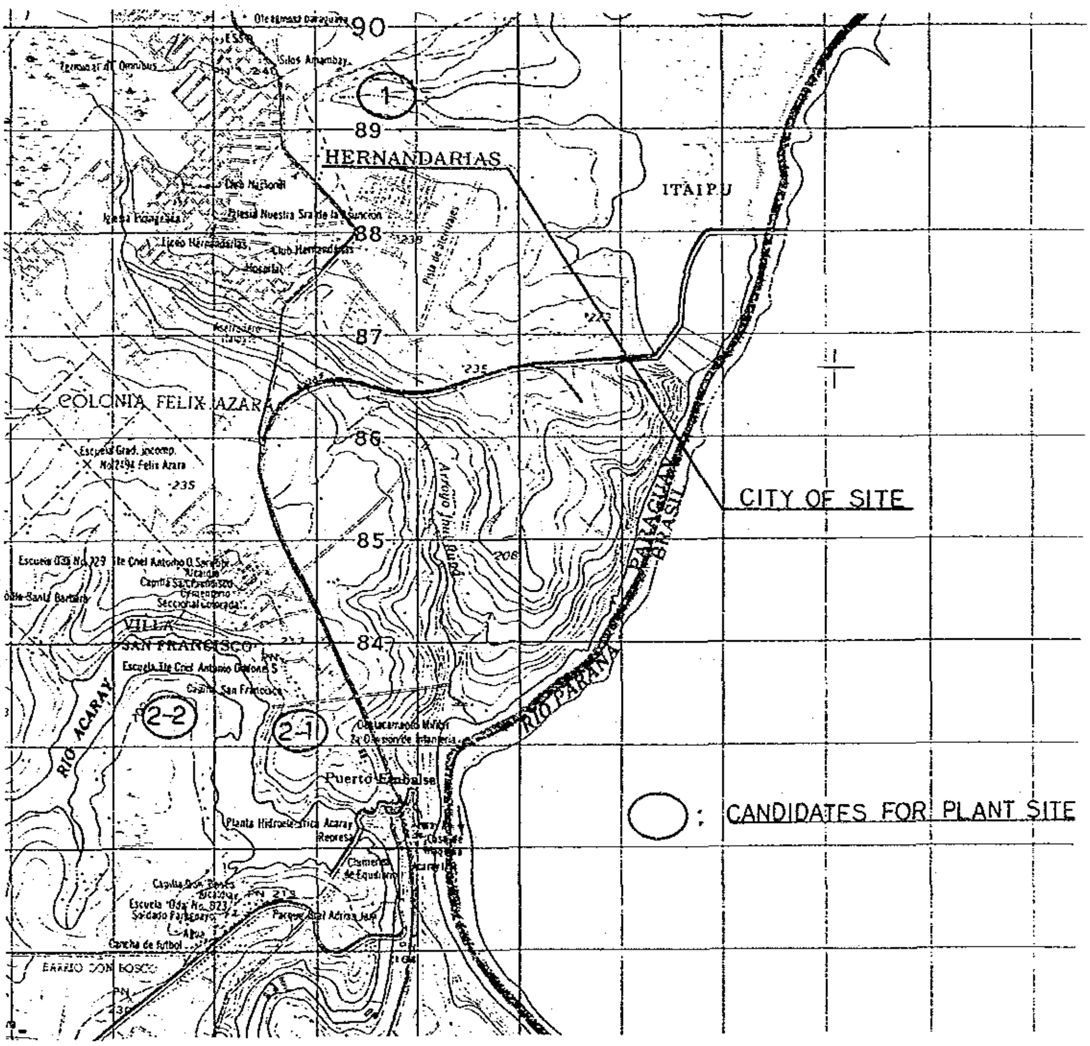


Figure 6-1-2 Proposed Site of Plant

Assuming that the fertilizer plant will purchase electric power direct from Itaipu, the rate would be the same as that paid by ANDE. The tentative rate for 1986 is US$10/kW Month, but this figure is expected to rise to US$14.06 in 1987, and ANDE expects that this is the rate that the fertilizer plant will eventually pay. Using these two figures, Table 6-1-8 calculates the kWh per price according to the ratio of consumed power to contracted power. As can be seen, the absolute lowest per unit price to be expected, which assumes that 100% of contracted power is used, would be US$1.39/kWh for the US$10.00/kW Month rate, ¢1.95/kWh for the US$14.06/kWh Month monthly rate.*

Table 6-1-8 Price of Electric Energy

Consumption Rate based on reserved kW (%)	Price of Electric Energy (cent/kWh)	
	in case of 10 US$/kW·M	in case of 14.06 US$/kW·M
100	1.39	1.95
95	1.46	2.06
90	1.54	2.17

* *It should be noted, however, that as the power must be contracted for two years in advance, any stoppage of production due to technical problems or product changeover will bring about a sharp drop in the ratio of consumed power to contracted power, and a corresponding rise in the kWh per unit rate.*

6.2 Phosphate Rock

Phosphate rock, the main raw material used in production of phosphate fertilizer, is of extreme importance to the Paraguayan fertilizer project. Although the characteristics of phosphate rock vary with origin, mineralogically speaking, this material is composed chiefly of apatite $Ca_5(FOH)(PO_4)_3$, mixed with small amounts of limestone, clay, and silica.

Not only due the characteristics and quality of phosphate rock vary from region to region, but there is often a considerable difference in rock taken from different sections of the same mining area. In order to keep the quality within set bondaries, phosphate rock is usually beneficiated after it is mined. Quality is determined by the amount of P_2O_5 contained in the rock, and the product distributed on the world market usually contains 28%-38%. For commercial purposes, the quality of phosphate rock is traditionally expressed in a BPL rating. BPL, short for Bone Phosphate of Lime, is calculated by multiplying the P_2O percentage by 2.185, and phosphate rock with a BPL rating between 65 and 78 is traded internationally.

6.2.1 Phosphate Rock Resources in Paraguay

The Republic of Paraguay has recently undertaken a national project to investigate the nation's sub-surface mineral resources. At present, however, although there is a possibility that phosphate rock might be present in parts of Concepcion, Amambay, Guaira and Paraguari Districts, no information is available about the quality or potential volume of these reserves. At this stage, there is only MOPC data on the chemical analysis of minerals in the Cerro Cora region of Northeast Paraguay (Amambay district), which is as follows:

P_2O_5	:	3.3%
CaO	:	1.6%
Mg	:	unknown
Fe_2O_3	:	14.3%
Al_2O_3	:	5.2%
SiO_2	:	17.1%

As can be seen from the above data, although Fe_2O_3 and SiO_2 are present in substantial portions, there appears to be very little of the P_2O_5 and CaO that constitute the main ingredients of phosphate rock. Furthermore, there is no data on the potential volume of the reserves upon which this analysis is based. Thus, at this stage, this report concludes that the fertilizer project can not expect to rely on Paraguayan resources of phosphate rock.

6.2.2 Import of Phosphate Rock

1) Producing country

The world reserves of phosphate rock are said to total 144 billion tons, and 153 million tons were consumed in 1984. Thus, from the standpoint of the world market, there is a surplus of reserves, and as can be seen from Table 6-2-1, the present capacity for mining and beneficiating phosphate rock exceeds the demand. These conditions of supply and demand should result in a market favorable to buyers.

Table 6-2-1 Phosphate Rock - World Market Balance
(million tonnes phosphate rock)

	1985	1986	1987	1988	1989	1990
World Capacity	180.29	185.03	190.39	194.57	199.19	204.10
World Demand	150.72	158.40	165.24	171.22	175.22	179.91
Surplus	29.57	26.63	25.15	23.13	23.97	24.19
Capacity Utilization (%)	83	86	87	88	88	88

Source: Phosphorus & Potassium No.141 (1986)

Table 6-2-2 shows production and consumption of phosphate rock by country, and Table 6-2-3 traces movement of phosphate rock from the chief exporting nations (horizontal axis) to the main importers (vertical axis). As was mentioned earlier, domestic supplies of phosphate rock are most likely insufficient, and the fertilizer project thus must rely on imported raw material.

Table 6-2-2 World Phosphate Rock Production and Consumption

(Unit; 1,000 t)

	1982		1983		Preliminary 1984	
	Production	Apparent Consumption	Production	Apparent Consumption	Production	Apparent Consumption
WORLD TOTAL	123,467	123,494	135,485	138,231	149,753	152,585
Western Europe	357	19,202	554	20,949	701	21,120
Austria	—	324	—	459	—	470
Belgium	—	2,049	—	2,477	—	2,437
Cyprus	—	30	—	60	—	—
Denmark	—	215	—	181	—	184
Finland	231	721	381	842	477	828
France	15	4,417	12	4,570	—	4,606
Germany F.R.	—	1,813	—	1,909	—	1,643
Greece	—	467	—	624	—	684
Italy	—	1,317	—	1,443	—	1,549
Netherlands	—	1,958	—	2,320	—	2,202
Norway	—	392	—	360	—	354
Portugal	—	372	—	315	—	427
Spain	—	2,334	—	2,464	—	2,859
Sweden	88	642	107	744	128	808
Turkey	23	774	54	695	96	633
United Kingdom	—	1,357	—	1,480	—	1,430
Eastern Europe	27,520	32,796	28,500	35,091	29,000	35,803
Albania	—	106	—	80	—	61
Bulgaria	—	762	—	861	—	769
Czechoslovakia	—	899	—	868	—	789
Germany D.R.	—	1,109	—	1,126	—	1,105
Hungary	—	611	—	669	—	579
Poland	—	3,407	—	3,413	—	3,407
Romania	—	2,559	—	2,922	—	2,903
USSR	27,520	22,169	28,500	23,600	29,000	24,629
Yugoslavia	—	1,173	—	1,552	—	1,562
North America	37,414	31,113	42,573	37,592	49,197	44,877
Canada	—	2,363	—	2,762	—	3,130
United States	37,414	28,750	42,573	34,830	49,197	41,747
Central America	331	1,478	436	1,578	375	1,549
Mexico	331	1,467	436	1,573	375	1,530
South America	2,779	3,181	3,229	3,448	3,890	4,424
Brazil	2,732	2,978	3,208	3,306	3,855	4,264
Colombia	18	71	18	77	22	59
Venezuela	—	73	—	34	—	54
Africa	30,285	11,053	34,159	12,601	36,065	14,191
Algeria	947	245	893	283	1,002	371
Egypt	708	468	647	533	1,043	794
Morocco	17,860	3,889	20,107	5,328	21,133	6,151
Senegal	1,247	329	1,522	356	2,123	553
South Africa	3,173	2,656	2,742	1,968	2,585	2,499
Togo	2,035	2	2,081	—	2,696	—
Tunisia	4,196	3,312	6,016	3,943	5,346	3,662
Zimbabwe	120	120	133	129	125	125
Asia	23,212	21,651	24,329	23,966	29,882	27,930
Bangladesh	—	100	—	145	—	93
China P.R.	11,730	12,147	11,630	12,209	14,210	14,829
Christmas Is.	1,365	79	1,066	62	1,257	74
India	552	2,105	787	2,184	883	2,555
Indonesia	5	275	5	443	6	769
Iraq	363	363	1,199	1,199	1,000	1,000
Israel	2,717	979	2,969	1,109	3,312	1,433
Japan	—	2,127	—	2,477	—	2,349
Jordan	4,431	263	4,749	631	6,263	975
Korea, North	450	559	500	667	500	541
Korea, South	—	1,607	—	1,663	—	1,704
Malaysia	—	191	—	160	—	263
Pakistan	—	199	—	284	—	266
Philippines	5	54	5	93	5	182
Syria	1,455	206	1,229	178	1,514	345
Taiwan	—	253	—	275	—	350
Vietnam	120	120	170	170	180	180
Oceania	1,568	3,020	1,705	3,007	1,376	2,692
Australia	235	2,112	21	2,109	17	1,824
Nauru	1,333	—	1,684	—	1,359	—
New Zealand	—	908	—	898	—	868

Source: Phosphorus & Potassium No. 141 (1986)

Table 6-2-3 World Phosphate Rock Export 1984

Importing Countries	Exporting Countries													
	United States	Morocco & Sahara	Egypt	Tunisia	Algeria	Togo	Senegal	Jordan	Israel	Syria	Nauru & Xmas Is.	Other	U.S.S.R.	Total
World Total	11,488	14,951	205	1,165	568	2,761	1,356	4,695	2,042	934	2,542	653	4,383	47,743
Western Europe	2,792	10,330	45	588	176	1,792	939	620	1,831	55	—	288	911	20,367
Austria	—	—	—	—	10	36	—	126	114	—	—	—	—	286
Belgium	524	1,648	—	—	—	232	—	—	—	—	—	—	107	2,511
Cyprus	—	—	—	—	40	—	—	—	—	—	—	—	—	40
Denmark	—	144	—	—	—	—	—	—	—	—	—	—	40	184
Finland	150	116	—	—	37	—	—	—	—	—	—	—	48	351
France	629	1,953	45	295	89	572	243	164	529	—	—	14	—	4,533
West Germany	539	414	—	6	—	43	—	—	197	—	—	167	292	1,658
Greece	—	324	—	62	—	27	170	93	8	—	—	—	—	684
Ireland	—	5	—	—	—	—	—	—	—	—	—	—	—	5
Italy	85	718	—	11	—	248	31	68	286	55	—	—	—	1,502
Netherlands	640	677	—	—	—	371	—	—	540	—	—	—	—	2,228
Norway	—	67	—	—	—	84	—	—	—	—	—	107	96	354
Portugal	12	402	—	—	—	3	—	—	—	—	—	—	—	417
Spain	—	2,260	—	16	—	85	134	—	—	—	—	—	—	2,855
Sweden	187	275	—	—	—	—	—	—	4	—	—	—	328	794
Switzerland	—	3	—	—	—	—	—	—	—	—	—	—	—	3
Turkey	—	51	—	167	—	6	—	169	140	—	—	—	—	533
United Kingdom	26	913	—	33	—	86	362	—	12	—	—	—	—	1,432
Eastern Europe	1,290	2,209	12	533	336	783	112	1,610	156	737	—	—	3,467	11,245
Albania	—	46	—	—	15	—	—	—	—	—	—	—	—	61
Bulgaria	—	114	—	71	—	—	—	69	—	109	—	—	405	768
Czechoslovakia	—	109	—	65	100	—	—	112	—	—	—	—	403	789
GDR	—	—	—	16	—	—	—	—	—	—	—	—	1,089	1,105
Hungary	—	124	—	—	79	—	—	—	—	—	—	—	468	671
Poland	857	1,080	—	173	69	284	—	225	—	84	—	—	636	3,408
Romania	433	459	12	204	45	499	—	861	115	322	—	—	418	3,368
USSR	—	—	—	—	—	—	—	—	—	12	—	11	—	23
Yugoslavia	—	278	—	4	28	—	112	342	41	210	—	—	47	1,062
Africa	138	—	—	—	—	86	3	—	—	—	—	—	—	238
Ivory Coast	—	—	—	—	—	—	3	—	—	—	—	—	—	3
Mozambique	—	—	—	—	—	—	—	—	—	—	—	3	—	3
Nigeria	—	—	—	—	—	17	—	—	—	—	—	—	—	17
South Africa	138	—	—	—	—	70	—	—	—	—	—	—	—	208
Zimbabwe	—	—	—	—	—	—	—	—	—	—	—	8	—	8
North America	3,158	—	—	—	—	—	—	—	—	—	—	—	—	3,158
Canada	3,158	—	—	—	—	—	—	—	—	—	—	—	—	3,158
Latin America	481	823	—	—	10	29	21	—	—	—	—	—	5	1,369
Brazil	9	—	—	—	—	—	—	—	—	—	—	—	—	9
Colombia	36	—	—	—	—	—	—	—	—	—	—	—	—	36
Cuba	—	—	—	—	10	—	—	—	—	—	—	—	5	15
Mexico	427	769	—	—	—	29	—	—	—	—	—	—	—	1,225
Uruguay	9	—	—	—	—	—	21	—	—	—	—	—	—	30
Venezuela	—	54	—	—	—	—	—	—	—	—	—	—	—	54
Asia	3,366	1,495	148	44	46	70	282	2,353	55	142	363	32	—	8,396
Bangladesh	—	—	—	—	—	—	—	93	—	—	—	—	—	93
China	—	206	94	—	—	41	—	76	—	101	55	—	—	573
India	349	306	9	—	—	29	220	812	—	—	—	—	—	1,725
Indonesia	145	165	46	44	46	—	62	363	—	—	—	—	—	871
Japan	1,310	633	—	—	—	—	—	300	9	—	47	22	—	2,321
North Korea	—	—	—	—	—	—	—	—	—	41	—	—	—	41
South Korea	1,514	—	—	—	—	—	—	136	—	—	56	11	—	1,717
Malaysia	—	21	—	—	—	—	—	85	—	—	158	—	—	264
Pakistan	—	—	—	—	—	—	—	266	—	—	—	—	—	266
Philippines	25	116	—	—	—	—	—	6	—	—	31	—	—	178
Taiwan	23	50	—	—	—	—	—	217	46	—	16	—	—	352
Oceania	263	94	—	—	—	—	—	113	—	—	2,179	—	—	2,649
Australia	212	94	—	—	—	—	—	55	—	—	1,420	—	—	1,781
New Zealand	51	—	—	—	—	—	—	58	—	—	759	—	—	868

Source : Phosphorus & Potassium No. 138 (1985)

As can be clearly from Table 6-2-2 and Table 6-2-3, The United States and Morocco are the two largest producers of phosphate rock. About 80% of U.S. production and 25% of all the phosphate rock consumed in the world comes from the State of Florida. Phosphate rock mining in Florida has a long history, and in the past has controlled a major share of the world market. Recently, however, the easily mined areas have become depleted, with a resultant drop in quality. New mines are being developed, but environmental restrictions raise development costs, and the price of the phosphate rock will increase accordingly. Thus, production of phosphate rock in Florida should not be expected to either increase or decrease sharply in the near future.

Morocco is the world's leading producer of phosphate rock, and through development of new mines can be expected to increase its share of the market even further.

As can be seen from the above discussions, both the U.S. and Morocco are in a geographical position and have the productive capacity to offer a steady, reliable supply of phosphate rock to Paraguay.

2) Phosphate rock produced in Brazil

Brazil should also be considered as a potential supplier of phosphate rock for the fertilizer Plant. As is illustrated in Table 6-2-4 Brazilian production of phosphate rock has increased rapidly in recent years. In 1984, 3.9 million tons were mined, a nearly fourfold increase over the 1978 figure of 1 million tons. Accordingly, Brazil has become self-sufficient in terms of phosphate rock requirements, with imports dropping from 1 million tons in 1978 to zero in 1983.

Table 6-2-4 Brazil Phosphate Rock Production and Consumption

(Unit: 1,000 tonnes)

	1977	1978	1979	1980	1981	1982	1983	1984
Production	608	1,094	1,697	2,921	2,764	2,732	3,208	3,855
Apparent Consumption	2,164	2,159	2,462	3,692	2,930	2,978	3,306	n.a.

Source: Phosphorus & Potassium

Table 6-2-5 Import Phosphate Rock to Brazil

	Exporting Countries						
	U.S.A.	Morocco	Tunisia	Algeria	Israel	Egypt	Total
1977	572	715	152	37	80	-	1,556
1978	347	410	202	59	48	-	1,065
1979	389	272	10	31	66	-	768
1980	113	414	41	-	195	8	771
1981	115	209	-	-	134	-	458
1982	85	43	-	-	81	-	209
1983	-	-	-	-	-	-	-
1984	9	-	-	-	-	-	9

Source: Phosphorus & Potassium

Considering the outlook for the future, Brazil's phosphate rock reserves, shown in Table 6-2-6, are estimated at 2.9 billion tons. As yearly consumption is only 4 million tons, there are ample deposits for long range domestic use. Furthermore, as can be seen in Table 6-2-7, Brazil's present day mining and benefication capacity is estimated at 4.9 million ton/yr. Thus from the standpoint of macro-analysis, Brazil is capable of supplying the phosphate rock necessary for the Paraguayan fertilizer plant.

Table 6-2-6 Brazil Deposits of Phosphate

State	Site	Total Reserves (1,000 m.t.)	Measured Reserves (1,000 m.t.)	Content in P_2O_5 (%)
Maranhao	Trauira / Pirocaua	25.000	n.a.	21
Pernambuco / Paulista	Paulista Igarassu etc.	65.000	13.300	20
Minas Gerais	Araxa	500.000	115.000	14
	Pato de Minas	417.000	236.000	13
	Tapira/Patrocinio	950.000	318.000	9
	Other	1.000	n.a.	12
Sao Paulo	Jacupiranga	100.000	72.000	5
	Ipero (Ipanema)	120.000	n.a.	7
	Registro	18.000	n.a.	16
Goias	Catalao/Ouvidor	370.000	219.000	8
Santa Catarina	Anitapolis	320.000	281.000	
Other		10.000	n.a.	n.a.
Totals		2,896.000	1,254.300	

Source: Novas Areas de Persquisa de Fosfato no Brasil - Albuquerque, Gildo de A.S.C. e Giannerini, J.F. in "II Encontro Nacional de Rochn Fosfatica" (Brasilia, April, 1981)

In particular, Goiasfertil, a phosphate rock producing firm, is a relatively new company that only began serious production in 1981. Furthermore, this company does not own a fertilizer plant, and is thus eager to export its phosphate rock. If the Paraguayan fertilizer plant project is realized, this company can be considered as a major protential supplier of raw material.

6.2.3 Quality

The quality of phosphate rock varies widely from region to region. Table 6-2-8 compares the quality of phosphate rock from Morocco, Florida and Goias of Brazil. From the results of chemical analysis, the Brazilian phosphate rock can be deducted to be of igneous nature, composed of apatite combined with fluorine, lime and phosphoric acid from the earth. The Florida and Moroccan phosphate rock, on the other hand, is continental in nature, formed by deposition of remains of benthic marine life along the edges of the continent.

The physical properties of these phosphate rocks, as determined by their chemical composition, result in differences in the way that they react with acid. In the Paraguay fertilizer plant project, however, phosphate rock will be utilized in the following three processes:

* production of phosphoric acid through the electric furnace process.
* production of fused magnesium phosphate (FMP) through the electric furnace process.
* production of TSP by the slurry process.

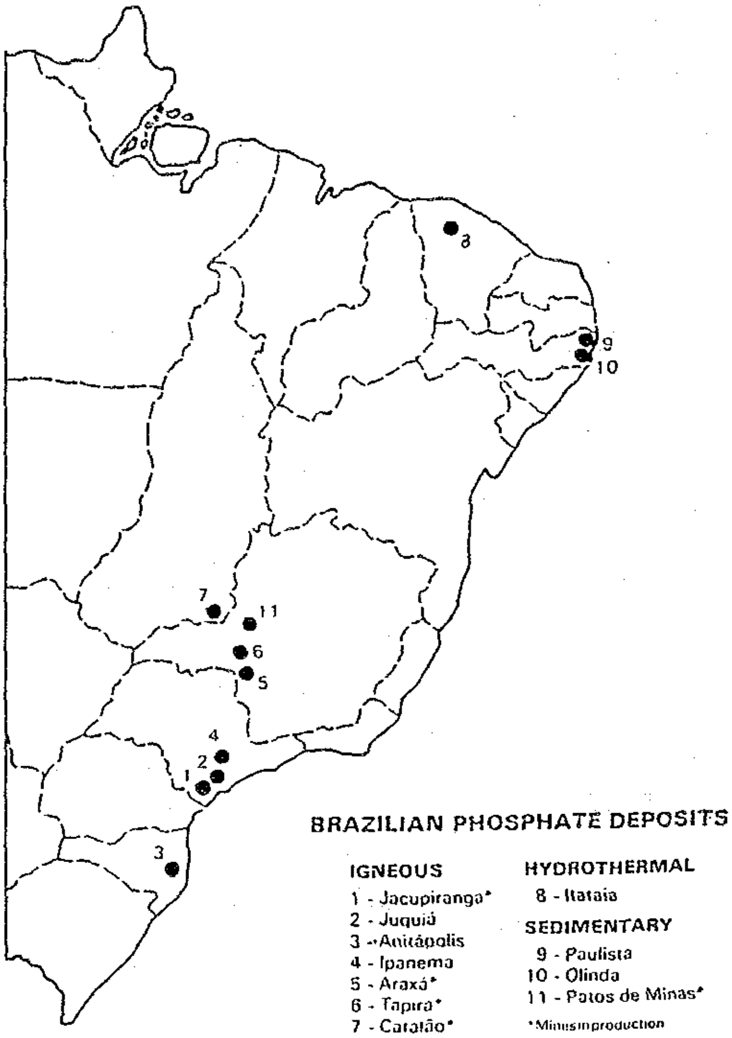
Of these, the first two, involving phosphoric acid and FMP processes, would not be effected by the differences in phosphoric rock described above. Thus phosphate rock from either Florida, Morocco or Goias could be used without problem. For the third process, production of TSP, the reactivity of phosphate rock with phosphoric acid would be slightly effected by differences in the rock from the three regions. Although this would result in some differences in the percentages of soluble and water-soluable phosphate in the TSP produced, these differences would not be expected to create major problems.

Table 6-2-7 Brazilian Phosphate Rock Production Capacity (1983)

Company	Location	Content of P_2O_5 (%)	Capacity 1,000 tons/year
Quimbrasil/Serrana			
	Jacupiranga (Sao Paulo)	36	450.000
	Ipanema (Sao Paulo)	38	500.000
Fosfertil			
	Patos de Minao (Minas Gerais)	24 [***]	150.000
	Tapira (Minas Gerais)	36	900.000
Arafertil			
	Araxa (Minas Gerais)	36	700.000
		28	50.000
		24 [***]	200.000
Fosfago			
	Catalao/Ouvidor (Goias)	38	500.000
Goiasfertil			
	Catalao (Goias)	38	620.000
Lushsinger Madorin [*]			
	Anitapdis (Santa Catarina)	37	600.000
Paulista Project **			
	Paulista (Pernambuco)	32	214.000
Total			4,884.000

Remarks: [*] Start-up is scheduled for 1984
[**] Start-up is scheduled for the second half of 1985
[***] For direct application fertilizer

Source: IFA and ANDA



Source : Phosphorus & Potassium

Figure 6-2-1 Brazilian Phosphate Deposit

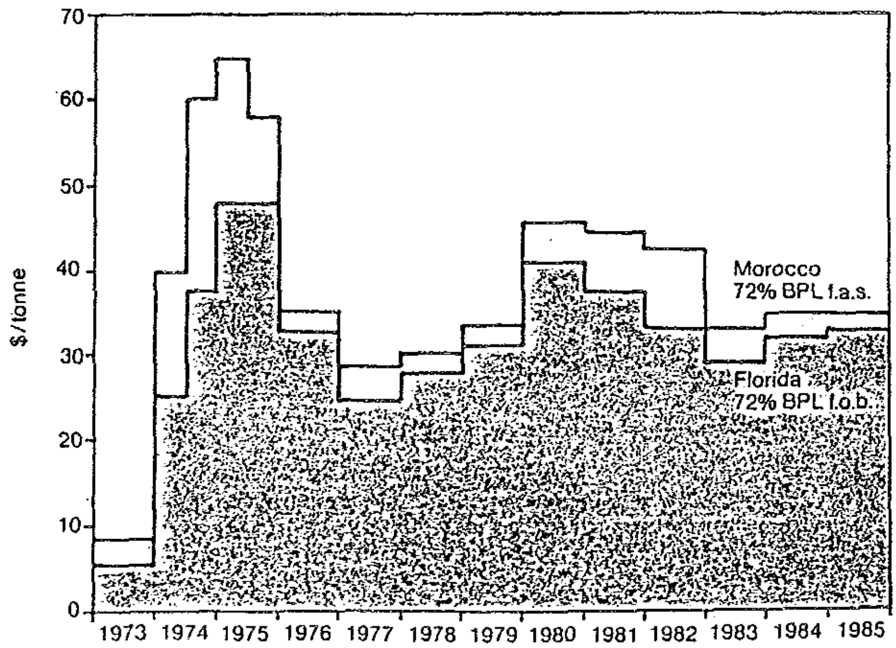
Table 6-2-8 Typical Analysis of Phosphte Rock

Source	Brazil Catalao (Goias)	Florida Inc.					Morocco Khouribga		
Grade		67/68	69/70	71/72	73/74	75/76	70/71	72/73	75/76
P_2O_5 (%)	38	31.12	32.04	32.95	33.87	34.78	32.04	33.26	34.55
CaO (%)	50	45.95	46.97	47.52	48.53	49.64	50.68	51.18	52.71
Fe_2O_3 (%)	2.5	3.08	2.78	2.32	2.22	2.31	0.24	0.22	0.33
Al_2O_3 (%)	0.3	3.08	2.78	2.32	2.22	2.31	0.40	0.40	0.47
Co_2 (%)	0.18	4.32	3.83	3.67	3.46	3.52	5.60	4.90	3.16
So_3 (%)	-	1.01	1.07	1.00	1.04	0.88	1.90	1.61	0.92
SiO_2 (%)	1.2	8.93	7.78	5.71	3.78	3.04	3.32	2.44	3.00
K_2O (%)	0.04	0.11	0.11	0.09	0.12	0.06	0.07	0.08	0.07
Na_2O (%)	1.0	0.58	0.53	0.53	0.55	0.52	0.70	0.78	0.48
MgO (%)	0.2	0.52	0.56	0.38	0.36	0.30	0.50	0.37	0.22
F (%)	1.5	3.58	3.70	3.68	3.80	3.86	3.90	3.97	4.35
Cl (ppm)	20	80	80	80	80	70	200	200	500
Organic matter	-	2.92	2.88	2.80	2.55	2.30	0.20	0.17	0.19
Combined H_2O	-	2.92	2.88	2.80	2.55	-	-	-	-
BaO	0.32	-	-	-	-	-	-	-	-
TiO_2	0.55	-	-	-	-	-	-	-	-

6.2.4 Price

Figure 6-2-2 graphs the changes in standard quality 72% BPL phosphate rock prices for Florida and Morocco from 1973 to 1985. Although these are officially quoted prices, which often differ from the actual transaction price, this difference is probably not very signigicant. Phosphate rock prices skyrocketed along with the oil shocks of 1974 and 1979, but at present are relatively stable. Considering the present status of supply and demand, there is no reason to expect price increases in the near future.

Goiasfertil has been contacted about the price of Goias phosphate rock to be supplied to the Paraguayan fertilizer plant, which would be US$31.7/ton FOB delivered by train from the Goias mine to Catalao City. This works out to US$0.83/%$P_2O_5$/ton (31.7 divided by 38=0.83). The Brazilian rock thus compares favorably with Florida phosphate rock, which has an officially quoted FOB price of US$32/ton ($0.97/%P_2O_5/ton).



Source : Phosphorus & Potassium No. 140 (1985)

Figure 6-2-2 Phosphate Rock Prices (1973 - 85)

6.2.5 Transportation and Transportation Costs

1) Transportation

At present, Paraguay does not have a well developed system for transporting large quantities of bulk raw materials necessary for industry. There is, however, a working system for moving large amounts of agricultural products such as soybeans and cotton. Using this as a base, there will be a need to develop a new economically efficient system for transporting industrial raw materials such as phosphate rock.

(1) If phosphate rock is purchased form Goiasfertil

Transportation will be overland by 25 ton truck from Catalao to the plant site. Although the distance is 1,500 km, the road is a paved first class national highway, and transportation can be expected to proceed smoothly.

(2) If phosphate rock were imported from Florida or Morocco

The material would first arrive by ship at Paranagua Port in Brazil (District of Parana). From there the rock would continue overland by 25 ton truck to the plant site, a distance of 700 km. In this case also, a paved first class national road is available, and truck transportation would present no problems.

During the soybean harvest season, spanning five months from March through July, this road is exceptionally crowded. None the less, there would still be capacity for moving the phosphate rock necessary for this project. In fact, costs could possibly be reduced by having the trucks carry soybeans out and phosphate rock in. The port facilities at Parangua are said to be adequate, but more research needs to be done on their offloading capacity and charges.

2) Transportation costs

Transportation charges for the two options can be estimated as follows:

(a) Goias phosphate rock overland freight=US$35/ton
(b) Florida or Moroccan phosphate rock

ocean freight	US$15/ton
unloading fees	US$10/ton
inland freight	US$25/ton
Total	US$50/ton

6.2.6 Conclusions Concerning Phosphate Rock

Phosphate rock is an important raw material for the Paraguayan fertilizer project. Considering the deep economic relations between Brazil and Paraguay, the geographical proximity, and the relatively low costs of importing Brazilian phosphate rock, the best course at present seems to be to purchase from Goiasfertil. Phosphate rock obtained through this route would cost an estimated US$67.7/ton.

There is, however, always the possibility of importing phosphate rock from Florida or Morocco to assure a stable supply. Unfortunately, this would involve landing the rock at Paranagua then trucking it to the site, resulting in a final price of US$82/ton for 72% BPL (33%$P_2O_5$) rock. When compared to the price of Brazilian phosphate rock, imports from Florida or Morocco would cost US$2.48/%$P_2O_5$ton (82/33=2.48) against US$1.76/%$P_2O_5$ton (66.7/38=1.76).

6.3 The Possibility of Importing Phosphoric Acid

The basic concept of the Paraguayan plant project is to utilize plentiful and inexpensive hydroelectric power to produce phosphorus in an elecric furnace. The yellow phosphorus produced in this fashion would be used to form phosphoric acid, which is an intermediate product in the production of phosphate fertilizers like DAP, TSP and NPK. However, phosphate rock, the major raw material required in this process, can not likely be secured From domestic sources, and must be imported from Brazil or elsewhere.

Recently, phosphoric acid produced through the wet method has been distributed worldwide as raw material for fertilizer production. The following discussion explores the possibility, including cost considerations, of using phosphoric acid in place of phosphate rock in the Paraguayan fertilizer plant.

6.3.1 Phosphoric Acid as Raw Material for Fertilizer Production

There are two methods, described below, for producing phosphoric acid, the so called "dry method" employing an electric furnace, and the "wet method," which involves treating the phosphate rock with sulphuric acid.

* electric furnace (dry method) - This method uses heavy loads of electric power to melt phosphate rock in a furnace and reduce it to yellow phosphorus. The yellow phosphorus is then burned and combined with water to form phosphoric acid. The phosphoric acid produced by this method has a high degree of purity, and is used for industrial purposes and also as a food additive.
* wet method - The phosphate rock is treated using sulphuric acid, separating gypsum by-product, producing phosphoric acid. Phosphoric acid procuced in this fashion retains the original impurities contained in the phosphate rock, and is thus used mainly as raw material for fertilizer, the wet method phosphoric acid traded on the world market contains 54% P_2O_5.

The dry method requires large amounts of cheap electric power, and at present is too expensive to be used to produce phosphoric acid for fertilizer. Thus the phosphoric acid available on the world market for production of fertilizer is wet method material. Table 6-3-1 shows the results of chemical analysis for a typical sample of this phosphoric acid.

Table 6-3-1 Typical Analysis of Phosphoric Acid

Source	U.S.A. Florida	Morocco	Tunisia
P_2O_5 (%)	54	54	52/56
SO_4 (%)	3.5	3.5	
CaO (%)	0.4	0.15	0.6
Fe_2O_3 (%)	1.4	0.70	0.6
Al_2O_3 (%)	2.6	0.70	1.2
MgO (%)	0.7	0.75	1.8
F (%)	1.6	0.35	0.5
Suspended solid	0.5	0.5	1.0
Density	1.6 at 15°C	1.62	1.7 at 15°C

6.3.2 Supply Capacity

In 1984, the amount of phosphoric acid consumed worldwide was 23.95 million tons P_2O_5, and this figure is expected to increase 17% by 1990, resulting in a total of 27.98 million tons P_2O_5. As can be seen in Table 6-3-2, the average rate of annual increase is expected to be 2.5% between 1984 and 1987, and 3% between 1988 and 1990.

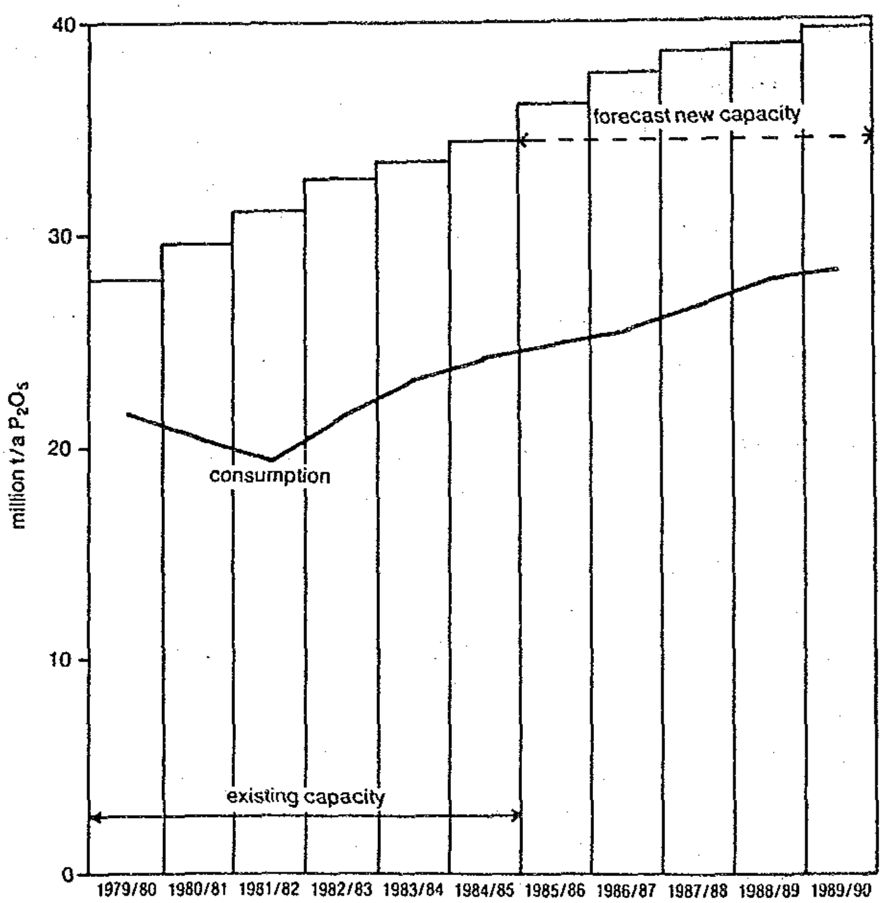
On the other hand, world production capacity for phosphoric acid stood at 33.58 million tons P_2O_5 in 1984, and is expected to increase 17.6% to 39.47 million tons P_2O_5 by 1990. On a worldwide basis, production facilities in 1984 were operating at only 71% of capacity. At present there is thus an overcapacity to supply phosphoric acid, and this trend is expected to continue into the future. Resultingly, there should be no problems with obtaining a supply of this raw material for the fertilizer plant.

Table 6-3-2 Phosphoric Acid: Index of Forecast Capacity and Consumption

(1984=100)

	Capacity	Consumption	Average Utilization Rate (%)
1984	100.0	100.0	71
1985	102.7	102.3	71
1986	108.4	104.9	69
1987	112.6	107.4	68
1988	115.4	110.6	68
1989	115.9	113.9	70
1990	117.6	117.2	71

Source: Phosphorus & Potassium No. 138 (1985)



Source : Phosphorus & Potassium No. 138 (1985)

Figure 6-3-1 World Phosphoric Acid Capacity Development and Forecast Consumption

As shown in Table 6-3-3, the total amount of phosphoric acid traded internationally in 1984 was 3.2 million tons P_2O_5, or about 10% of total production capacity. Similar to the case with phosphate rock, export of phosphoric acid is dominated by the U.S. and Morocco, which have nearly equal shares. Table 6-3-4 lists the amount imported by country from the top four exporting nations, respectively in order of prominence, U.S., Morocco, Tunisia and South Africa. As can be interpreted from this chart, Moroccan exports are aimed chiefly at European and Asian nations, but also go to Brazil. America exports mainly to the Soviet Union, Canada, Latin American nations and Asia.

In the past, the U.S. enjoyed an overwhelming dominance in export of phosphoric acid, but at present is being chased closely by Morocco. The U.S. is able to maintain export volume because of the large amounts of super-phosphoric acid that are bartered to the Soviet Union in exchange for ammonia. None the less, no large increases in exports can be expected for the near future.

Morocco's present capacity to produce phosphoric acid is estimated at 1.68 million tons P_2O_5/yr, and new facilities capable of an additional 1.32 million tons P_2O_5 are expected to be completed in 1986. Some of this phosphoric acid is used for domestic fertilizer production, but most is destined for export. Thus Morocco's share of the export market is likely to increase in the near future.

Table 6-3-3 Export of Phosphoric Acid

(Unit: tonnes P_2O_5)

	Exporting Countries													
	Belgium	Finland	France	Netherl.	Israel	Jordan	Spain	U.S.A.	Mexico	Morocco	Tunisia	Senegal	S.Africa	Total
1982	83,486	54,000	109,252	106,662	76,086	-	95,850	911,178	68,936	652,384	311,500	-	288,117	2,757,451
1983	113,941	49,300	82,018	100,623	79,000	18,435	94,135	789,310	43,000	869,409	380,000	-	123,306	2,739,034
1984	130,193	36,600	75,520	103,499	-	32,000	93,400	1,069,549	-	1,080,780	333,500	60,307	211,886	3,227,234

Source: IFA

Table 6-3-4 Phosphoric Acid Exports from Main Countries

	Main Exporting Countries							
	Morocco		U.S.A.		Tunisia		S. Africa	
Destination	1983	1984	1983	1984	1983	1984	1983	1984
Belgium	20,979	11,811	3,121			4,000		
Denmark	22,000	38,016			6,000			
France	6,000	32,628		7,174	69,000	15,000		
West Germany	60,000	79,646	15,632	34,005	3,000			
Greece	6,027			3,376				3,300
Holland	3,174	7,504						
Italy	76,000	95,230			61,000	55,000		
Spain		991				3,000		
United Kingdom	22,000	34,203						
Bulgaria	4,000				2,000			
Czechoslovakia		5,530		15,378				
U.S.S.R.			519,190	505,833				
Yugoslavia					9,000	5,500		
Canada			28,018	45,173				
Jamaica			39	161				
Mexico			12,978	11,404				
Brazil	14,000	33,967	78	113,990				69,349
Colombia			3,031	5,039				
Venezuela			28,265	54,119				
New Zealand			132					
Turkey	234,000	218,448	36,892	75,667	93,000	95,000	22,630	18,000
India	267,000	370,444	83,281	147,172	88,000	88,000		
Indonesia	134,000	152,362	58,653	51,058	49,000	61,000		
Japan							38,300	38,300
Taiwan, China							455	
Unkn. Dest.							61,921	82,837
	869,180	1,080,780	789,310	1,069,549	380,000	326,500	123,306	211,786

Tunisia now has the capacity to produce 0.75 million tons P_2O_5/yr, and is in the process of constructing a new plant with 0.17 million tons P_2O_5 capacity. Furthermore, two more plants of similar capacity are in the planning stage. The plant presently under construction will be accompanied by a fertilizer plant with matched capacity, and thus the phosphoric acid produced will not be exported. None the less, Tunisia plans to follow Morocco's example as a major exporter of phosphoric acid.

6.3.3 Transportation of Phosphoric Acid

Phosphoric acid has been developed as a commercial product and traded on the international market only recently. In 1975, the total amount traded was only 0.7 million tons P_2O_5, but in the ten years between then and 1984, this figure increased nearly five times to 3.2 million tons P_2O_5. One reason for this increase has been that the commercially available phosphoric acid contains 54%P_2O_5, around 1.5 times the percentage contained in phosphate rock. Another reason has been the development of special tankers with rubber lined or stainless steel tanks capable of holding phosphoric acid.

In the past, a shortage of cargo space had stifled trade, but recently both exporters and importers have been building the special tankers capable of handling the phosphoric acid, and this shortage is no longer a problem. Tanker size has been ranging from 5,000-8,000 dwt, and recently many 25,000 dwt ships are being constructed.

In the Paraguayan fertilizer project were to rely on import of phosphoric acid, facilities for offloading the tankers would be necessary. According to written documents, such facilities exist at Brazil's port of Rio Grande. Here the Fertisul Company has facilities capable of offloading 1,100 tons/hr and of storing 36,000 tons. The Paraguayan fertilizer plant could possibly import phosphoric acid through these facilities though there would be a 1,200 km journey by lorry from the port to the plant site.

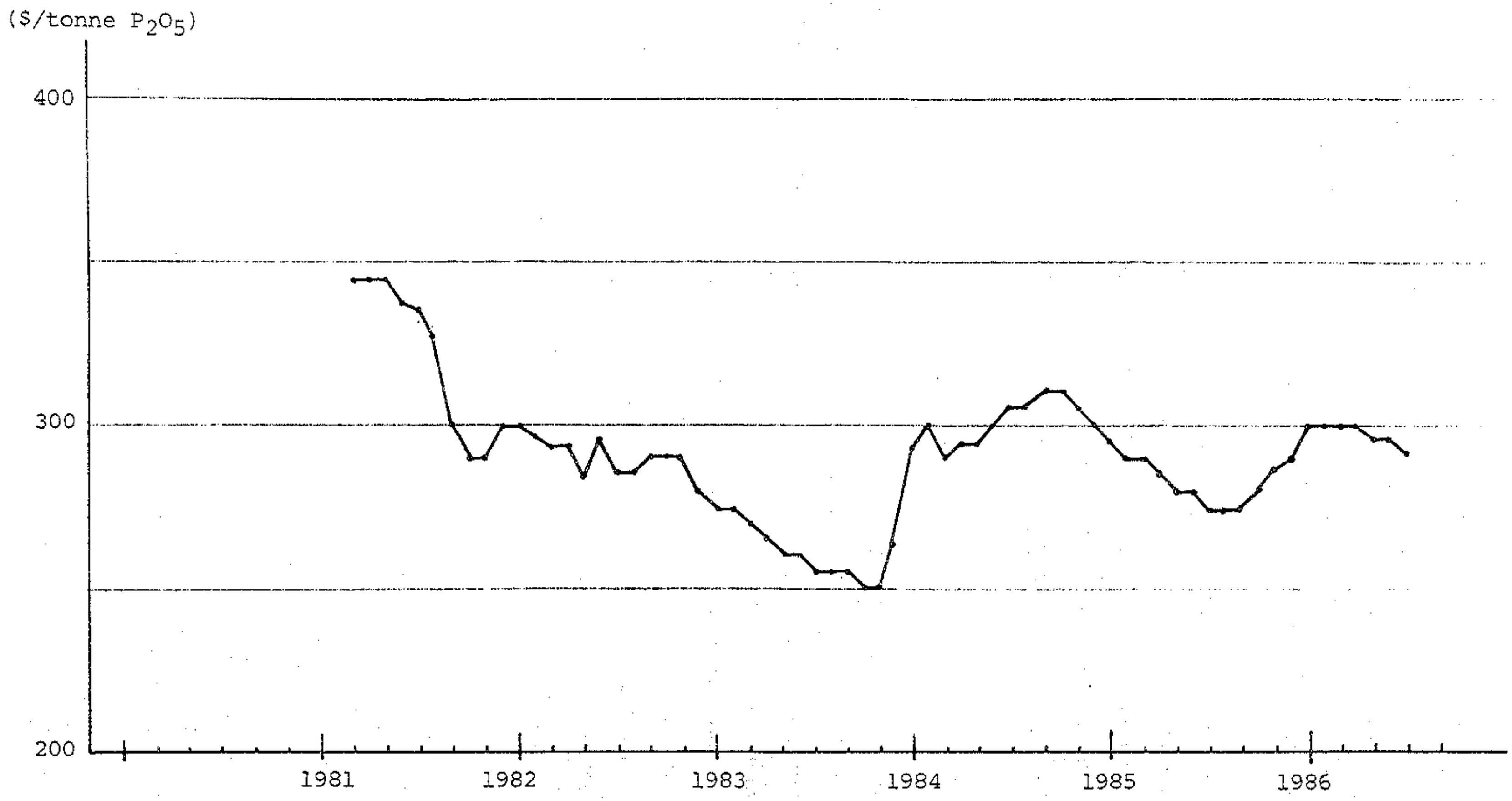
6.3.4 Price of Phosphoric Acid

Figure 6-3-2 graphs the U.S. Gulf FOB price of phosphoric acid from 1981 through 1986. Although there is considerably fluctuation, the general downward trend reflects the supply and demand situation discussed earlier. Following is an estimate of the cost of importing phosphoric acid for the Paraguayan fertilizer plant.

* FOB U.S. Gulf US$300/ton P_2O_5
* sea freight US$50/ton P_2O_5 (U.S. Gulf to Brazil)
* Offloading and storage costs US$20/ton P_2O_5
* overland freight US$50/ton P_2O_5
* total cost to Foz do Iguacu at border US$420/ton P_2O_5

6.3.5 Conclusions

Phosphoric acid for fertilizer manufacture, produced by the "wet" process, is traded on the international market. If the Paraguayan project wished to import phosphoric acid instead of phosphate rock, world supply and demand conditions indicate that either Florida or Morocco would be possible sources. This project, however, plans to make good use of the abundant and relatively inexpensive electric power to produce phosphoric acid as an intermediate product using the "dry" (electric furnace) process.



Source : Phosphorus & Potassium

Figure 6-3-2 Phosphoric Acid Price (FOB U.S. Gulf $/tonne P_2O_5)

6.4 Ammonia

Ammonia is necessary as a source of nitrogen for production of DAP, MAP and NPK fertilizers. The Paraguayan fertilizer plant would be capable of producing ammonia as an intermediate product, but the alternative exists to purchase it as a raw material. As this choice will have important economic ramifications for the plant, the following discussion explores the possibilities of importing ammonia.

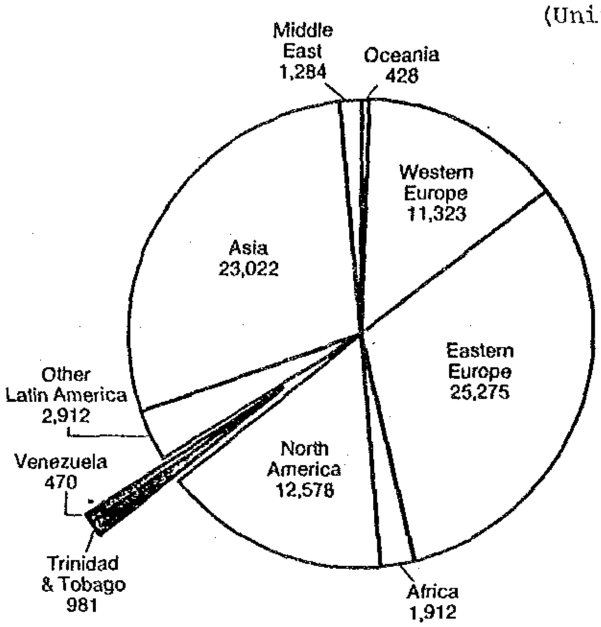
6.4.1 Trends in Production, Supply and Demand, and Price of Ammonia

1) Production

Until 1960, ammonia production was limited to the more developed nations, with the U.S., Europe and Japan accounting for 90% of the total 15 million tons N production. Between 1960 and 1975, however, ammonia production spread rapidly to other areas of the world. In the past ten years, the Soviet Union, China, India and Indonesia have shown remarkable growth rates. World Production in 1983 stood at 80.19 million tons N, and Figure 6-4-1 graphs this amount by region of production.

World Production Capacity, on the other hand, was estimated at 114.5 milion tons N for 1984/85, indicating a surplus capacity to produce. Figure 6-4-2 projects world production capacity up to 1988/89, when this figure is expected to reach 122 million tons N.

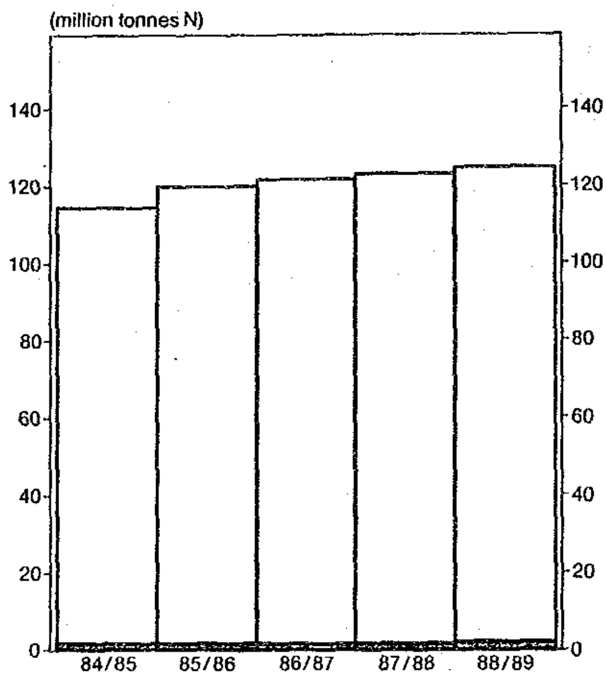
(Unit; 1,000t)



1983 Production: 80.19 million tonnes N

Source : Nitrogen No. 155 (1985)

Figure 6-4-1 World Ammonia Production

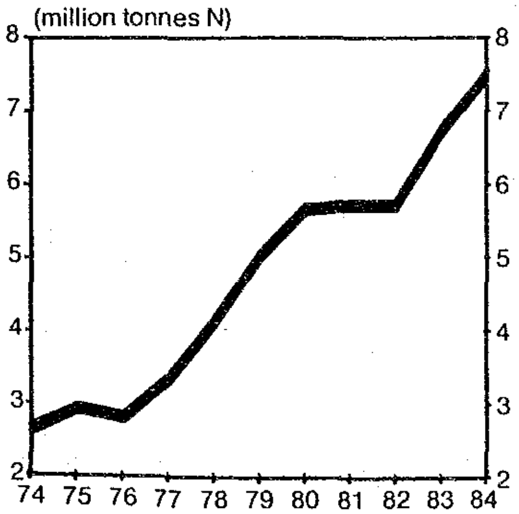


Source : Nitrogen No. 155 (1985)

Figure 6-4-2 World Ammonia Capacity

2) Supply and demand

Trade in ammonia is growing steadily throughout the world, as can be seen in Figure 6-4-3. World trade in 1984 amounted to 7.44 million tons. Table 6-4-1 lists import and export figures by geographical region. As can be clearly seen, ammonia is now an international commercial product traded around the world by tanker.



Source : Nitrogen No. 156 (1985)

Figure 6-4-3 World Export of Ammonia

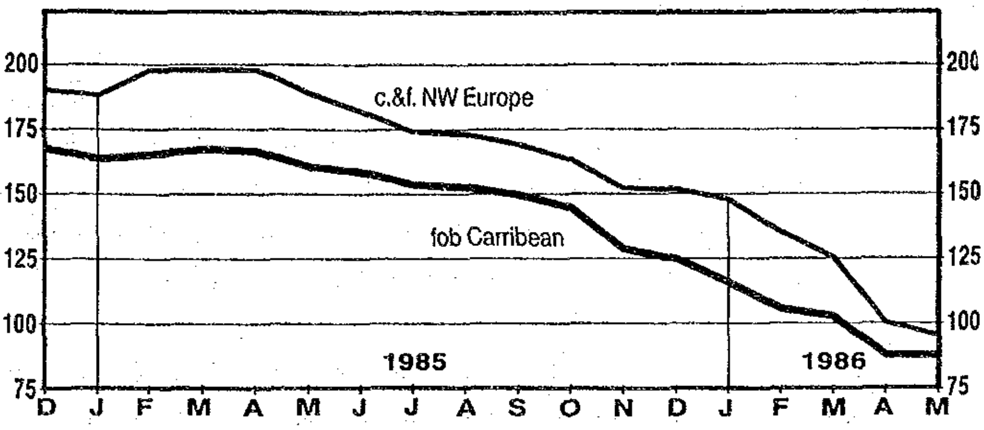
Table 6-4-1 Ammonia Trade (Percentage of Total)

	1983	1984
Imports		
Western Europe	51	46
Eastern Europe	5	3
North America	30	32
Latin America	1	1
Asia	9	13
Exports		
Western Europe	16	21
USSR	31	32
Eastern Europe (other)	3	3
North America	12	15
Central America	24	18
South America	3	3
Africa	6	3
Asia	4	5
Oceania	1	0.6
Total trade	6.68 million tonnes N	7.44 million tonnes N

Source: Nitrogen No. 156 (1985)

3) Price

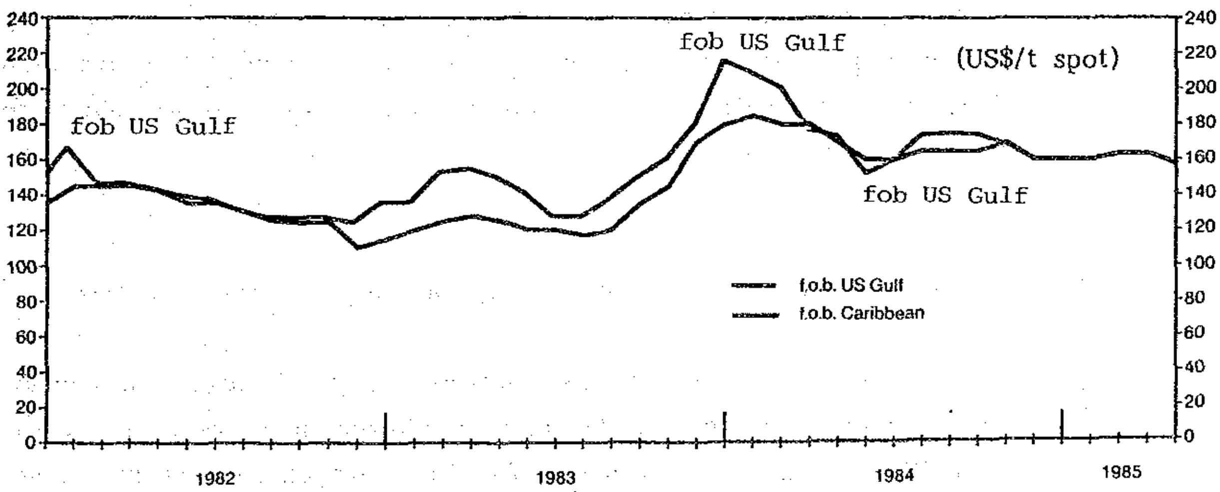
Recent trends in ammonia prices are graphed in Figure 6-4-4. The overall downward trend can be attributed to the surplus capacity to produce. In particular, oil based economies in the Caribbean Region, troubled by reductions in oil export levels, are trying to diversify by utilizing their abundant natural gas resources to produce and export ammonia.



Source : Nitrogen No.161 (1986)

Figure 6-4-4 Ammonia Price Trend

(US$/t spot)



Source : Nitrogen No. 155 (1985)

Figure 6-4-5 Ammonia Prices (1982 - 1985)

6.4.2 The Future Outlook

According to research by the World Bank, the growth rate of nitrogen fertilizer consumption in the more developed nations, influenced by the depressed agricultural sector and the mature market for fertilizers, stands at 2%. For the lesser developed nations this figure is estimated at 5%, and for the planned economies 3%.

The demand for industrial use ammonia in 1982/83 was 10.2 million tons N, about 13% of the total, and a 2.1%/yr growth rate is postulated for the future. Given these figures, the present day excess capacity to produce can be expected to continue for another two or three years, with supply and demand coming into balance around 1988/89.

During the five year period between 1989/90 and 1994/95, world demand for nitrogen fertilizers is expected to increase by 11.7 million tons N. To meet this demand, existing ammonia plants will have to be upgraded, and new plants with a capacity of more than 1,000 tonN/day constructed. In Latin America, not only Trinidad, Tobago and Venezuela, but nations such as Brazil and Argentina are likely to invest in such plants.

6.4.3 Present Status and Future Outlook for Ammonia Production in Brazil

The previous discussion presents a macro-analysis of supply and demand for ammonia on a world wide basis. Following is a treatment of the possibility of importing ammonia for the Paraguayan fertilizer plant from Brazil, which is favorably located from a geographical standpoint and which has deep economic ties with Paraguay.

1) Production and consumption

Table 6-4-2 shows Brazil's ammonia production and consumption figures for 1981 through 1985. In recent years, production has increased sharply while imports dropped. Although the volume is low, some ammonia is now being exported as well. Brazil was once a net importer of ammonia, but production has risen enough to meet domestic demand, and Brazil is presently moving towards an export position.

Table 6-4-2 Production and Consumption of Ammonia in Brazil

(Unit: 1,000 tonnes N)

	1981	1982	1983	1984	1985
Production	375.7	503.2	738.1	873.8	944.9
Import	145.3	46.9	0	28.3	14.0
Export	0	0	87.3	34.8	27.6
Consumption	488.3	568.8	663.7	867.3	934.3

Source: IFA

2) Future outlook

Brazil's present capacity to produce ammonia is estimated at 1 million tons N/yr. After 1988, two new plants are expected to begin operation, bringing the production capacity up to 1.4 million tons N/yr. Thus Brazil would most likely be able to supply the ammonia needed by the Paraguayan fertilizer plant.

Furthermore, many of Brazil's existing and planned plants are large scale, and natural gas is used as the raw material. Thus production costs in Brazil can be expected to compare favorably with worldwide levels.

6.4.4 Comparison of Import and Domestic Production

1) Technological aspects

(1) Production of ammonia

Ammonia was first tested by Haber as an industrial compound of nitrogen and hydrogen. This research was continued by a group centering on Bosch of Germany's BASF, and in 1913 ammonia was successfully produced for industrial purposes. Since then, ammonia production has become a fundamental unit in chemical industry. Over the years, production costs have been reduced through changes in sources of hydrogen as raw material, introduction of large scale plants, and more efficient use of energy, leading to the technology of today.

Ammonia production costs are determined primarily by the price of energy and hydrogen, and the size of the plant. Historically, hydrogen was first obtained from coke oven gas, then later a series of processes were developed to produce hydrogen through water electrolysis and solid fuels such as coal and coke. After World War Two, as oil resources stabilized and prices dropped, there occurred a worldwide shift towards using fluid fuels, such as natural gas, naphtha and fuel oil, for producing syntheses gases. Recently, the worldwide trend has been to rely primarily on the relatively cheap and abundant natural gas resources.

As the ammonia production process uses much equipment and machinery, substantial merit can be had through increasing the scale of the plant. As a result, large scale plants are common throughout the world, with 1,000 tons/day capacity being the norm since 1960. Using centrifugal compressors and energy-saving technology, large scale ammonia plants have cut production costs and played a major role in reducing the price of ammonia.

(2) Ammonia Production at the Paraguayan Fertilizer Plant

If ammonia were to be produced at the Paraguayan fertilizer plant, the best method would be to make good use of the inexpensive electric power by employing the electrolysis process. If this option were to be chosen, the following considerations must be taken into account.

(a) The first consideration concerns Paraguay's ability to accept transfer of the technology necessary to produce ammonia. Ammonia production uses much equipment and high-pressure technology that is basic to the chemical industry. Paraguay, as mentioned earlier, is primarily an agricultural nation, and the chemical industry at present is limited to cement production and oil refining. Generally speaking, as minimal requirements, the recipient of technological transfer must be in a position to supply adequately trained engineers, and have a machine manufacturing company capable of installing and maintaining the equipment.

Concerning these minimal requirements, engineers in various fields are trained at Asuncion University, and there are companies like OTI (Oficina Technica Industrial S.A.) capable of plant construction and installation and maintenance of precision machinery. Therefore, Paraguay is in a position to accept transfer of the technology necessary for producing ammonia.

(b) Production Costs

The Paraguayan fertilizer plant will require approximately 30 tons/day of ammonia. An analysis of the comparative economics of production versus import is necessary, and will be presented below. However, generally speaking, 30 tons/day is an exceptionally small capacity for an ammonia plant, electric power for water electrolysis would cost US$0.015/kWh, and if natural gas were used as raw material, the cost of hydrogen would be prohibitively high. Thus production of ammonia would not likely be cost-effective.

(c) Cost-effectiveness

In order to determine whether or not producing ammonia would be cost effective, the following analysis considers the cost of electric power for water electrolysis and the scale of the plant.

(i) Energy costs

At present, natural gas is used worldwide as the source of hydrogen for ammonia production, and 35 million BTU of gas are required to produce one ton of ammonia. The domestic price for natural gas in the U.S. is said to average US$2.5/million BTU. Using the energy conversion factor of 293 kWh/million BTU, this figure converts to US$0.008/kWh (2.5/293). In other words, the energy costs in electric power equivalent to US$2.5/million BTU of natural gas is US$0.008/kWh, compared to US$0.015/kWh for electric power at the Paraguayan plant. Thus using electric power as a source of hydrogen for ammonia production would be economically inefficient.

(ii) Plant scale

As was mentioned earlier, ammonia plants benefit substantially from increases in scale, and plants with 1,000 tonN/day capacity are the worldwide norm. Compared to this, the Paraguayan plant will require only 30 tonN/day.

For the above reasons of energy costs and economics of scale, production costs of ammonia at the Paraguayan fertilizer plant would most likely be higher than the price of imported ammonia. Brazilian ammonia, on the other hand, would cost little more than international levels. Ammonia could also be purchased from Caribbean nations, offloaded at Rio Grande or Santos ports in Brazil, then carried overland by lorry to Foz do Iguacu at border at a total cost of around $200/ton.

6.4.5 Conclusions

Because of high energy costs and the small scale of the plant, production of ammonia by water electrolysis would not be cost-effective for the Paraguayan fertilizer project. At this stage, ammonia could be imported from Brazil and transported to the site via Foz do Iguacu at the border at US$180/ton. Plans for constructing an ammonia plant in Paraguay, as explained elsewhere, should proceed cautiously, and take into consideration a more economical source of hydrogen, and the domestic demand for nitrogen fertilizers.

6.5 Potash

On a worldwide basis, three main types of potash fertilizers are available, potassium chloride, potassium sulfate and potassium magnesium sulfate. All of these are used as the potash source in NPK fertilizers, and their potash content is listed in Table 6-5-1. Potassium chloride contains the highest percentage of potash, and is also relatively inexpensive. Thus, as can be seen in Table 6-5-2, potassium chloride accounts for 87% of all exported potash sources. The Paraguay fertilizer project would most likely use potassium chloride as a potash source for production of NPK fertilizers.

Table 6-5-1 Typical Potash (K_2O) Content of Main Potash Fertilizers

	K_2O (%)
Potassium Chloride	60
Potassium Sulphate	50
Potassium Magnesium Sulphate	20

Table 6-5-2 Potash Fertilizer Export by Product

(Unit: 1,000 tonnes K_2O)

	1981/82	1982/83	1983/84
Potassium Chloride	13,681	13,312	15,160
Potassium Sulphate	735	308	780
Potassium Magnesium Sulphate	60	71	61
Other Straights	57	70	65
Compounds	962	1,158	1,308

Source: Phosphorus & Potassium

6.5.1 Supply and Demand for Potash

Table 6-5-3 presents world potash reserves by nation. The major resources are to be found in Canada (48.9%) and the Soviet Union (33.1%), with countries like Thailand (6.6%), the U.S. (4.0%), East Germany (3.3%) and West Germany (2.4%) also possessing substantial reserves. Production, as can be seen in Table 6-5-4, is geographically limited to North America (Canada and the U.S.), Eastern Europe (East Germany and the Soviet Union), Western Europe (West Germany, France, Italy, Spain and England) and the Middle East (Israel and Jordan).

Table 6-5-3 World Potash Resources

(Unit: million tonnes K_2O)

	Resources	(%)
North America	72,575	52.9
Canada	67,132	48.9
U.S.A.	5,443	4.0
South America	299	0.2
Chile	18	-
Peru	9	-
Brazil	272	0.2
West Europe	3,937	2.9
France	181	0.1
West Germany	3,266	2.4
Italy	36	-
Spain	181	0.1
United Kingdom	272	0.2
East Europe	48,895	36.4
East Germany	4,536	3.3
U.S.S.R.	45,359	33.1
Asia	10,284	7.5
China	18	-
Iran	60	-
Israel	1,089	0.8
Jordan		
Laos	45	-
Thailand	9,072	6.6
Africa	181	0.1
Congo	181	0.1
Oceania	18	-
Australia	18	-
Total	137,190	100

Source: U.S. Bureau of Mines, Potash MCP-11

Table 6-5-4 World Potash Production Estimates

(thousand tonnes K_2O)

	1983	1984
Western Europe		
West Germany	2,419	2,650
France	1,539	1,800
Spain	659	677
United Kingdom	303	320
Italy	133	130
Eastern Europe		
GDR	3,341	3,400
U.S.S.R.	9,294	9,300
North America		
Canada	5,928	7,780
United States	1,423	1,540
Asia		
China	29	30
Israel	942	1,000
Jordan	168	250

Source: Phosphorus & Potassium No.135 (1985)

In Table 6-5-5, supply and demand for potash is listed for three years. As can be seen, there is a slight trend towards overproduction. According to estimates of the British Sulfur Company, consumption of potash will increase by an average annual rate of 3.5% between 1985 and 1990, reaching a total of 34.55 million tons K_2O by the end of that period. Table 6-5-6 shows projected increases in potash production and consumption from 1985 through 1990 by geographical region. The increase in consumption shown for Latin America will be mostly in Brazil.

World production of potash, 29.78 million tons K_2O in 1984, is expected to reach 36 million tons K_2O by 1990. During this period, nations like the U.S., Tunisia, Bolivia and Brazil are likely to develop new mines, but North America and eastern Europe's dominance of world supply, now standing at 79% of total consumption, is likely to continue into the future. With production overshadowing consumption, the Paraguayan fertilizer plant should expect no difficulties in obtaining sufficient supplies of potash. From the standpoints of geographical proximity and reliability of supply, Canada or the U.S. would be likely sources for this potash.

Table 6-5-5 World Potash Fertilizer Supply/Demand Balance

(thousand tonnes K_2O)

	1982/83	1983/84	Preliminary 1984/85
Production	24,430	27,842	28,886
Available Supply*	23,209	26,450	27,442
Available Supply for Fertilizers†	22,582	25,760	27,687
Consumption	22,725	25,408	25,587
Balance‡	-143	+352	+830

* Available supply equals production minus losses incurred by transport, bagging and handling operations, estimated at 5% of production.
† Available supply minus industrail sales
‡ Balance equals notional stock change.

Source: Phosphorus & Potassium No.141 (1986)

6.5.2 Present Status and Future Outlook for Potash Production in Brazil

As Paraguay is already importing potash fertilier from Brazil, this country should be evaluated as potential source of potash for the Paraguayan fertilizer plant.

1) Import and consumption

By both Latin American and world standards, Brazil is a major importer and consumer of potash, and import volumes for 1980 through 1984 are shown in Table 6-5-7. The figure for 1984 stands at 1.08 million tons K_2O, which amounts to 6.5% of all world trade in this product.

Table 6-5-6 Potash: Consumption and Production Forecast (1985 - 1990)
Analysis by Region

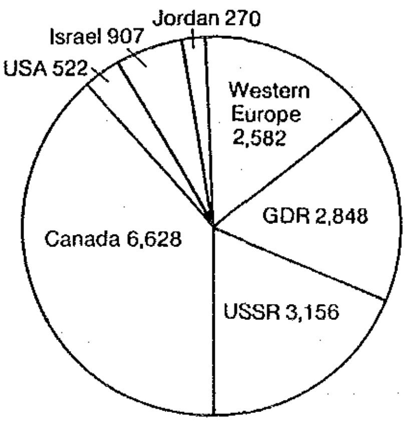
(thousand tonnes K_2O)

	1985	1986	1987	1988	1989	1990
Western Europe						
Production	5,525	5,540	5,655	5,720	5,785	5,850
Consumption	6,600	6,700	6,800	6,900	7,000	7,100
Eastern Europe						
Production	13,200	13,250	13,500	13,800	14,100	14,550
Consumption	10,575	10,950	11,325	11,700	12,175	12,500
Africa						
Production	-	-	10	20	30	40
Consumption	370	400	430	460	490	520
North America						
Production	9,840	11,090	11,640	11,955	12,090	12,980
Consumption	6,360	6,550	6,740	6,930	7,070	7,210
Latin America						
Production	74	125	175	226	276	326
Consumption	1,600	1,660	1,740	1,840	1.950	2,060
Asia						
Production	1,590	1,730	1,890	2,020	2,150	2,220
Consumption	3,388	3,650	3,900	4,180	4,480	4,790
Oceania						
Production	-	-	-	20	25	30
Consumption	270	279	288	297	306	315
World Total						
Production	30,229	31,735	32,870	33,781	34,456	35,996
Consumption	29,163	30,189	31,223	32,307	33,471	34,545

Source: Phosphorus & Potassium No.139 (1985)

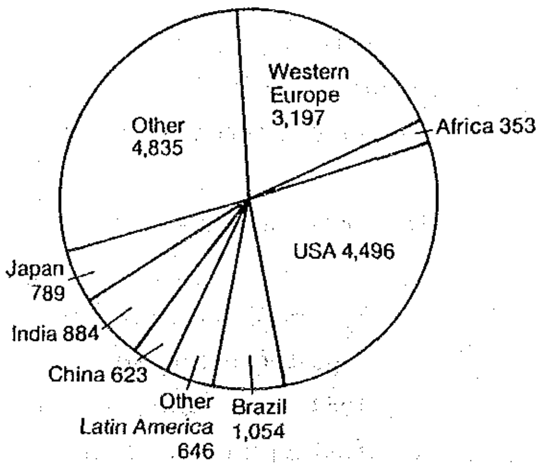
(thousand tonnes K_2O)

Exports



1984 Total: 1.691 million tonnes K_2O

Imports



1984 Total: 1.668 million tonnes K_2O

Source : Phosphorus & Potassium No. 139 (1985)

Figure 6-5-1 Analysis of World Trade (1984)

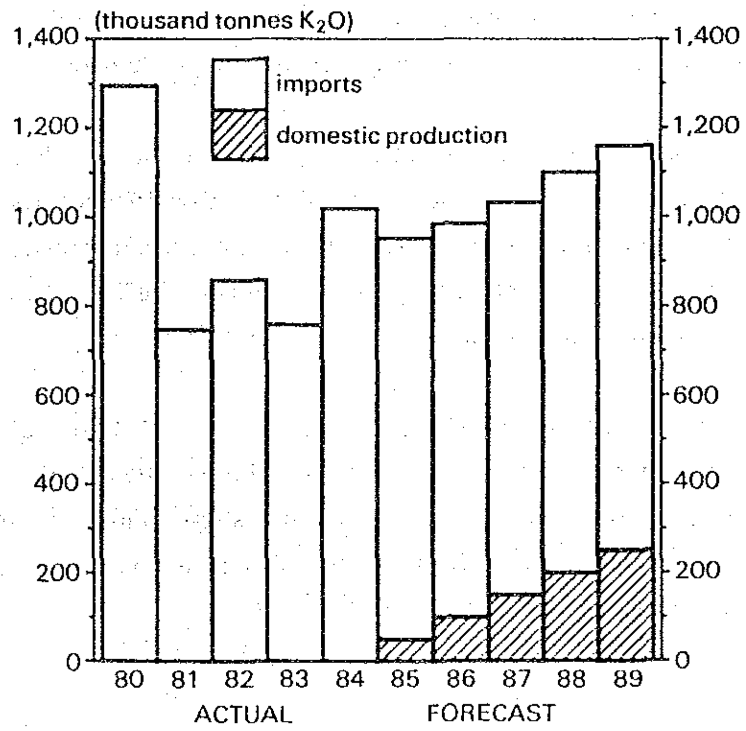
Table 6-5-7 Brazil: Potash Imports (1980 - 1984)

(thousand tonnes K_2O)

	1980	1981	1982	1983	1984
Total Imports	1,296	747	859	759	1,076
% of Total World Trade	8.0	4.9	6.1	4.6	6.5*

* estimated

Source: Phosphorus & Potassium No.137 (1985)



Source : Phosphorus & Potassium No. 137 (1985)

Figure 6-5-2 Brazil: Potash Consumption and Imports (1980 - 1989)

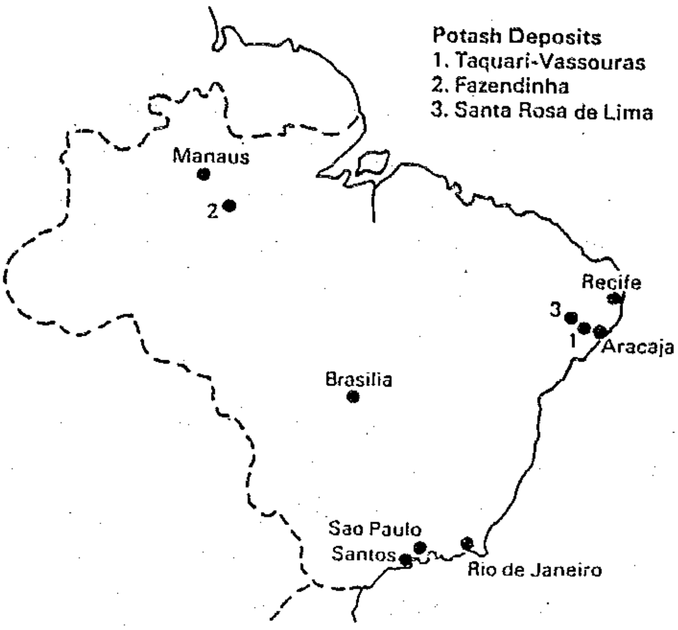
Brazil's import pattern has shown considerable fluctuation over the past five years. This pattern is possibly influenced strongly by cutbacks in the agricultural assistance programs due to downturns in the national economy.

2) Production

As was stated earlier, the full extent of Brazil's potash reserves have yet to be confirmed. A new mine has been developed at Taquari-Vassouras in the district of Sergipe, 40 km inland from the port of Aracuju (see Figure 6-5-3), which expects to begin producing potassium chloride in 1985. Production capacity at this mine is estimated at 0.6 million tons/yr, which is 1/3 of Brazil's total yearly consumption. Some time, however, will most likely be required before the mine moves into full production.

In addition, there are also promising reserves at Santa Rosa de Lima about 15 miles from the new mine. Considering the investment capital needed to develop this area, however, a substantial number of years will most likely be required before Brazil becomes self-sufficient in potash.

The potassium chloride produced in the district of Sergipe is probably destined to be supplied to the northeastern region of the country. Due to the size of the ships and the geography of consumption, imports from North America are now offloaded at Santos port.



Source : Phosphorus & potassium No. 137 (1985)

Figure 6-5-3 Brazil: Location of Potash Developments

6.5.3 Price of Potash

The cost of potassium chloride, as can be seen in Figure 6-5-4, is relatively stable. According to our own research in Paraguay, 50 kg bags of potassium chloride fertilizer are now imported from Brazil at a cost of US$200/ton. The Paraguayan fertilizer plant, however, would most likely import the necessary potash in bulk from North America. The total cost of such potash, as shown below, would be around US$140/ton at Foz do Iguacu on at border,

* potassium chloride FOB North America-US$80/ton
* sea freight costs-US$20/ton
* offloading costs-US$15/ton
* overland freight-US$25/ton
* total cost-US$140/ton

One probable route for this potash would be overland by truck from Santos port, but more detailed research still needs to be done on the transportation aspect.

6.6 Silica Gravel

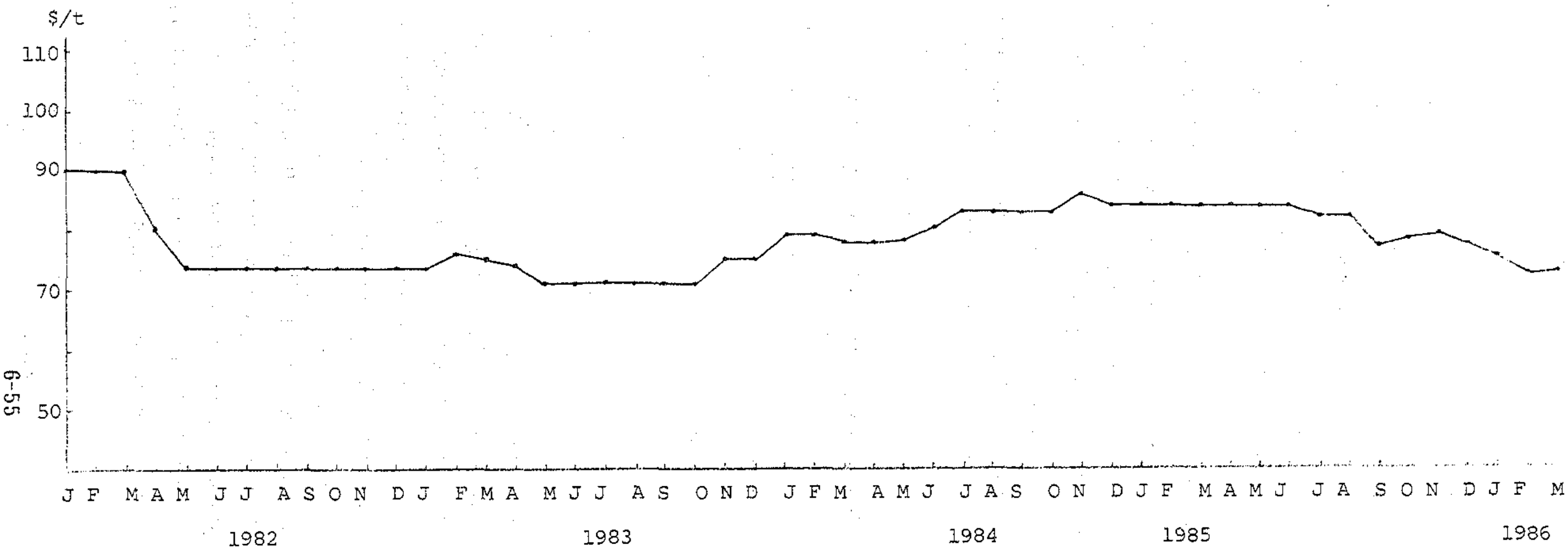
In production of yellow phosphorus, the phosphate rock is introduced into the electric furnace and melted, then reduced using coke, Silica is used as a fluxing agent in the dissolution process. The amount of silica required depends on the relative percentages of CaO and SiO_2 in the phosphate rock, with enough added to bring the ratio in the slag to between 1.0-1.2 CaO/SiO_2.

The main component of silica gravel is SiO_2, but the yellow phosphorus process does not require exceptionally pure material, and an SiO_2 percentage of more than 90% is usually sufficient. This is because the silica has no effect on the quality of the yellow phosphorus produced, but forms a slag composed chiefly of calcium silicate and components of the phosphate rock other than P_2O_5 and Fe_2O_3, which is then removed from the furnace.

High quality silica is produced in the center of Paraguay's Eastern region, but the fertilizer project would use material that can be obtained for 4,000 Gs/ton in the area around the plant site.

6.7 Coke

Like silica, coke is required for production of yellow phosphorus in an electric furnace, where it is used as a reducing agent for reducing calcium phosphate into phosphorus. The possibility of using charcoal in place of coke in the Paraguayan fertilizer plant has been considered, but charcoal lacks the strength to insured adequate ventilation inside the furnace. Thus the fertilizer project will rely on coke, which can be imported from Brazil or Argentina for an estimated cost of $140/ton delivered to Foz de Iguacu at the border.



Source : Phosphorus & Potassium

Figure 6-5-4 Potassium Chloride Price
F.O.B. Vancouver, Bulk

6.8 Serpentine and Peridotite

Either serpentine or peridotite is required as a source of MgO in production of fused magnesium phosphate fertilizers. There is little fundamental difference between these two materials, and peridotite is capable of changing into serpentine.

Table 6-8-1 shows the MgO content, SiO_2 content and ignition-loss for serpentine and peridotite. The minimum percentage of MgO needed as raw material for fused magnesium phosphate depends on the quality of the phosphate rock, but 35% or above is usually sufficient.

In Paraguay, serpentine is being mined in eastern Asunciion, but more detailed research needs to be done on the size and quality of these reserves.

Table 6-8-1 Constituent of Serpentine and Peridotite

	MgO (%)	SiO_2 (%)	Ig. loss (%)
Serpentine	39.4	39.3	11.2
Peridotite	45.0	37.8	4.1

6.9 Fuel

In the Paraguayan fertilizer project, fuel will be required for pre-treatment of the phosphate rock, drying the fertilizer, and the boiler as a source of heat. Part of this requirement can be met with carbon monoxide produced as a by-product in the electric furnace, but additional outside sources will also be necessary.

At present, Paraguay's reserves of oil and natural gas have yet to be confirmed, but coal reserves are said to be present in southern Paraguay. The fertilizer project, however, will most likely purchase fuel oil (heavy oil) from PETROPAR, an oil company. This fuel oil will cost an estimated 75 Gs/l delivered to the plant site by lorry.

6.10 Packing Material

The fertilizer produced at the Paraguayan plant will be packed and shipped in 50 kg bags. Normally, heavy duty polyethylene or polypropylene-woven bags are used as packing material. This project will rely on domestically produced woven bags.

At present, woven bags are produced in Paraguay and used for preserving and transporting seed for soybeans and other agricultural product. Fertilizer bags, however, must be strong enough to withstand handling during storage and shipment, and also airtight to prevent moisture from reaching the fertilizer. Thus the presently produced seed bag will have to be strengthened and laminated on the inside.

Production of these bags should present no problems, as they will involve only making some improvements on the existing seed bags. The estimated price of the improved bags delivered to the plant site is 300 Gs/bag, compared to 180 Gs/bag paid by farmers for ordinary seed bags.

6.11 Electrodes

Electrodes, made of carbon, are the final conductors that pass electric power into the furnace. Two types are available, commercially manufactured graphite electrodes, and the kind that the users bake themselves.

Commercially available graphite electrodes use coke as raw material, to which pitch is added. The mixture is then shaped and baked at 1,000°C. Afterwards, the pitch is replenished and the electrode is graphitized at 3,000°C. These electrodes have low electrical resistance and are mechanically strong and inflexible. Thus they are more compact than the self-baked variety, and as they can be connected simply by being pushed up through the taper-nipple, are easy to use. The Paraguayan fertilizer plant would require 30 inch graphite electrodes.

The self-baking electrodes are encased in a cylindrical metal tube. As the need arises, the cylindrical case is pushed into position, and coke and pitch are mixed inside it. When the case is connected to the furnace, heat from the electric current and from the furnace itself bakes the electrode while in use. Compared to the commercially produced graphite electrodes, however, the self-baking variety is difficult to use. While the graphite electrodes require only a hoist on top of the furnace to lift them in place, the self-baking electrodes necessitate stores of raw materiais and facilities for mixing and replenishing as well.

From the bottom up, self baking electrodes are composed of fully baked, half-baked and unbaked sections. While in use, balance must be maintained between the rate of baking and the rate of exhaustion. If this balance is lost, the resulting breakdown can cost many days of down time before repairs can be effected. As was explained in Section 6-1, such down time will result in a large jump in the per-unit costs of electric power.

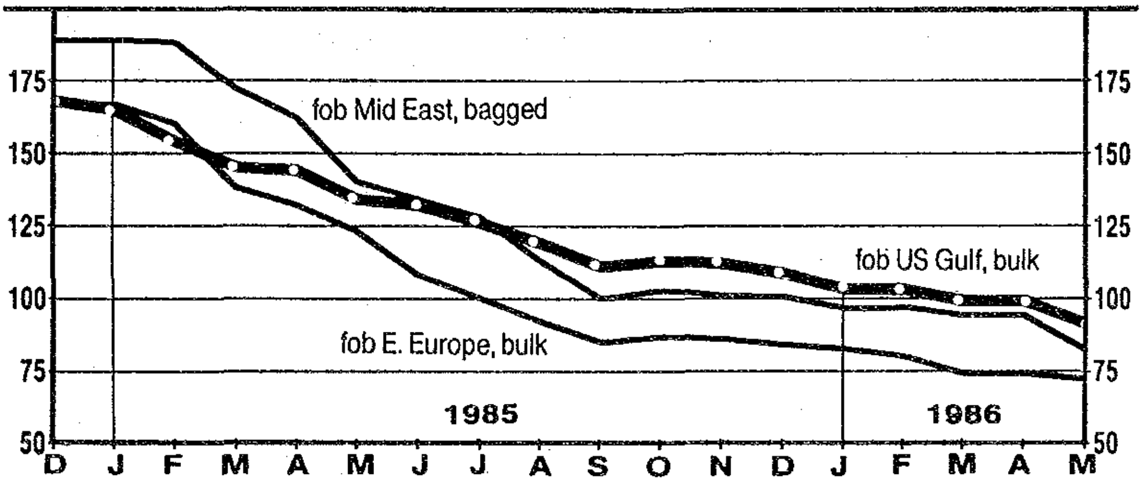
Considering the above points, self-baking electrodes are clearly unsuitable for the Paraguayan fertilizer plant. Commercially available graphite electrodes will be imported at an estimated cost of US$3,000/ton Fog do Iguacu at the border.

6.12 Urea

In the Paraguayan fertilizer plant, 4,000 tons/yr of 15-15-15 will be produced as a NPK fertilizer, requiring approximately 890 ton/yr of urea. The urea will be used as raw material, and can be imported from Brazil in 50 kg bags and stored at the plant.

Month by month price trends for urea are graphed in Figure 6-12-1. As can be seen, there is a recent trend towards lower prices. According to our research in Paraguay, farmers now purchase 50 kg bags of imported Brazilian fertilizer for around US$280/ton. Considering the recent price trends, however, the price of urea delivered to Foz do Iguacu at the border is expected to be around $175/ton.

* FOB bagged urea US$150/ton
* overland freight costs US$25/ton
* total cost US$175/ton



Source : Nitrogen

Figure 6-12-1 Urea Price

6.13 Coating Agent

Normally, chemical fertilizers are composed chiefly of inorganic compounds that are water-soluble salts. When stored over a long period, increased pressure from the weight above, as well as changes in air temperature and humidity, cause alternating solution and recrystallization at the point of contact between particles of fertilizer. This is referred to as "bridging," and if the particles of fertilizer become bound and hard, a troublesome phenomenon called "caking" occurs. Caking impedes smooth, uniform spreading of the fertilizer, and thus lowers the product's commercial value.

In TSP and DAP fertilizers caking is not a common problem, but NPK fertilizers require some sort of preventive measures. One method is to coat the fertilizer particles with fine powder of chemically inactive minerals such as talc, clay or diatomaceous earth. These fine powder of chemically inactive minerals are known as anti-caking agents, of which the Paraguayan fertilizer plant would require approximately 360 ton/yr. Anti-caking agents can most likely be obtained domestically, and would cost an estimated 80,000 Gs/ton delivered to the plant.

CHAPTER VII BASIC PLAN OF FERTILIZER PROJECT

7.1 Bases of Plan

Following is the basic plan of this fertilizer project.

7.1.1 Capacity of Plant and Types of Fertilizers to be Produced.

Based on the analyses presented in Chapter V, the recommended fertilizer types and yearly production figures are shown in Table 7-1-1.

Scenario 1 shows the plant scheme with importation of ammonia to produce the designated phosphate fertilizers, and Scenario 2 has production of ammonia in the planned plant in Paraguay.

Table 7-1-1 Fertilizer to be produced and Production Capacity

Scenario 1 and 2

Fertilizer	Application	Product (t/y)
DAP (18-46-0)	Wheat	29,000
TSP (0-46-0)	Wheat, Soybean	5,000
NPK (6-30-10)	Soybean	32,000
NPK (15-15-15)	Sugarcane, Vegetables	4,000
		70,000

Scenario 3

FMP		15,000

According to the production schedule previously agreed upon, the DAP, NPK and TSP will all be produced in one train of the plant. In addition, the phosphoric acid necessary for their manufacture would be produced as an intermediate product in a separate unit, in the amount of 25,380 ton/yr.

7.1.2 *Specification of Raw Materials, Utilities, Chemicals and Products*

The specification of raw materials, various utilities, chemicals and products necessary to produce fertilizer are as follows:

1) Raw materials

(1) Phosphate rock

- Source : Goias, Brazil

- Chemical composition (wt% dry basis)

P_2O_5	:	38%
CaO	:	50%
Fe_2O_3	:	2.5
SiO_2	:	1.2%
F	:	1.5%
MgO	:	0.2%
Al_2O_3	:	0.3%
BaO	:	0.32%
TiO_2	:	0.55%
K_2O	:	1.0%
CO_2	:	0.18%
Cl	:	20 ppm
Moisture	:	1-2%

- Size distribution

+100 mesh: 20%

-200 mesh: 31%

- Bulk density : 1.50 t/m^3

- Receiving condition : Bulk by truck

(2) Potassium chloride (Muriate of potash)

- K_2O content : 60% min.
- Free moistire : 1% max.
- Size : -10 Tyler mesh +60 Tyler mesh: 95%
- Bulk density : 0.9 t/m^3
- Receiving condition : Bulk by truck

(3) Urea

- Nitrogen content : 46% min.
- Free moisture : 0.5% max.
- Size distribution : -8 Tyler mesh +16 Tyler mesh: 85-90%
- Bulk density : 0.9 t/m^3
- Receiving condition : Bags by truck

(4) Silica Gravel

- SiO_2 content : 95% min.
- Free moisture : 0.5% max.
- Size distribution : 15-25 mm
- Bulk density : 1.5 t/m^3
- Receiving condition : Bulk by truck

(5) Coke

- Fixed carbon content: 85% min.
- Free moisure : 0.5% max.
- Size distribution : Approx. 10 mm
- Bulk density : 0.5 t/m^3
- Receiving condition : Bulk by truck

(6) Liquid ammonia (In case of Scenario 2, liquid ammonia is produced in Paraguay.)

- Purity : 99.5 wt% min.
- Free moisture : 0.5 wt% max.
- Pressure : 14 kg/cm^2G saturated
- Receiving condition : Tank truck

(7) Coating agent

- Material : Diatom earth
- Free moisture : 3% max.
- Size distribution : -325 Tyler mesh 99%
- Bulk density : 0.15 t/m^3
- Receiving condition : Bags by truck

(8) Serpentine rock (Scenario 3 only)

- Chemical composition
  - MaO : 35 wt% min.
  - SiO_2 : 39 wt% min.
  - Moisture : 0.5 wt% max.
  - Size : 10-20 mm
- Bulk density : 1.5 t/m^3
- Receiving condition : Bulk by truck

2) Utilities

(1) Raw water (River water)

- Hardness : 200 ppm as $CaCO_3$
- Turbidity : 20 ppm as kaoline
- PH : 7

(2) Fuel oil (Heavy oil)

- High calorific value: 10,300 kcal/kg
- Specific gravity : 0.93
- Sulphur content : 1 wt% max

(3) Instrument air

- Pressure : 7 kg/cm^2G
- Temperature : Ambient
- Dew point : -20°C

(4) Electric power

- Income voltage : 220 kV
- Frequency : 50 Hz

3) Chemicals

The specifications of chemicals for water, waste water and exhaust gas treatment will be as follows.

(1) Oxygen and nitrogen gas

- Specification : Industrial grade
- Receiving condition : Cylinder by truck

(2) Caustic soda (NaOH)

- Specification
  - NaOH : 97 wt% min.
  - Na_2CO_3 : 2 wt% max.
  - NaCl : 1 wt% max.
- Receiving condition : Bags by truck

(3) Slaked lime

- Specification
  - CaO : 65 wt% min.
  - Size : -28 Tyler mesh: 100%
- Transportation : Bags by truck

(4) NaClO

- Specification
  - Effective chlorine : 12%
- Receiving condition : Bottles by truck

(5) Hydro chloric acid

- Specification

  HCl : 36 wt%

- Receiving condition : Bottles by truck

(6) Alum

- Specification : Suitable grade for water treatment

- Receiving condition : Bags by truck

4) Product specification

(1) DAP (18-46-0)

N	:	18%
P_2O_5	:	46%
Moisture	:	1.5%
Size	:	2-4 mm: 90%

(2) NPK (6-30-10)*

N	:	6%
P_2O_5	:	30%
K_2O	:	10%
Moisture	:	1.5%
Size	:	2-4 mm; 90%

Note (*)

5-30-10 NPK fertilizer is imported from Brazil and is used in Paraguay at present. In this project, however, 6-30-10 NPK will be produced utilizing high purity phosphoric acid which is produced by means of the Electric Furnace Process.

(3) NPK (15-15-15)

N	:	15%
P_2O_5	:	15%
K_2O	:	15%
Moisture	:	1.5%
Size	:	2-4 mm; 90%

(4) TSP (0-46-0)

Available P_2O_5	:	46%
Moisture	:	4%
Size	:	2-4 mm; 90%

(5) Fused magnesium phosphate (0-20-0)

Citric soluble P_2O_5	:	20%
Citric soluble MgO	:	15%
Moisture	:	0.5%
Size	:	-2 mm sandy

7.1.3 Consumption of Raw Materials Utilities and Chemicals

The amount of raw materials and utilities necessary to produce 1 ton of fertilizer are shown in Table 7-1-2, Figure 7-1-1 and Figure 7-1-2 respectively.

Table 7-1-2 Consumption Figure of Raw Material and Utility

Raw Material (Unit= kg per M.ton of Product)

	SCENARIO-1					SCENARIO-3
	P A (100%)	DAP (18-46-0)	NPK (6-30-10)	NPK (15-15-15)	TSP (0-46-0)	FMP (0-20-0)
PHOS. ROCK (P_2O_5=38%)	2960	-	-	-	426	540
PHOS. ACID (P_2O_5=100%)	-	465	303	152	317	—
AMMONIA (NH_3=100%)	-	221	74	61	-	-
UREA (N=46%)	-	-	-	221	-	-
M.POTASH (K_2O=60%)	-	-	168	254	-	-
FILLER	-	122	314	239	91	-
COATING AGENT	-	-	10	10	-	-
ELECTROD	11	-	-	-	-	2
COKES	640	-	-	-	-	-
SILICA GRAVEL (SiO_2=95%)	1390	-	-	-	-	59
SERPENTINE (MgO=38%, SiO_2=39%)	-	-	-	-	-	453

Cont'd

Raw Material (Unit= kg per M.ton of Product)

	SCENARIO-2					
	P A (100%)	DAP (18-46-0)	NPK (6-30-10)	NPK (15-15-15)	TSP (0-46-0)	NH_3
PHOS. ROCK (P_2O_5=38%)	2960	-	-	-	426	-
PHOS. ACID (P_2O_5=100%)	-	465	303	152	317	-
AMMONIA (NH_3=100%)	-	221	74	61	-	-
UREA (N=46%)	-	-	-	221	-	-
M.POTASH (K_2O=60%)	-	-	168	254	-	-
FILLER	-	122	314	239	91	-
COATING AGENT	-	-	10	10	-	-
ELECTROD	11	-	-	-	-	
COKES	640	-	-	-	-	-
SILICA GRAVEL (SiO_2=95%)	1390	-	-	-	-	-
SERPENTINE (MgO=38%, SiO_2=39%)	-	-	-	-	-	-
PURE WATER	-	-	-	-	-	1,800

Cont'd

Utility (Unit = per M.ton of Product)

	SCENARIO-1					SCENARIO-3
	P A (100%)	DAP (18-46-0)	NPK (6-30-10)	NPK (15-15-15)	TSP (0-46-0)	FMP (0-20-0)
Electric Power (kWh)	6,890	40	32	40	50	935
Fuel Oil ($x10^6$ kcal)	0.37	0.10	0.08	0.10	0.30	0.09
Process Water (m^3)	34	1	0.9	1	0.5	20
Steam (kg)	5	100	85	100	110	-
Lime (CaO=65%) (kg)	34	-	-	-	-	-
HcL (36%) (kg)	28	-	-	-	-	-
NaOH(solid) (kg)	100	-	-	-	-	-
NacLO(cL=12%) (kg)	120	-	-	-	-	-
O_2 Gas (Nm^3)	1.6	-	-	-	-	-

Utility (Unit = per M.ton of Product)

	SCENARIO-2					
	P A (100%)	DAP (18-46-0)	NPK (6-30-10)	NPK (15-15-15)	TSP (0-46-0)	NH_3
Electric Power (kWh)	6,890	40	32	40	50	12,000
Fuel Oil ($x10^6$ kcal)	0.37	0.10	0.08	0.10	0.30	
Process Water (m^3)	34	1	0.9	1	0.5	480 (Cooling Water)
Steam (kg)	5	100	85	100	110	-
Lime (CaO=65%) (kg)	34	-	-	-	-	-
HcL (36%) (kg)	28	-	-	-	-	-
NaOH(solid) (kg)	100	-	-	-	-	5
NacLO(cL=12%) (kg)	120	-	-	-	-	-
O_2 Gas (Nm^3)	1.6	-	-	-	-	-

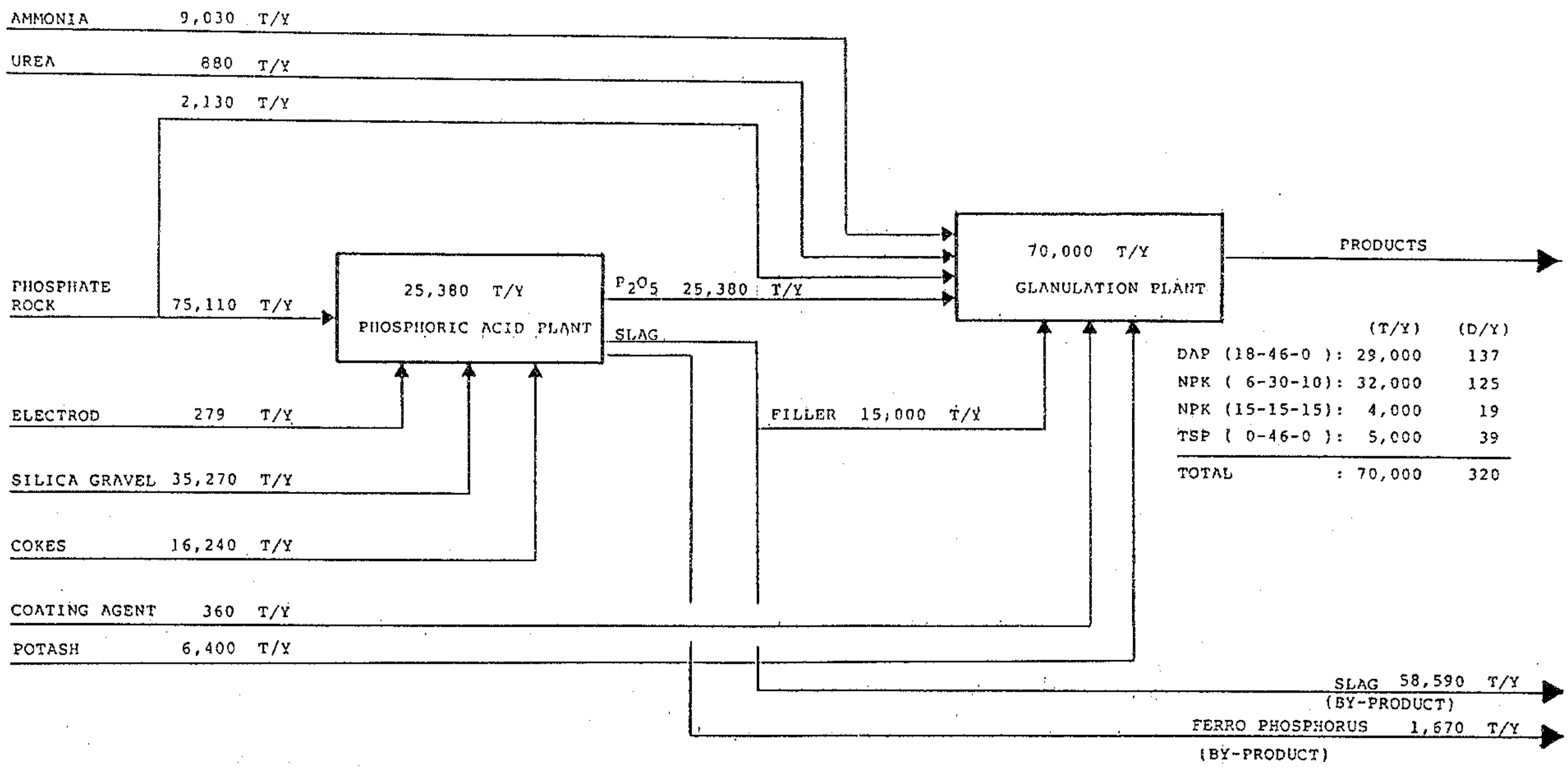


FIGURE 7-1-1 (1/3) OVERALL RAW MATERIAL AND SUB-MATERIAL BALANCE (SCENARIO 1)

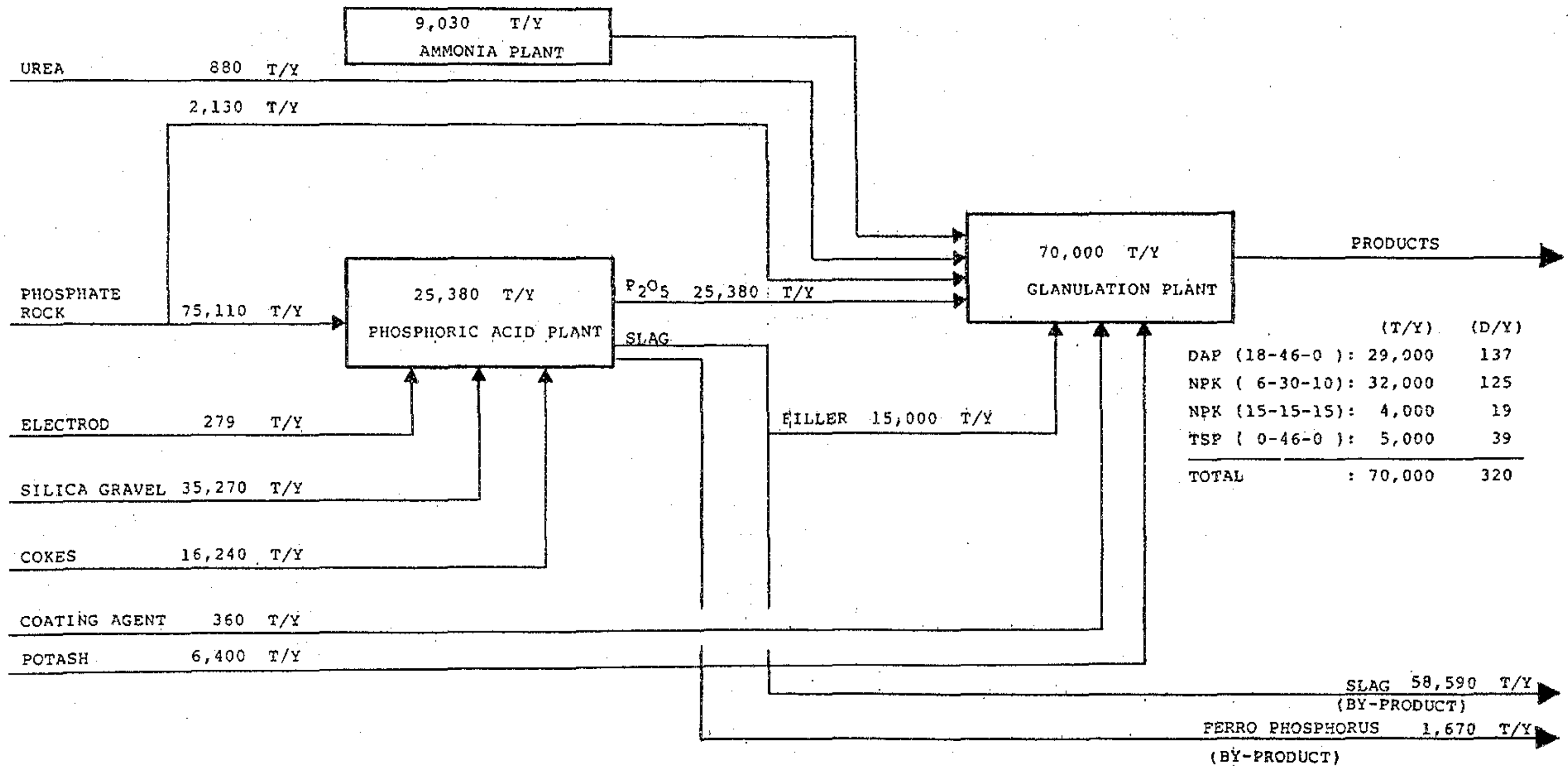


FIGURE 7-1-1 (2/3) OVERALL RAW MATERIAL AND SUB-MATERIAL BALANCE (SCENARIO 2)

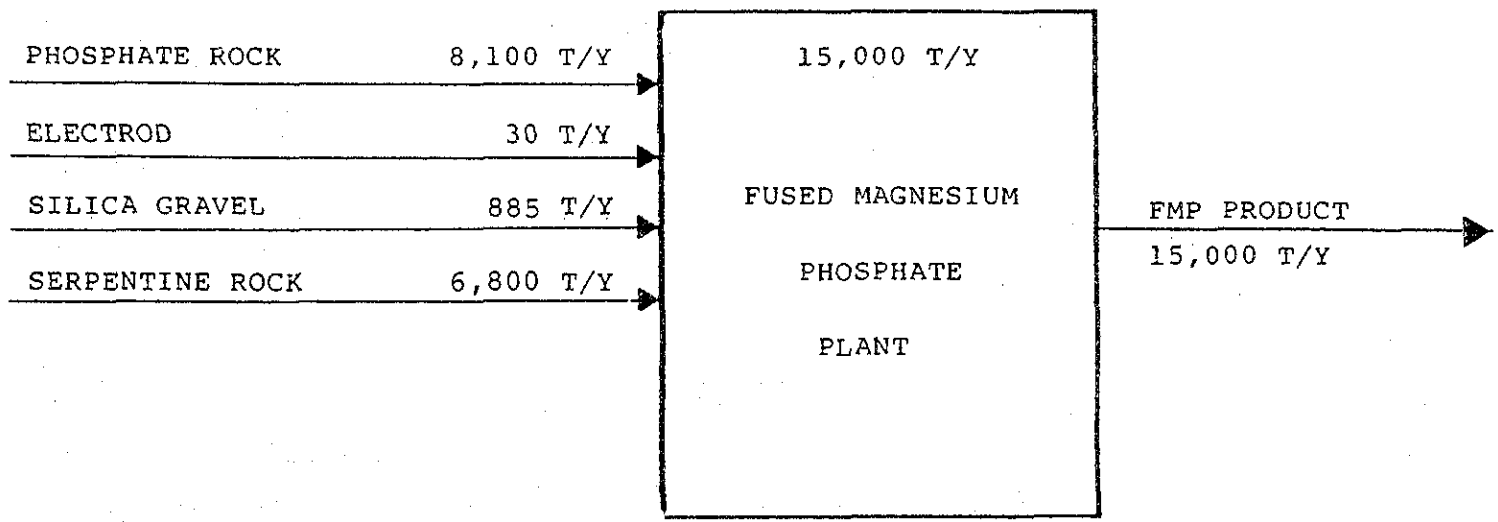


FIGURE 7-1-1 (3/3) OVERALL RAW MATERIAL AND SUB-MATERIAL BALANCE (SCENARIO 3)

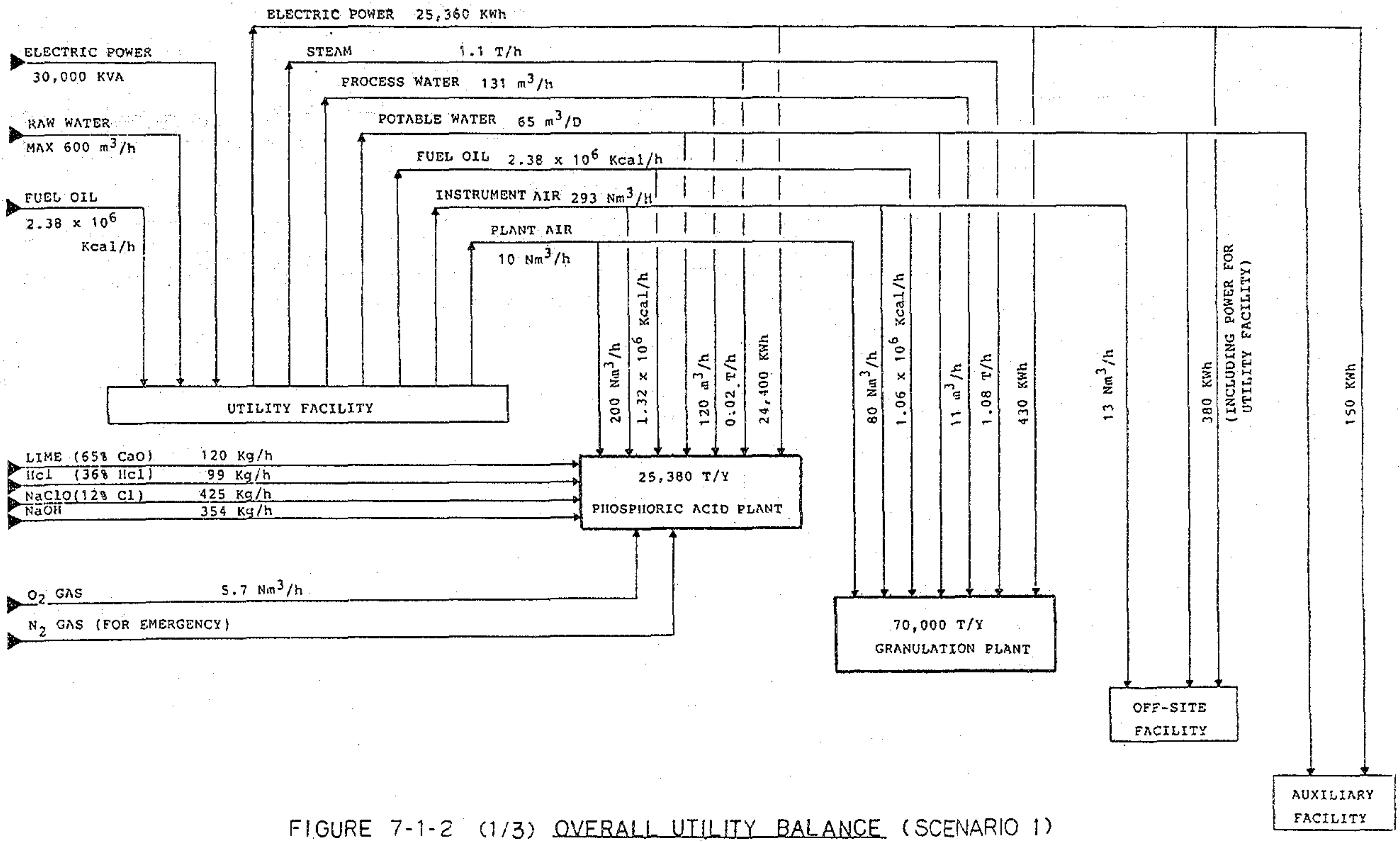


FIGURE 7-1-2 (1/3) OVERALL UTILITY BALANCE (SCENARIO 1)

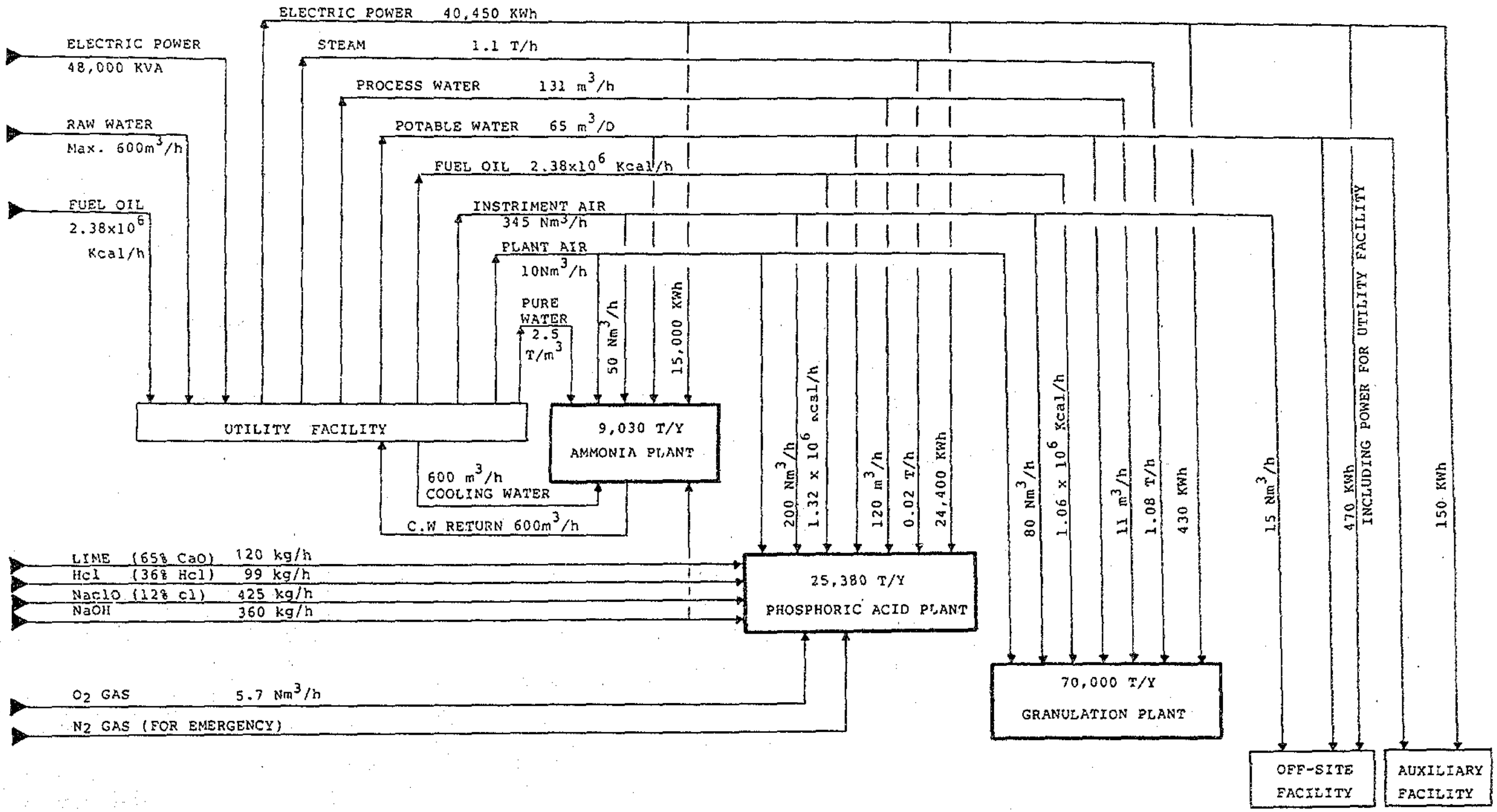


FIGURE 7-1-2 (2/3) OVERALL UTILITY BALANCE (SCENARIO 2)

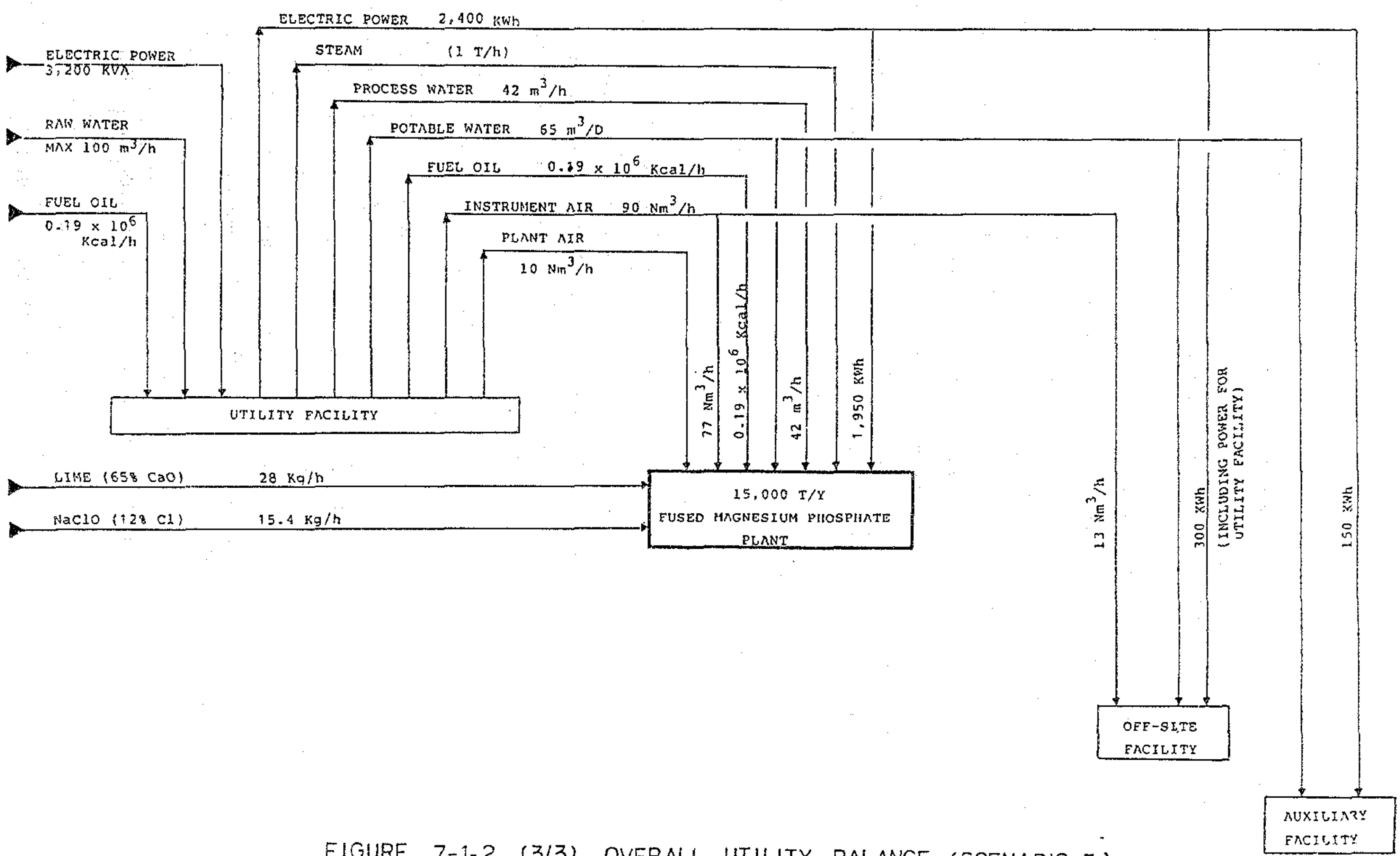


FIGURE 7-1-2 (3/3) OVERALL UTILITY BALANCE (SCENARIO 3)

7.2 Description of the Production Process

7.2.1 Phosphate fertilizers (Scenario 1 and 2)

Scenario 1, as described below, consists of production of phosphoric acid as an intermediate product and imported ammonia, then use of these as raw material for manufacturing the fertilizer. In the first step, the Electric Furnace process (dry process) will be used to produce phosphoric acid; and the Slurry Granulation process will be employed in the manufacture of fertilizers such as DAP, TSP and NPK. The rationale behind there choices, explained below, is based on consideration of availability of raw materials, the market for fertilizers, and other pertinent local conditions in Paraguay.

1) Basis of process selection

(1) Production of phosphoric acid

Two processes, the Electric Furnace process (dry process) and the wet process are commonly utilized for production of phosphoric acid. Following is a brief description of these two alternatives with analyses of their advantages and disadvantages.

(a) Wet process (Di-hydrate process)

Di-hydrate process, as a example, is briefly described below. In this process, ground phosphate rock is reacted with sulphuric acid and phosphoric acid (a part of the product is recirculated) to produce a slurry containing gypsum and phosphoric acid, which are then separated with a filter. The reaction formulas involved in the process are:

$$Ca_3(PO_4)_2 + 4H_3PO_4 + 3H_2O \rightarrow 3CaH_4(PO_4)_2.H_2O$$

$$3CaH_4(PO_4)_2.H_2O + 3H_2SO_4 + 3H_2O \longrightarrow 3CaSO_4.2H_2O + 6H_3PO_4$$

Phosphoric acid produced by this wet process usually contains approximately 30% P_2O_5. As stronger material is often required, the phosphoric acid is then concentrated under vacuum to 54% P_2O_5, which is the standard percentage of the commercially traded product.

Wet process phosphoric acid retains the impurities originally contained in the phosphate rock, as well as quantities of surplus gypsum and sulphuric acid left over from the reaction, These impurities, however, present no problems for fertilizer manufacture, and as production costs are low, most of the phosphoric acid used for this purpose is produced by the wet process.

In summary, the major characteristics of the wet process are as follows:

- Sulfuric acid is required for extraction of P_2O_5 from the phosphate rock.
- As the impurities contained in the phosphate rock are retained in the product, phosphoric acid produced by this process, although commonly used in fertilizer manufacture, must be purified before use in other industrial chemical applications.

(b) Electric furnace process (Dry procss)

In this process, phosphate rock is reduced with carbon in an electric furnace. The resultant volatilized phosphorus gas is condensed by means of a water shower, and converted to yellow phosphorus, which is then oxidized (into phosphorus pentoxide) and hydrated to produce phosphoric acid.

- High purity phosphoric acid is produced, which can be used in the food and pharmaceutical industries as well as in other industrial purposes.
- There is no need for sulphuric or other acid in digesting the phosphate rock
- Energy consumption is much higher than in the wet process.

As can be seen from the above discussion, the wet process offers low energy costs, but requires use of sulphuric acid for digesting the phosphate rock, while the dry process requires large amounts of energy, but no sulphuric acid. In most cases where phosphoric acid is produced for fertilizer manufacture, the energy costs outweigh all other considerations, and the wet process is preferable.

In the Paraguayan fertilizer project, however, electric power, as explained in Section 6.1, will be plentiful and relatively inexpensible. On the other hand, there is no sulfuric acid plant in Paraguay, and a supply of this raw material would be difficult to obtain. Thus the Electric Furnace process would be most suitable for phosphoric acid production in this project.

(2) Manufacture of fertilizer

Depending on the type of reaction method employed, there are a variety of processes for producing fertilizer.

In all these processes, however, the granulation, drying and screening systems are essentially the same, and the difference is rather in the know-how required for engineering and plant operation. Following is an outline of the various reaction methods.

(a) Reaction under atmospheric pressure with a neutralizer tank and granulator.

This process was developed in the U.S. by TVA, and has been widely adopted for production of DAP and NPK fertilizers. Phosphoric acid is placed in a neutralizer tank and neutralized under atmospheric pressure with ammonia, producing an ammonium phosphate slurry, which is then fed into the granulator. Depending on the nutrient composition desired in the final product, additional ammonia is sometimes required in the granulator.

When this method is applied to the production of TSP fertilizers, the neutralizer tank serves also as a reactor tank for the reaction between phosphate rock and phosphoric acid.

The major characteristics of this reaction method are:

- ease of operation
- flexibility with regards to the type of fertilizer produced.

(b) Reaction under pressure

The powder process, in which a MAP slurry is usually produced in a pressurized reaction vessel, is a famous example of this process. The resultant slurry is solidified in a counter air flow tower, producing MAP powder. As the reaction takes place in a pressurized vessel, the temperature of the slurry can be raised, thus decreasing the moisture content.

If desired, the MAP powder can be granulated, and DAP or NPK fertilizers produced by addition of a nitrogen source such as ammonia, urea, ammonium nitrate or ammonium sulfate. For TSP production, however, an additional reactor tank (for the phosphate and phosphoric acid) is required.

(c) Pipe reactor process

This is a another type of pressurized system, in which low moisture content slurry is obtained by reacting phosphoric acid with ammonia in a pipe equipped at granulator (then later in a dryer as well). Unfortunately, no way has yet been found for adopting this method to production of TSP fertilizers.

(d) Reaction methods for producing TSP

The atmospheric pressure system described above in (a), as well as the so-called "Den" and ROP (Run-of-Pile) methods, are all used widely for exclusive production of TSP fertilizers. If DAP and NPK are also to be produced, however, a separate system for reacting phosphoric acid with ammonia is required.

In the Paraguayan fertilizer project, local demand dictates that many kinds of fertilizers, including DAP, NPK and TSP, be produced within a single plant. Thus the atmospheric pressure system (slurry process) developed by TVA, which is employed on a worldwide basis and has the advantages of extreme flexibility, would be the most suitable process for this project. Provision should also be made for addition of a pipe-reactor system if necessary.

This flexibility will be important if, for example, results of future experiments determine that a different nutrient ratio of NPK is ideal under certain conditions, or if market demand shifts towards some new product. Production at the fertilizer plant would then be able to respond accordingly.

2) The electric furnace process for production of phosphoric acid

The electric furnace process to be employed in the Paraguayan fertilizer plant for production of phosphoric acid has a long history of use in places like the U.S. and Japan. Generally speaking, the process can be divided into the following three steps:

- pre-processing of raw material
- production of yellow phosphorus in the electric furnace
- production of phosphoric acid

(1) Pre-processing of the raw material

As can be seen in the flow sheet in Figure 7-2-1, the necessary raw materials are coke, silica and phosphate rock, which eventually must react inside the furnace according to the formula:

$$2Ca_3(PO_4)_2 + 10C + 6SiO_2 \rightarrow 6CaSiO_3 + 10CO + P_4$$

As can be inferred from this reaction formula, the carbon monoxide gas and gaseous phosphorus that are produced in the furnace must be able to diffuse freely. Thus the particles of raw materials must be prepared to a particular diameter before entering the furnace. This pre-processing of the raw material is accomplished in the manner diagrammed In Figure 7-2-1.

The phosphate rock is first ground in a mill then granulated to a granule size of approximately 8-10 mm. These granules are then calcinated in a rotary-kiln to a compression strength of over 50 kg/granule. The coke and silica are first dried,

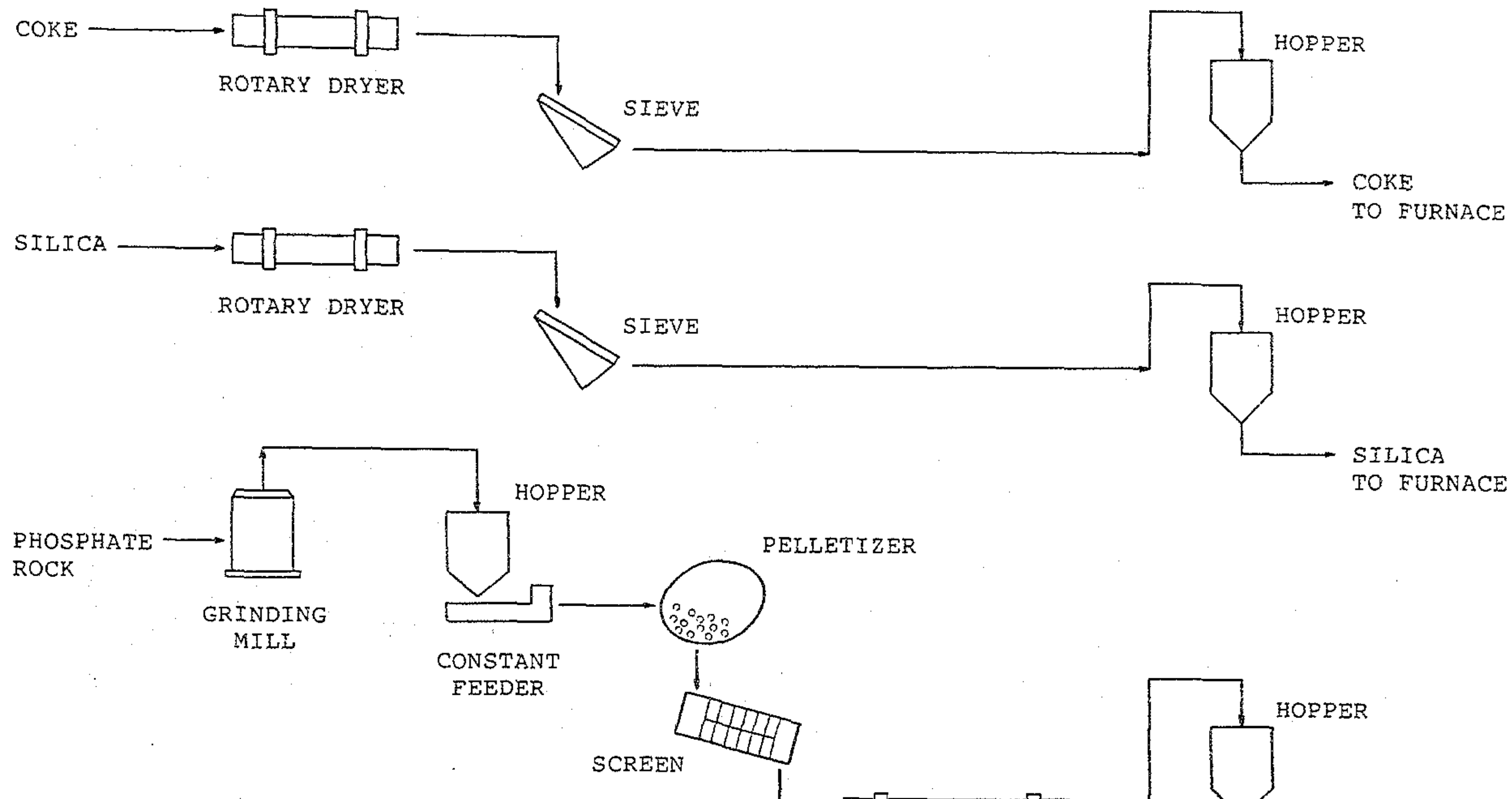


FIGURE 7-2-1

PHOSPHORIC ACID PLANT - ELECTRIC FURNACE PROCESS

FLOW SHEET - RAW MATERIAL PREPARATION SECTION then sieved to granule sizes of 10 mm and 15-25 mm respectively.

(2) Production of yellow phosphorus in the electric furnace

Three sets of commercially available graphite electrodes, approximately 30 inches in diameter, are attached to the furnace in a manner that allows for vertical movement. Electric power is conducted through these electrodes into the furnace.

Figure 7-2-2 diagrams the functioning of the electric furnace. Phosphate rock, silica and coke, all prepared to the proper diameter in the process described above, are fed into the furnace at a designated rate. Inside the furnace, the chemical reaction listed above produces carbon monoxide and gaseous phosphorus, which are then removed.

The gaseous phosphorus is condensed with a water shower to form liquid yellow phosphorus, while the carbon monoxide is recycled to be used as fuel in the rotary kiln for calcination of the phosphate rock.

Slag and ferrophosphorous collect at the bottom of the furnace, and are removed periodically at set intervals. The slag is cooled and sieved to a pre-determined granule size. Some of the slag can be used as filler for the fertilizer, and some can even be sold as a silicate fertilizer.

(3) Production of phosphoric acid

In this final step, the phosphoric acid is produced from the liquid yellow phosphorus according to these two reaction formulas:

$$P_4 + 5O_2 \rightarrow 2P_2O_5$$
$$P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$$

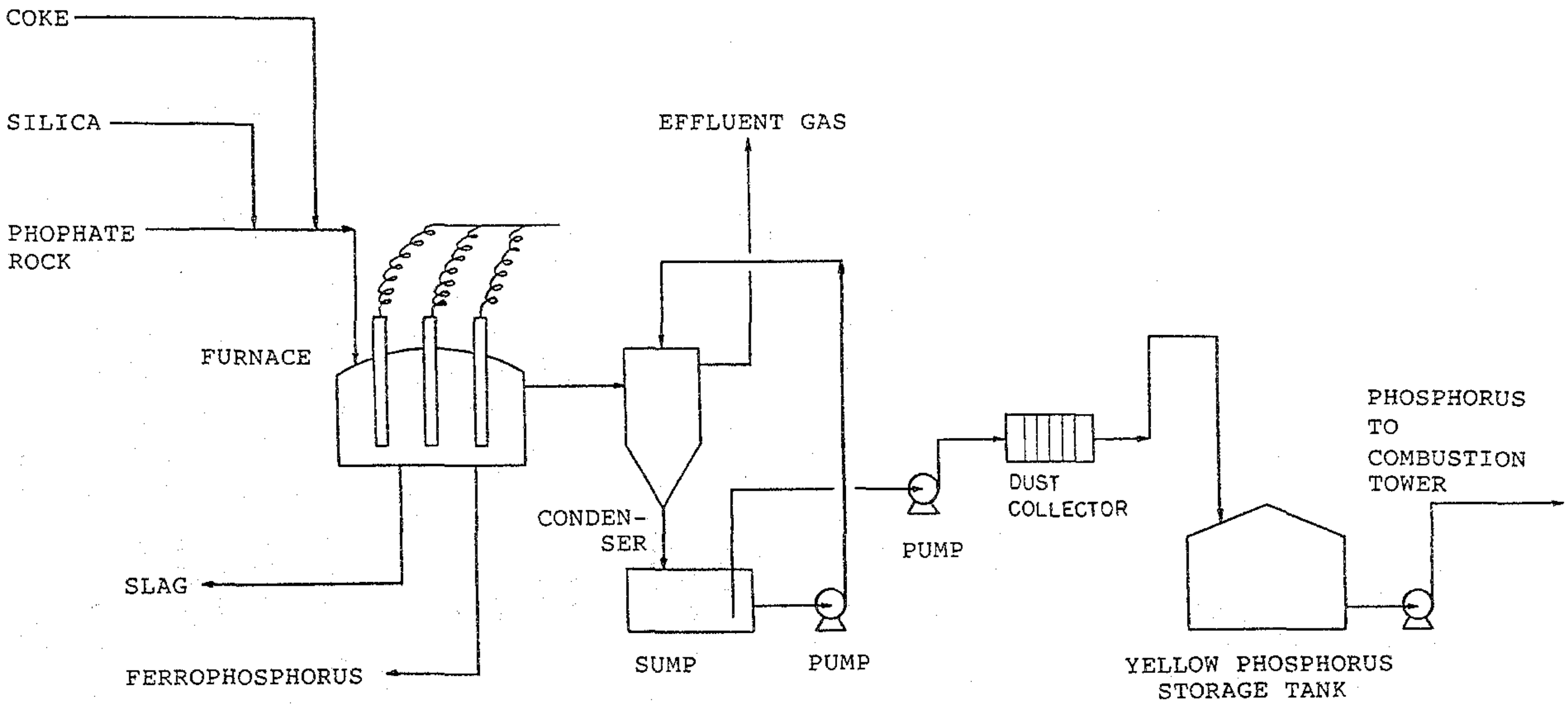


FIGURE 7-2-2

PHOSPHORIC ACID PLANT - ELECTRIC FURNACE PROCESS

FLOW SHEET - FURNACE SECTION

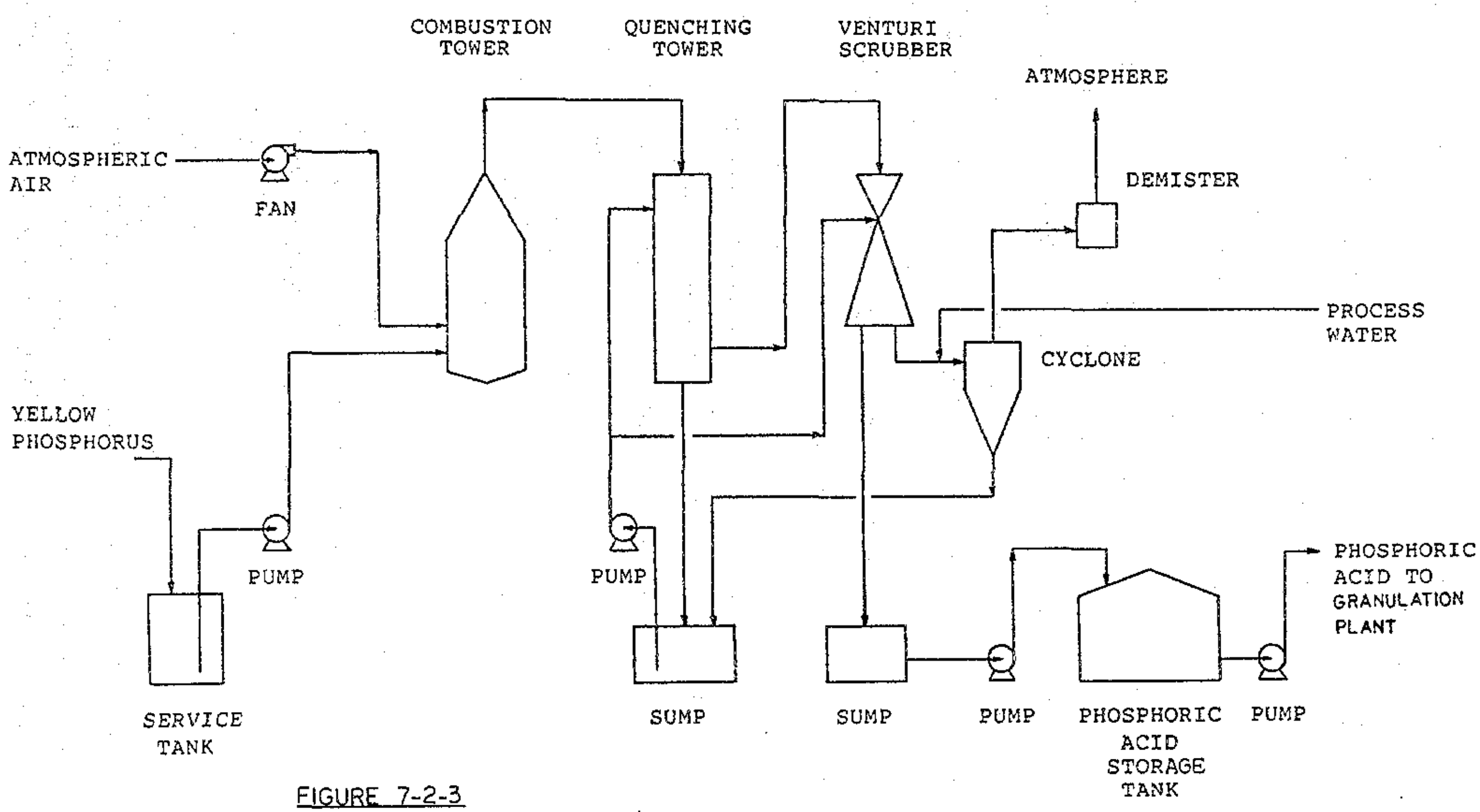


FIGURE 7-2-3

PHOSPHORIC ACID PLANT - ELECTRIC FURNACE PROCESS

FLOW SHEET - ACID PRODUCTION SECTION

The process involved is flow-sheeted in Figure 7-2-3. The yellow phosphorus is oxidized in a combustion tower to form phosphorus pentoxide gas, which is then passed through a quenching tower on into a venturi scrubber. In the venturi scrubber, gas is absorbed, and phosphoric acid, the raw material for fertilizer manufacture, is produced.

3) Fertilizer production using the slurry process

The process to be employed for manufacturing fertilizer from the phosphoric acid obtained as described above is essentially the slurry method developed in the U.S. by TVA. This method, which uses an ammoniator-granulator, is employed in Japan and throughout the world. Advantages are that the process can be adapted to production of a wide range of fertilizer types, and the resultant product is hard, well rounded and free flowing, with uniform composition and granule size.

The basic function of the Paraguayan fertilizer plant will be to use this TVA slurry process and an additional pipe-reactor system to produce DAP, NPK and TSP fertilizers. Figure 7-2-4 presents a flow sheet of the production process, which can be divided into the following five systems:

(1) slurry system
(2) granulation system
(3) handling of solid raw materials
(4) product cooling system
(5) dust collection and fume scrubbing system

(1) Slurry system

In manufacturing of DAP and NPK fertilizers, an ammonium phosphate slurry is produced through a chemical reaction between ammonia and phosphoric acid in a neutralizer tank, then transferred with a slurry pump to a granulator.

Most of the phosphoric acid is metered directly into the neutralizer tank, but a pre-determined portion is reserved for the scrubbers, where it is used to scrub ammonia gas out of the exhaust fumes from the granulator, dryer and the neutralizer tank. After further scrubbing with water, the exhaust fumes are released into the atmosphere and the removed ammonia recycled back into the neutralizer tank. The supply of ammonia is metered in pre-determined portions into the neutralizer tank and the granulator.

For manufacture of TSP fertilizer, the tank used for neutralization in DAP and NPK production changes function into a reactor tank, in which phosphate rock and phosphoric acid are reacted to produce a calcium phosphate slurry, which is then transferred to the granulator.

(2) Granulation system

The function of this system is to transform the slurry obtained from the chemical reaction into a granular fertilizer product of desired size and composition. In the granulator, slurry is sprayed onto a bed of undersized or crushed oversized granules, and the rotation of the granulator produces uniform, well rounded and layered granules.

The granulator also functions as an ammoniator. As the ammoniation reaction generates heat, moisture in the granules is evaporated in the granulator. This enhances the granulation process and also reduces the load on the dryer.

Inside the granulator, a counter-current air to the material flow is used to sweep up and remove the fumes and water vapor, which are then conducted to the scrubber for treatment along with exhaust gases from other equipment.

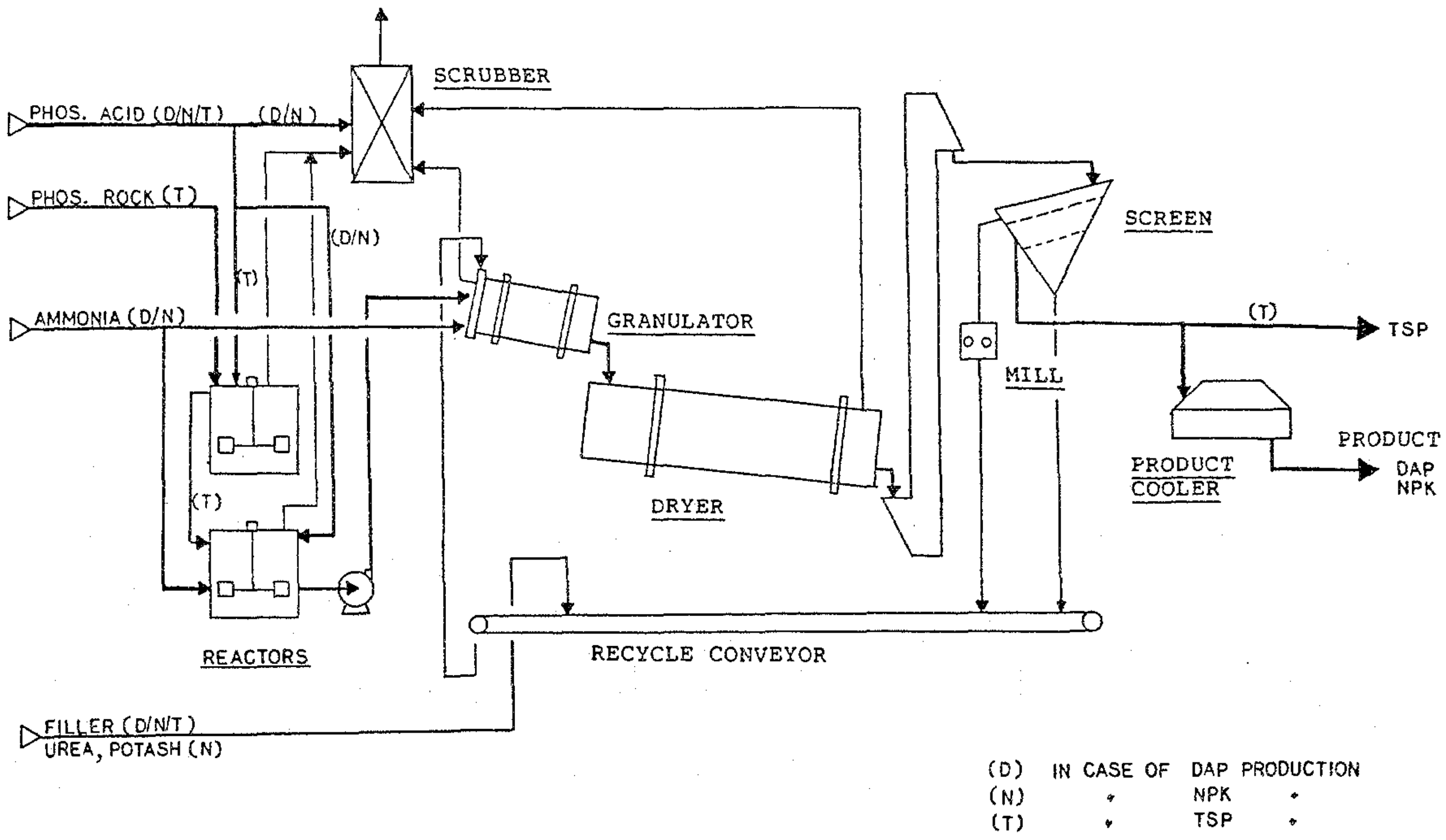


FIGURE 7-2-4 TYPICAL FLOW SHEET OF GRANULATION PLANT

The product granules leave the granulator through the grizzly bar at the end of the rotating drum, then move through the dryer feed chute into the dryer. Here the granules are dried by a co-current flow of hot air from the dryer furnace. Lumps are broken up as they pass through the revolving grizzly bar at the discharge end of the dryer.

From the dryer, the granules are lifted by an elevator and fed into the screen, where oversized granules are pulverized and recycled along with the undersized granules. In order to maintain a uniform recycling rate, some product-size granules are also sent from the hopper to the recycle conveyor via the recycle feeder. All these granules, as well as collected dust, are thus returned to the granulator. The recycle feeder controls the output of product indirectly, by adjusting the recycle flow rate at the recycle conveyor.

(3) Handling of solid raw materials

Raw material supply bins are provided to input filler, urea and potassium chloride, which are used as filler for adjustment of the product grade and also as raw material for production of NPK fertilizers. These solid raw materials are continuously measured by a gravimetric belt weigher and supplied to the recycle conveyor.

(4) Product cooling system

The product granules move from the screen into the product cooler, where they are cooled with ambient air supplied by the fan. TSP granules, however, bypass the product cooler and go directly to the storehouse.

(5) Dust collection and fume scrubbing system

Exhaust gases from the dryer, neutralizer tank (reactor tank in the case of TSP production) and the granulator contain quantities of ammonia and dust. The scrubber system is designed to remove this ammonia and dust, both for recovering purposes and to minimize their discharge into the atmosphere as an anti-pollution measure.

Exhaust fumes from the dryer are treated in a venturi type dryer-scrubber, while those from the neutralizer tank (reactor tank) and granulator are treated in a venturi type fume-scrubber. Following this, all exhaust gases are subsequently treated in a dust scrubber before release into the atmosphere.

A dust collection system is installed to maintain a dust-free environment within the plant. Dust from the mills, screen, belt conveyor and other sources is sucked up through a dust cyclone into the dust scrubber. Air discharged from the product cooler is also collected and scrubbed in this manner then discharged into the atmosphere. The dust collected in the dust cyclone is returned to the system along the recycle conveyor.

The scrubbing agent used in the dust scrubber is process water, while in the dryer-scrubber and fume-scrubber the agent (in case of DAP or NPK production) is a mixture of phosphoric acid and the liquid discharged from the dust scrubber. When TSP fertilizer is being produced, however, phosphoric acid is not used, and all scrubbing is done with water. After use, the scrubbing agent is supplied to the neutralizer tank. As a general principle, no process liquid effluent is=discharged from the plant under normal operating conditions.

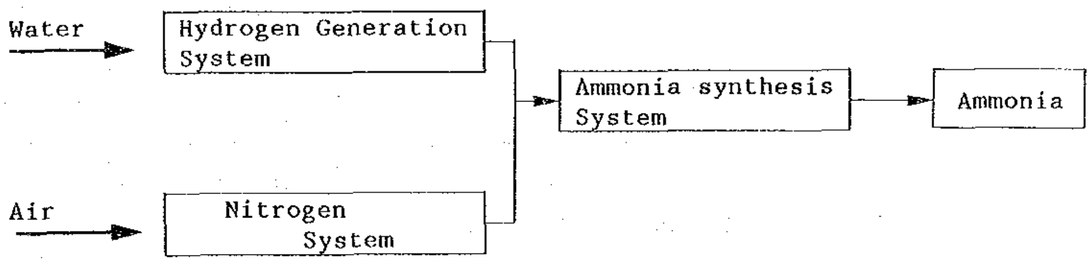
In the above system, most of the ammonia and fertilizer dust is collected by the dryer-scrubber and fume-scrubber, while the dust scrubber recovers fluorine compounds and smaller amounts of ammonia and dust.

7.2.2 Production Process for Ammonia (Scenario 2)

Scenario 2 shows the case of ammonia produced in the plant in parallel with phosphoric acid. As can be seen in Figure 7-1-1, the amount of ammonia needed for fertilizer production at the plant is 9,030 ton/yr. Some of the technical and economic aspects of ammonia production were discussed briefly in Section 6.4.4, and the following presentation builds on this information in outlining the process for producing this substance.

1) Production process

Ammonia production, diagrammed below, consists of a hydrogen generation system, a nitrogen system and an ammonia synthesis system



Ammonia Plant

The production process used commonly around the world involves obtaining hydrogen gas from a hydrocarbon such as natural gas, naphtha or fuel oil. The Paraguayan project, however, will make use of the abundant and inexpensive electric power to produce hydrogen from water electrolysis, then combine this with nitrogen generated by cryogenic process of ambient air to produce ammonia.

(1) The hydrogen generation system

This project would electrolyze water to form hydrogen gas, which is a basic raw material for production of ammonia compounds. The process to be employed is flow charted in Figure 7-2-5, and consists primarily of an electrolyzer. An alkaline water solution would be used as electrolyte in order to obtain oxygen and hydrogen gas.

The generated oxygen and hydrogen gas become mixed with the electrolyte, and each must be removed separately from the separator. First the electrolyte is separated out with a gas/liquid separator. As the temperature of this liquid is raised by heat generated during the electrolysis reaction, it must be cooled before being recycled back to the electrolyzer.

The oxygen and hydrogen gases, separated at gas/liquid separator, are scrubbed with water in separately installed gas scrubbing sections. The oxygen is then released into the atmosphere, and the hydrogen gas sent to the gas holder or directly to the ammonia systhesis system after eliminating alkalimist.

The electrolysis process employed in the hydrogen generation is based on Faraday's Law, explained in the following equation:

$$2H_2O + \text{Electricity } (96{,}500 \text{ coulomb}/1.008 \text{ g-}H_2) \rightarrow 2H_2 + O_2$$

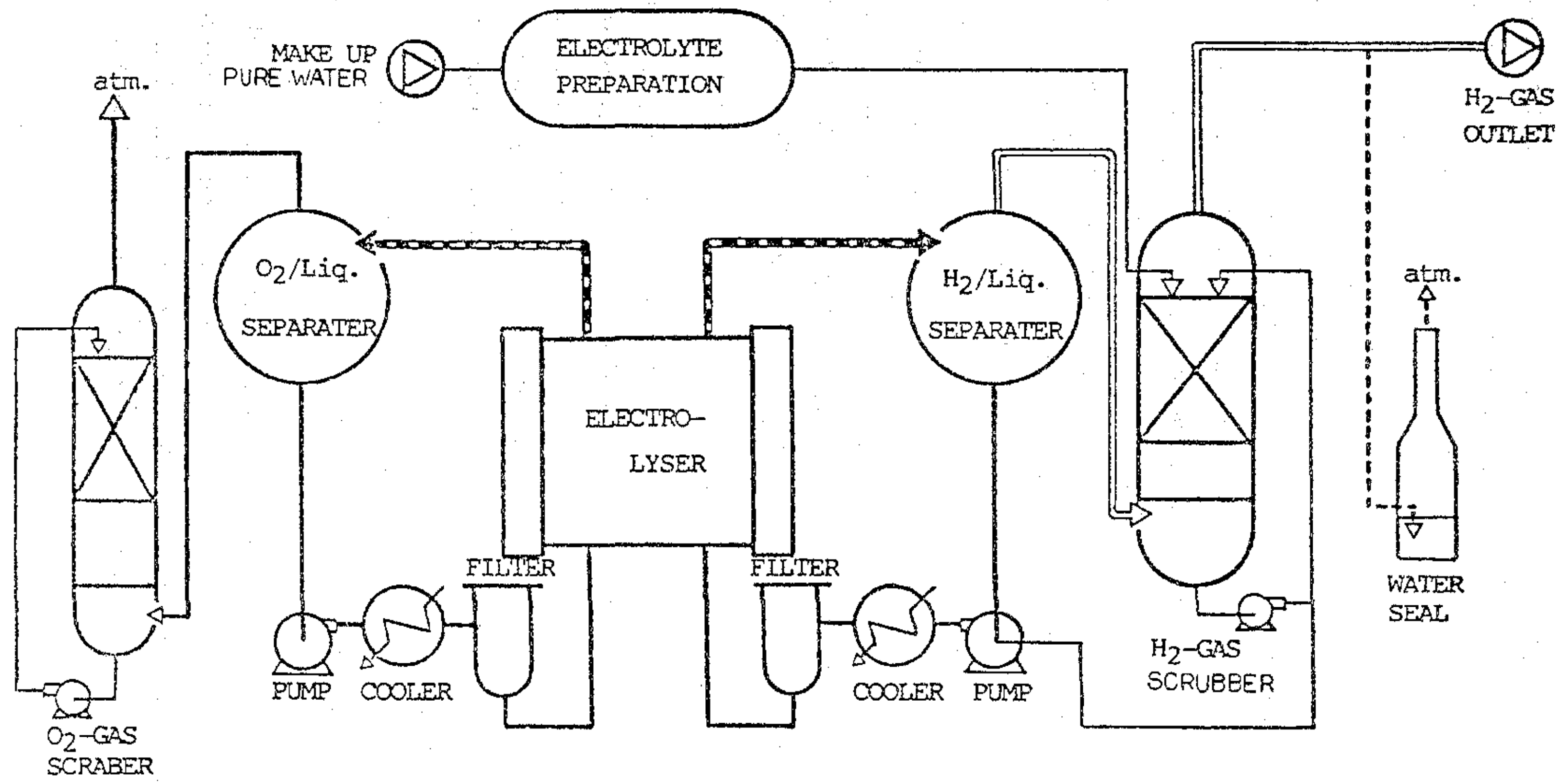


FIGURE 7-2-5 Flowsheet of Water Electrolysis Hydrogen Production System.

Operating conditions in the electrolyzer are temperature of 80-90°C, and 1.0-30 atm pressure. 25% caustic alkali water is used as the electrolyte, and the purity of the resultant gases is 99.7-99.9% for the hydrogen and 99.6% for oxygen.

2) The nitrogen system

As can be seen in Figure 7-2-6, nitrogen is separated from ambient air to produce high-purity nitrogen gas, which is another raw material in synthesis of ammonia. The air is first compressed to a pre-determined pressure in a air compressor, then scrubbed and cooled. Next, moisture and carbon dioxide are condensed and removed with a convertible heat exchanger.

Finally, the air is sent towards the bottom of the rectifier, where waste liquid containing oxygen collects on the bottom and is separated from the nitrogen gas, which rises and is removed from the top of the rectifier. The nitrogen gas is then warmed with a heat exchanger and sent to the gas holder or the ammonia synthesis system.

The liquid oxygen from the bottom of the rectifier is made to exchange heat with the nitrogen gas from the top of the rectifier in a condenser, then sent to an expander. Here the chilling necessary for the apparatus is generated under adiabatic expansion. The waste oxygen is finally released into the atmosphere.

3) The ammonia synthesis system

The ammonia synthesis system, flow charted in Figure 7-2-7, manufactures ammonia from the nitrogen and hydrogen gases obtained in the processes described above. The plant is composed chiefly of a compressor section and an ammonia synthesis section.

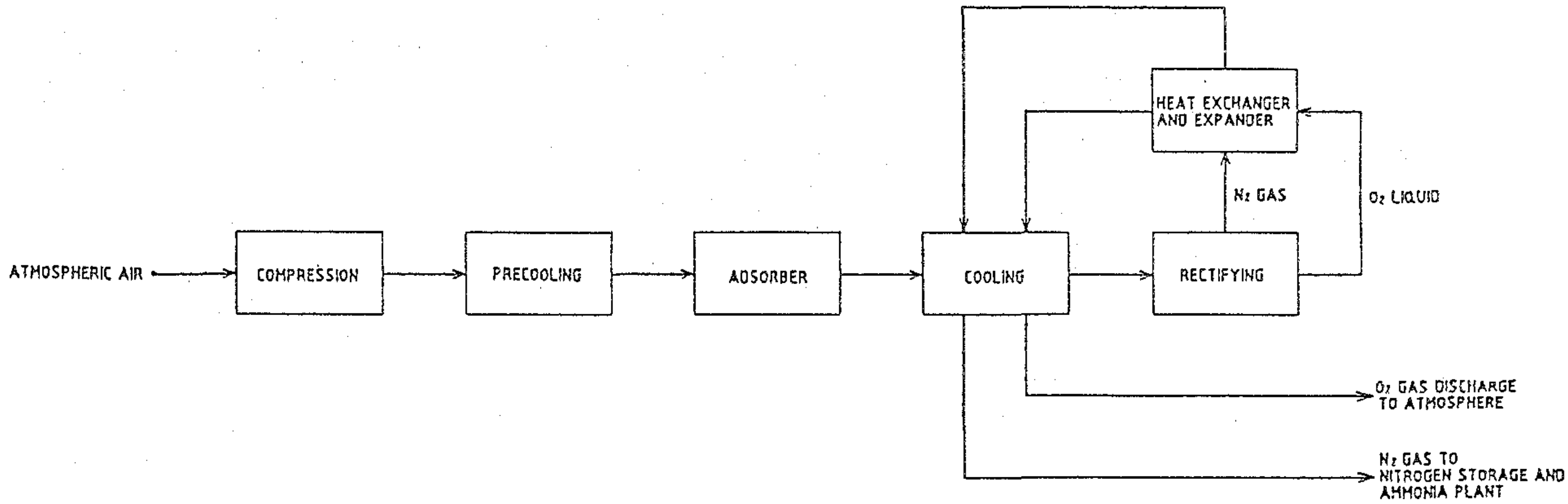


FIGURE 7-2-6 BLOCK DIAGRAM OF NITROGEN SYSTEM

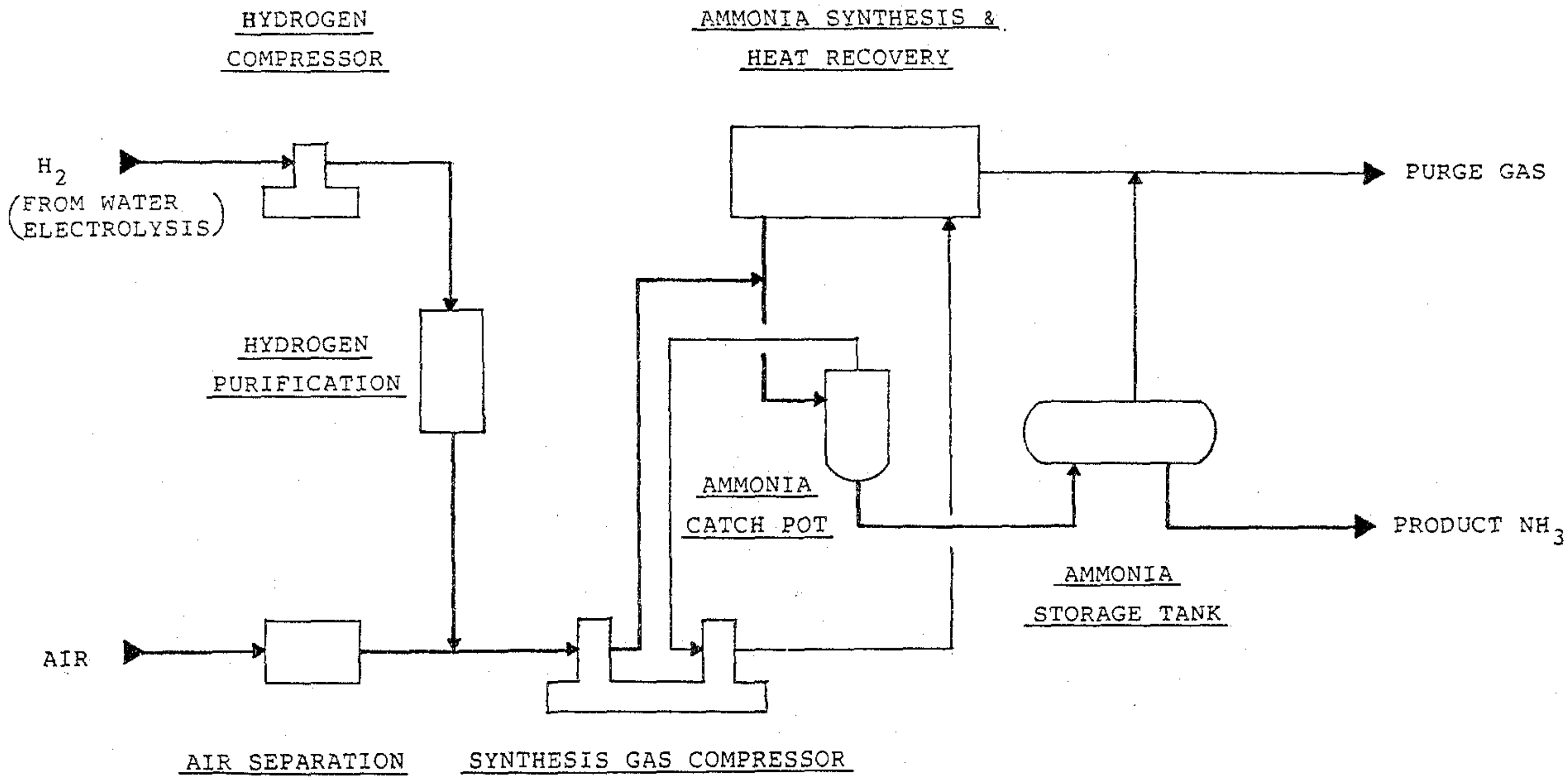


FIGURE 7-2-7 PROCESS FLOW SHEET OF AMMONIA SYNTHESIS SYSTEM

(1) Compressor section

Nitrogen and hydrogen gases are mixed in a mole ratio of 1:3, then pressurized to 310 ata in the compressor before being sent to a converter. The compressor is an electrically driven reciprocating type.

(2) Ammonia synthesis section

The pressurized synthesis gas passes through a gas/liquid separator and on into the converter. Here a catalyst is present, and the nitrogen and hydrogen gases combine according to the chemical reaction equation listed below to form ammonia gas. This gas then leaves the converter and enters a heat-recovery boiler, where heat is removed and the gas cooled down to a liquid state. The liquid ammonia is further purged of remaining gases in a gas/liquid separator and through a letdown process. The resultant product liquid ammonia is then sent to the ammonia storage tank.

The chemical reaction for producing ammonia is $3H_2+N_2=2NH_3$, which occurs at 310 ata pressure and 400°C temperature.

7.2.3 Production Process for Fused Magnesium Phosphate (Scenario 3)

Fused magnesium phosphate (FMP) is a type of phosphate fertilizer developed in Japan and manufactured since 1950. Since then, FMP technology has been introduced from Japan to Korea and Brazil, and plants are now in operation in these countries as well. Production of FMP fertilizers involves fusing phosphate rock with serpentine or olivine in an open hearth or electric furnace. The resultant mixture is quenched rapidly with water, and a greenish colored and sandy textured material, which actually has properties similar to glass, is produced.

In the Paraguayan fertilizer project, the phosphate rock would be fused with electricity in an electric furnace. The process, which is flow charted in Figure 7-2-8, consists of the following seven sections.

1) raw material preparation section
2) fusing section
3) quenching section
4) water separation section
5) drying section
6) screening and crushing section
7) exhaust gas scrubbing section

1) Raw material preparation section

Phosphate rock and serpentine (or olivine) are adjusted to the proper granule size, if necessary, and measured, mixed, then inputed into the electric furnace.

2) Fusing section

The temperature at which the raw materials are fused varies slightly with their composition, but usually fluctuates between 1,300 and 1,350°C. Using electric power, however, brings the temperature inside the furnace up to 1,450°C at actual operation. Thermal efficiency of the furnace depend on such factors as type, capacity and operation procedures, but usually works out to approximately 35% for open hearths and 60% for electric furnace.

3) Quenching section

The fused material is placed in rapidly-circulating water and quenched quickly. Sufficient quenching is necessary to produce FMP with a high content of citric soluble P_2O_5.

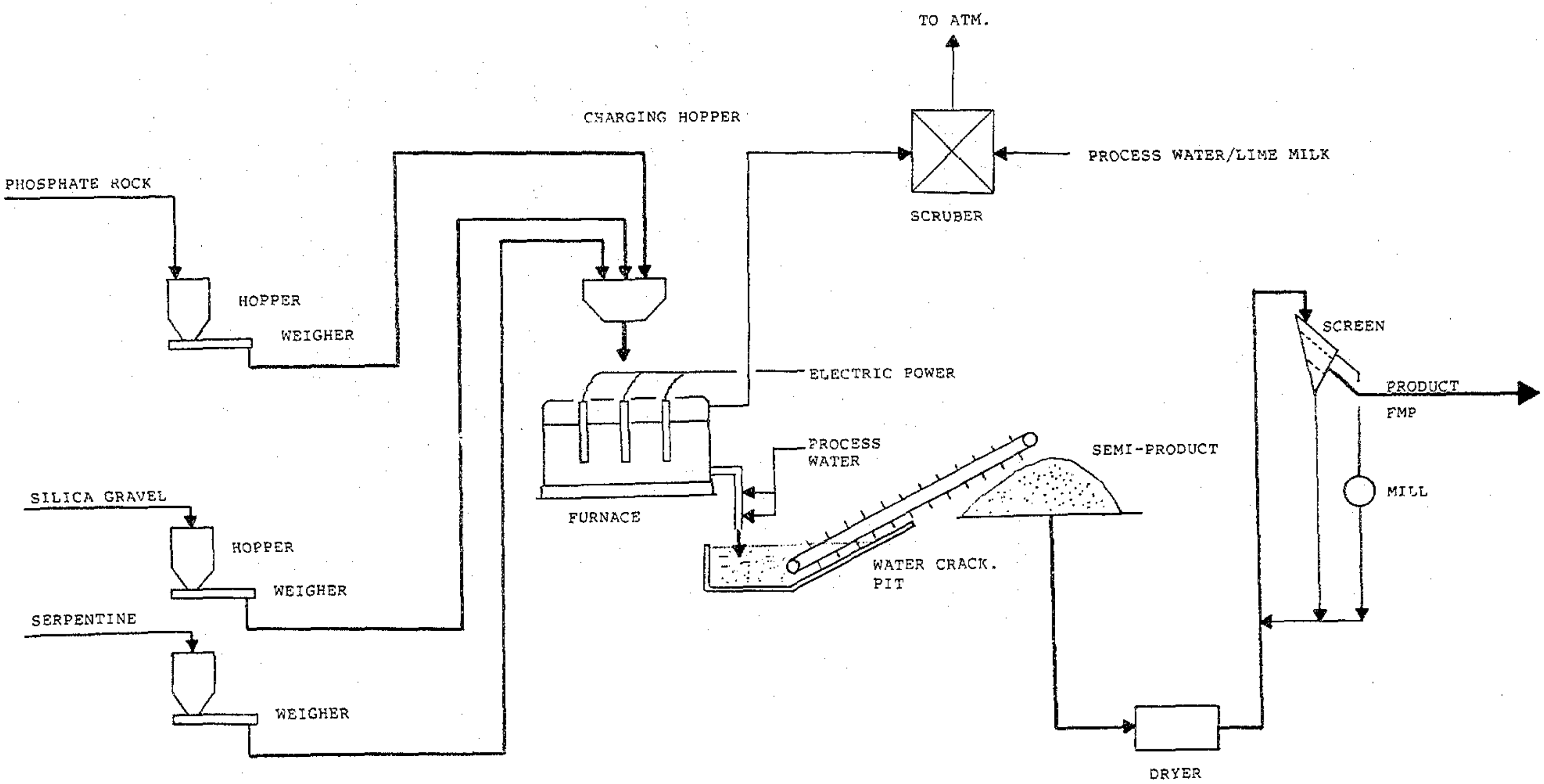


FIGURE 7-2-8 TYPICAL FLOW SHEET OF FMP PLANT

4) Water separation section

After quenching, the resultant semi-product must be separated from the water. One method is to remove the semi-product directly from the cooling pit via a drag belt conveyor. The semi-product removed in this fashion generally contains 20~30% water, but this percentage will eventually decrease to 5% while stacked in the storage yard.

5) Drying section

The semi-product next moves to the dryer, where drying is accomplished with hot air generated by combustion of fuel oil. At this stage, the temperature of the semi-product must not be allowed to exceed 500°C, or the phosphoric acid and other components will form into fluoapatite, resulting in a loss of citric soluble P_2O_5.

6) Screening and crushing section

The dried semi-product is adjusted by screening and becomes the final product. The adjustment of size is conducted by passing through a screen. The product which passes through the screen becomes the final product, while over size granules are sent to a crusher, broken up, and returned to the screen.

7) Exhaust gas scrubbing section

The exhaust gas from the electric furnace contains fluorine-compound that originate in phosphate rock, is scrubebd with lime mik and water and then release into the atmosphere.

7.2.4 Equipment List

Main equipment for each plants are summarized in Table 7-2-1 as for reference.

Table 7-2-1 Equipment List

(1) Phosphoric Acid Plant (#1000)

(a) Raw Material Preparation Section

Item No.	Name	Q'ty	Type	Material
B1101	Pneumatic Air Fan	1	Turbo	C.S.
B1103	Kiln Exhaust Gas Fan	1	Turbo	C.S.
B1105	Kiln Cooling Fan	1	Turbo	C.S.
B1107	Emergency Cooling Fan	1	Turbo	C.S.
C1101	P. Rock Bucket Elevator	1	Bucket	C.S.
C1103	Feed Elevator	1	Bucket	C.S.
C1105	Granulator Feed Conveyor	1	Belt	C.S./Rubber
C1106	Screen Feed Conveyor	1	Belt	C.S./Rubber
C1109	Dryer Feed Conveyor	1	Belt	C.S./Rubber
C1110	Kiln Feed Conveyor	1	Belt	C.S./Rubber
C1113	P.Rock Pellet Conveyor	1	Belt	C.S./Rubber
C1115	Cokes Receiving Conveyor	1	Belt	C.S./Rubber
C1116	Cokes Elevator	1	Bucket	C.S.
C1117	O.S Cokes Conveyor	1	Belt	C.S./Rubber
C1118	Silica Gravel Receiving Conveyor	1	Belt	C.S./Rubber

Item No.	Name	Q'ty	Type	Material
C1119	Silica Gravel Elevator	1	Bucket	C.S.
C1120	O.S Gravel Conveyor	1	Belt	C.S./Rubber
C1121	Mixing conveyor	1	Belt	C.S./Rubber
C1122	Mixed Materials Conveyor	1	Belt	C.S./Rubber
C1123	Feed Conveyor	1	Belt	C.S./Rubber
C1124	P. Rock Conveyor	1	Belt	C.S./Rubber
D1101	P. Rock Chute	1	Rectangular	C.S.
D1102	Calcined Material Silo	1	Vertical, Cylindrical	C.S.
D1103	Cyclone	1	Vertical	C.S.
D1104	P. Rock Powder Silo	1	Cylindrical	C.S.
D1105	P. Rock Pellet Silo	1	Cylindrical	C.S.
D1106	Exhaust Gas Cyclone	1	Vertical	C.S.
D1107	Oil Service Tank	1	Vertical	C.S.
D1108	Water Service Tank	1	Vertical	C.S.
D1109A/B	Binder Tank	2	Vertical	C.S.
D1110	Cokes Chute	1	Rectangular	C.S.
D1111	Cokes Hopper	1	Cylindrical	C.S.
D1112	Cokes Hopper	1	Cylindrical	C.S.
D1113	Silica Gravel Chute	1	Rectangular	C.S.
D1114	Silica Hopper	1	Cylindrical	C.S.
D1115	Silica Hopper	1	Cylindrical	C.S
E1101	Contact Cooler	1	Vertical	C.S./Brick

Item No.	Name	Q'ty	Type	Material
F1101	P. Rock Bag Filter	1	Bag	C.S.
F1102	P. Rock Screen	1	Rotary	C.S.
F1103	P. Rock Pellet Screen	1	Vibrating	C.S.
F1104	Bag Filter	1	Bag	C.S.
F1105	Cokes Screen	1	Vibrating	C.S.
F1106	Cokes Dryer Bag Filter	1	Bag	C.S.
F1107	Silica Gravel Screen	1	Vibrating	C.S.
F1108	Silica Dryer Bag Filter	1	Bag	C.S.
F1109	Mixed Material Bag Filter	1	Bag	C.S.
H1101	Band Dryer	1	Band	C.S./Brick
H1102	Rotary Kiln	1	Rotary	C.S.
H1103	Cokes Dryer	1	Rotary	C.S.
H1104	Silica Gravel Dryer	1	Rotary	C.S.
M1101	P. Rock Feeder	1	Belt	C.S.
M1102	P. Rock Weigh Feeder	1	Belt	C.S./Rubber
M1103	Fine Rock Feeder	1	Belt	C.S./Rubber
M1104	P. Rock Pelletizer	1	Pan	C.S.
M1105	Pellet Extractor	1	Vibrating	C.S.
M1106	Cokes Feeder	1	Belt	C.S.
M1107	Silica Gravel Feeder	1	Belt	C.S./Rubber
M1108	P. Rock Pellet Feeder	1	Belt	C.S./Rubber
M1109	Cokes Weigher	1	Belt	C.S./Rubber
M1110	Silica Gravel Weigher	1	Belt	C.S./Rubber

Item No.	Name	Q'ty	Type	Material
P1101	Water Pump	1	Centri.	C.S./Rubber
P1102	Binder Pump	1	Centri.	C.S./Rubber
Q1101	Mill	1	Roller	C.S.
Q1102	Pug Mill	1	Pug	C.S.
Q1103	Ball Mill	1	Wet	C.S.

(b) Furnace Section

Item No.	Name	Q'ty	Type	Material
D1201	Furnace Over Head Hopper	1	Cylindrical	C.S.
D1202	Condenser	1	Spray	316L S.S.
D1203	Condenser	1	Spray	316L S.S.
D1204	Condenser	1	Spray	316L S.S.
D1205	Hot Water Tank	1	Cylindrical	C.S.
D1206	Hot Water Tank	1	Cylindrical	C.S.
D1207	Condenser Seal Pit	1	Square	Concrete
F1201	Furnace Bag Filter	1	Bag	C.S.
H1201	Electric Furnace	1	Electric	Graphite
M1201	Electrod Driver	1	-	-
M1202	Tapping Machine	1	Air Hummer	-
M1203	Dust Collector	1	E.P	-
M1204	No.1 Hoist	1	Manual	C.S.
M1205	No.2 Hoist	1	Manual	C.S.
M1206	No.3 Hoist	1	Manual	C.S.

Item No.	Name	Q'ty	Type	Material
P1201A/B	Phosphorus Pump	1+1	Vertical	316L SS
P1202	Insulation Pump	1	Centri.	C.I.
P1203	Water Cracking Pump	1	Centri.	C.I.
P1204	Slurry Pumps	1	Centri.	C.I.
P1205	Cooling Pump	1	Centri.	C.I.
P1206A/B	Condenser Pump	1+1	Centri.	316L SS
P1207	Hot Water Pump	1	Centri.	C.I.
TK1201	Phosphorus Storage Tank	1	Cylindrical	316L
Z1201	Vacuum Pump	1	Nush	316SS

(c) Acid Production Section

Item No.	Name	Q'ty	Type	Material
B1301	Combustion Fan	1	Turbo	C.S.
B1302	Air Spray Compressor	1	Recipro.	C.I.
B1303	Exhaust Gas Fan	1	Turbo	C.S.
D1301	Air Holder	1	Cylindrical	C.S.
D1302A/C	Cyclone	3	Vertical	C.S.
D1303	Demister	1	-	-
D1304	Weak Acid Tank	1	Cylindrical	316L SS
D1305	Conc Acid Tank	1	Cylindrical	316L SS
D1306A/B	Acid Preparation Tank	2	Cylindrical	316L SS
D1307A/B	Hot Water Discharge Tank	2	Cylindrical	C.S.

Item No.	Name	Q'ty	Type	Material
E1301	Air Refrigerator	1	Centri	C.S.
E1302A/C	Acid Cooler	3	Shell & Tube	Carbon Graphite
J1301A/B	Venturi Scrubber	3	Venturi	Graphite
P1301	Phosphorus Feed Pump	1	Diaphragm	316 SS Rubber
P1302	Weak Acid Circ. Pump	1	Centri.	C.I/Rubber
P1303	Conc Acid Pump	1	Centri.	C.I/Rubber
P1304A/B	Product Acid Fump	1+1	Centri.	C.I/Rubber
P1305A/B	Water Discharge Pump	1+1	Centri.	C.I.
P1306	Acid Transfer Pump	1	Centri	C.I.
T1301	Combustion Tower	1	Vertical	316L SS
T1302	Cooling Tower	1	Cylindrical	C.S/carbon
TK1301	Product Acid Storage Tank	1	Cylindrical	316L SS

(d) Gas Washing Facility

Item No.	Name	Q'ty	Type	Material
B1401	Furnace Gas Exhaust Fan	1	Turbo	C.S.
B1411	Pit Gas Exhaust Fan	1	Turbo	C.S.
D1401	Over Head Hood	1	Square	C.S.
D1402	No.1 Mist Collector	1	Rectangular	C.S.
D1403	No.2 Mist Collector	1	Cylindrical	Plastic
D1404	Lime Milk Tank	1	Cylindrical	C.S.

Item No.	Name	Q'ty	Type	Material
D1411	Pit Gas Hood	1	Square	C.S.
D1412	Pit Gas No.1 Mist Collector	1	Packed Tower	C.S.
D1413	Pit Gas No.2 Mist Colector	1	Packed Tower	C.S.
P1401A/B	Furnace Gas Wash Pump	1+1	Centri.	C.I/Rubber
P1411	Pit Gas Wash Pump	1	Centri.	C.I/Rubber
T1401	Stack	1	-	C.S.
Z1401	Furnace Gas Venturi	1	Venturi	C.S.
Z1402	Furnace Gas Venturi	1	Venturi	C.S.
Z1411	Pit Gas Venturi	1	Venturi	C.S.
Z1412	Pit Gas Venturi	1	Venturi	C.S.

(e) Waste Water Treatment Facility

Item No.	Name	Q'ty	Type	Material
CL1501	Thickener	1	-	Concrete
D1501	NaCℓO Tank	1	Cylindrical	C.S.
D1502	Mixing Tank	1	Cylindrical	C.S.
D1503	Lime Milk Tank	1	Cylindrical	C.S.
D1504	Neutralizer	1	Cylindrical	C.S.
D1510	Dilution Pit	1	Square	Concrete
F1501	Filter Press	1	-	C.S.

Item No.	Name	Q'ty	Type	Material
M1501	Reactor Tank Agitator	1	Propeller	C.S.
M1502	Lime Milk Tank Agitator	1	Paddle	C.S.
M1503	Neutralizer Agitator	1	Paddle	C.S.
M1504	Rake	1	Center Drive	C.S.
P1501	NaCℓO Pump	1	Diaphragm	C.I/Rubber
P1502	Neutralizer Feed Pump	1	Centri.	C.I/Rubber
P1503	Lime Milk Pump	1	Centri.	C.I/Rubber
P1504	Thickener Feed Pump	1	Centri.	C.I/Rubber
P1505	Sludge Pump	1	Centri.	C.I/Rubber
P1506	Dilution Water Pump	1	Centri.	C.I.

(f) CO Gas Scrubbing Facility

Item No.	Name	Q'ty	Type	Material
B1601	Oxidation Tower Compressor	1	Screw	C.I.
D1601	Pressure Precipitater	1	Cylindrical	C.S.
D1602	Brine Tank	1	Cylindrical	C.S.
D1603	Gas Stripper	1	Cylindrical	C.S.
D1604	Drain Receiver	1	Cylindrical	C.S.
D1605	Air Receiver	1	Cylindrical	C.S.
D1606	NaOH Tank	1	Cylindrical	C.S.
D1607	NaCℓO Tank	1	Cylindrical	C.S.

Item No.	Name	Q'ty	Type	Material
D1608	Reagent Tank	1	Cylindrical	C.S.
D1609	Collection Tank	1	Cylindrical	C.S.
E1601A/B	Wash Water Cooler	2	Shell/Tube	C.S.
E1602	Refrigerator	1	-	C.S.
F1601	Filter Press	1	-	C.S.
P1601A/B	Wash Tower Cir. Pump	1+1	Centri.	C.I.
P1602A/B	Brine Cir. Pump	1+1	Centri.	C.I.
P1603A/B	Cooling Tower Pump	1+1	Centri.	C.I.
P1604A/F	Absorbing Tower Pump	4+2	Centri.	C.I.
P1605	Filter Press Feed Pump	1	Centri.	C.I.
P1606	Oxidation Tower Pump	1	Centri.	C.I.
P1607	Reagent Pump	1	Centri.	C.I.
P1608	Brine Feed Pump	1	Centri.	C.I.
P1609A/B	NaOH Pump	1+1	Centri.	C.I.
P1610	$NaC\ell O$ Pump	1	Centri.	C.I.
TK1601	CO Gas Holder	1	Floating Head	C.S.
T1601	Washing Tower	1	Spray	304L SS
T1602	Cooling Tower	1	Draft	PVC
T1603	Burner for Stack	1	-	-
T1604	H_2S Absorber	1	Cylindrical	C.S/Wood
T1605	Oxidation Tower	1	Bubbling	C.S.
T1606	Spray Absorber	1	Spray	Plastic
T1607	$C\ell_2$ Absorber	1	Spray	C.S.

(2) Granulation Plant (#2000)

(a) Slurry System

Item No.	Name	Q'ty	Type	Material
C2101	P. Rock Conveyor	1	Belt	C.S/Rubber
C2102	P. Rock Elevator	1	Bucket	C.S.
D2101	P. Rock Hopper	1	Rectangular	C.S.
D2102	Head Tank	1	Rectangular	316L SS
D2103	Reactor	1	Cylindrical	316L SS
D2104	Neutralizer	1	Cylindrical	316L SS
M2101	P. Rock Feeder	1	Belt	C.S./Rubber
M2102	Reactor Agitator	1	Paddle	316L SS
M2103	Neutralizer Agitator	1	Piched Impeller	316L SS
P2101A/B	Slurry Pump	1+1	Centri.	316L SS

(b) Granulation and Product Cooling System

Item No.	Name	Q'ty	Type	Material
B2201	Primary Air Fan	1	Turbo	C.S.
B2202	Secondary Air Fan	1	Turbo	C.S.
C2201	Screen Feed Elevator	1	Bucket	C.S.
C2202	Rcycle Conveyor	1	Belt (Closed)	C.S.
C2203	Recycle Elevator	1	Bucket	C.S.
C2204	Product Conveyor	1	Belt	C.S/Rubber
C2205	Product Conveyor	1	Belt	C.S/Rubber

Item No.	Name	Q'ty	Type	Material
C2206	Product Elevator	1	Bucket	C.S.
D2201	O.S Screen Hopper	1	Rectangular	C.S.
D2202	U.S Screen Hopper	1	Rectangular	C.S.
D2203	Product Hopper	1	Rectangular	C.S.
D2204	Dryer Cyclone	1	Vertical	C.S.
D2205	Dust Cyclone	1	Vertical	C.S.
E2201	Combustion Chamber	1	Oil Burning	C.S/Brick
F2201	O.S. Screen	1	Vibrating	C.S.
F2202	Product Screen	1	Vibrating	C.S.
M2201	Granulator	1	Rotary	C.S.
M2202	Dryer	1	Rotary	C.S.
M2203	O.S Mill	1	Chain	C.S.
M2204	Cooler	1	Rotary	C.S.
M2205	Product Scale	1	Belt	C.S/Rubber
M2206	Recycle Conveyor Feeder	1	Vibrating	C.S.
M2207	Coater	1	Screw	C.S.
R2201	Pipe Reactor	1	Pipe	Special Alloy

(c) Solid Raw Material Handling

Item No.	Name	Q'ty	Type	Material
B2301	Bag Filter Fan	1	Turbo	C.S.
C2301	Coating Agent Elevator	1	Hoist	C.S.
C2302	Solid Material Elevator	1	Bucket	C.S.
C2303	Solid Material Conveyor	1	Belt	C.S/Rubber
D2301	Solid Material Hopper	1	Rectangular	C.S.
D2302	Potash Bin	1	Rectangular	C.S.
D2303	Urea Bin	1	Rectangular	C.S.
D2304	Filler Bin	1	Rectangular	C.S.
D2305	Coating Agent Hopper	1	Rectangular	C.S.
D2306	Coating Oil Tank	1	Rectangular	C.S.
F2301	Bag Filter	1	Bag	C.S.
M2302	Potash Feeder	1	Belt	C.S/Rubber
M2303	Urea Feeder	1	Belt	C.S/Rubber
M2304	Filler Feeder	1	Belt	C.S/Rubber
M2305	Coating Agent Feeder	1	Screw	C.S.
P2301	Coating Oil Pump	1	Gear	C.I.

(d) Dust Collection and Fume Scrubbing System

Item No.	Name	Q'ty	Type	Material
B2401	Fume Scrubber Fan	1	Turbo	316 SS
B2402	Dryer Scrubber Fan	1	Turbo	316 SS
B2403	Dust Fan	1	Turbo	C.S.
D2401	Fume Scrubber Tank	1	Cylindrical	C.S + Rubber
D2402	Proces Sump	1	Square	Concrete/Brick
J2401	Fume Scrubber	1	Venturi	316L SS
J2402	Dryer Scrubber	1	Venturi	316L SS
J2403	Dust Scrubber	1	Spray	C.S + Rubber
M2401	Sump Agitator	1	Paddle	316L SS
P2401	Fume Scrubber Pump	1	Centri	316 SS
P2402	Dust Scrubber Pump	1	Centri	C.I/Rubber
P2403	Sump Pump	1	Vertical	316 SS
P2404	Sludge Pump	1	Centri	316 SS

(3) Fused Magnesium Phosphate Plant (#3000)

(a) Raw Material Preparation Section

Item No.	Name	Q'ty	Type	Material
C3101	No.1 P. Rock Conveyor	1	Belt	C.S/Rubber
C3102	No.1 Silica Gravel Conveyor	1	Belt	C.S/Rubber
C3103	No.2 Silica Gravel Conveyor	1	Belt	C.S/Rubber
C3114	No.1 Serpentine Conveyor	1	Belt	C.S/Rubber

Item No.	Name	Q'ty	Type	Material
C3115	No.2 Serpentine Conveyor	1	Belt	C.S/Rubber
D3101	P. Rock Hopper	1	Rectangular	C.S.
D3102	Silica Gravel Hopper	1	Rectangular	C.S.
D3103	Serpentine Hopper	1	Rectangular	C.S.
D3104	Mixing Hopper	1	Rectangular	C.S.
M3101	P. Rock Feeder	1	Vibrating	C.S.
M3102	P. Rock Weigher	1	Belt	C.S/Rubber
M3103	Silica Gravel Feeder	1	Vibrating	C.S
M3104	Silica Gravel Weigher	1	Belt	C.S/Rubber
M3105	Serpentine Feeder	1	Vibrating	C.S.
M3106	Serpentine Weigher	1	Belt	C.S/Rubber

(b) Fushing Section

Item No.	Name	Q'ty	Type	Material
C3201	No.1 Furnace Feed Conveyor	1	Belt	C.S/Rubber
C3202	No.2 Furnace Feed Conveyor	1	Belt	C.S/Rubber
C3203	Furnace Feed Elevator	1	Bucket	C.S.
C3204	Hopper Feed Conveyor	1	Belt	C.S/Rubber
D3201	Furnace Over Head Hopper	1	Rectangular	C.S.
F3201	Furnace Dust Filter	1	Bag	C.S.

Item No.	Name	Q'ty	Type	Material
H3201	Electric Furnace	1	Electric.	Graphite
M3201	Electrod Driver	1	-	-
M3202	No.1 Hoist	1	Manual	C.S.
M3203	No.2 Hoist	1	Manual	C.S.

(c) Quenching Section

Item No.	Name	Q'ty	Type	Material
C3301	Drag Conveyor	1	Flight	C.S.
C3302	Semi-Product Conveyor	1	Belt	C.S/Rubber
D3301	Water Cracking Pit	1	Rectangular	Concrete
D3302	Quenching Pit	1	Rectangular	Concrete
D3303	Water Sump	1	Rectangular	Concrete
P3301A/B	Quenching Water Pump	1+1	Centri	C.S.

(d) Water Separation and Drying Section

Item No.	Name	Q'ty	Type	Material
B3401	Dryer Fan	1	Turbo	C.S.
B3402	Primary Air Fan	1	Turbo	C.S.
B3403	Secondary Air Fan	1	Turbo	C.S.
C3401	Wet Product Conveyor	1	Belt	C.S/Rubber
C3402	Wet Product Elevator	1	Bucket	C.S.
C3403	Dryer Discharge Elevator	1	Bucket	C.S.

Item No.	Name	Q'ty	Type	Material
C3404	Screen Feed Conveyor	1	Belt	C.S/Rubber
C3405	Return Conveyor	1	Belt	C.S/Rubber
C3406	No.1 Product Conveyor	1	Belt	C.S/Rubber
C3407	No.2 Product Conveyor	1	Belt	C.S/Rubber
D3401	Wet Product Hopper	1	Rectangular	C.S.
D3402	Wet Product Silo	1	Cylindrical	C.S.
D3403	Screen Hopper	1	Rectangular	C.S.
D3404	Oil Service Tank	1	Cylindrical	C.S.
D3405	Dryer Cyclone	1	Vertical	C.S.
E3401	Furnace	1	Oil Burning	C.S/Brick
F3401	Bag Filter	1	Bag	C.S.
F3402	Product Screeen	1	Vibrating	C.S.
M3401	Vibrating Feeder	1	Vibrating	C.S.
M3402	Dryer	1	Rotary	C.S.
M3403	Mill	1	Roller	C.S.
M3409	Product Scale	1	Belt	C.S/Belt

(e) Waste Gas Scrubbing Section

Item No.	Name	Q'ty	Type	Material
B3501	Furnace Gas Exhaust Fan	1	Turbo	C.S.
D3501	Over Head Hood	1	Square	C.S.

Item No.	Name	Q'ty	Type	Material
D3504	Lime Milk Tank	1	Cylindrical	C.S.
P3501A/B	Furnace Gas Wash Pump	1+1	Centri	C.I/Rubber
T3501	Stack	1	-	C.S.
Z3501	Furnace Gas Venturi	1	-	C.S.

(5) Waste Water treatment Facility

Refer to (1), (2)

Note: C.S : Carbon Steel

C.I : Cast Iron

SS : Stainless Steel

(6) Ammonia Plant

(a) Water Electrolysis Hydrogen Production System

Item No.	Name	Q'ty	Type	Material
E4101	H_2-Liq. Cooler	1	Shell & Tube	316LSS
E4102	H_2-Gas Cooler	1	Shell & Tube	304 SS
E4103	O_2-Liq. Cooler	1	Shell & Tube	Ni-Alloy
E4104	O_2-Gas Cooler	1	Shell & Tube	304 SS
F4101	H_2-Liq. Separator	1	Cylindrical	316LSS
F4102	H_2 Filter	1	-	316LSS
F4103A/B	O_2-Liq. Separator	1+1	Cylindrical	316LSS
F4104	O_2 Filter	1	-	316LSS
F4105	Mist Separator	1	-	304 SS
J4101	H_2 Gas Scrubber	1	Packed	304SS
J4102	O_2 Gas Scrubber	1	Packed	304SS
M4101	Hoist	1	Motor Drive	C.S.
P4101	H_2-Liq. Pump	1	Centri	316SS
P4102	H_2 Gas Scrubber Pump	1	Centri	316SS
P4103	O_2 Liq. Pump	1	Centri	316SS
P4104	O_2 Gas Scrubber Pump	1	Centri	316SS

Item No.	Name	Q'ty	Type	Material
Z4101A/H	Electrolster	8	Filter Press	-
Z4102	Dosing Unit	1	-	-
Z4103	H_2 Gas Sealer	1	Cylindrical	C.S.
Z4104	Cooling Tower	1	Air Draft	C.S. Wood

(b) Ammonia Synthesis

Item No.	Name	Q'ty	Type	Material
B4221	Hydrogen Compressor	1	Recipro.	
B4202	Nitrogen Compressor	1	Recipro.	
B4203	Syngas Compressor & Circulator	1	Recipro.	
E4201	H_2 Gas Cooler	1	Shell & Tube	C.S.
E4202	BFW Heater	1	U-Tube	C.S.
E4203	Ammonia Cooler	1	U-Tube	C.S.
E4204	Dearator Heater	1	U-Tube	C.S.
E4205	Syngas After Cooler	1	Shell & Tube	C.S.
E4206	Condenser	1	U-Tube	C.S.
P4201A/B	BFW Pump	1+1	Centri	C.S./C.I.
P4202A/B	Ammonia Pump	1+1	Centri	304SS
TK4201	Deoxo Vessel	1	Cylindrical	C.S.
TK4202	Ammonia Catch Pot	1	Vertical	C.S.
TK4203	1st Ammonia Flash Vessel	1	Vertical	C.S.
TK4204	2nd Ammonia Flash Vessel	1	Vertical	C.S.
TK4205	Flash Gas Condenser Separator	1	Vertical	C.S.
TK4206	Ammonia Tank	1	Sphare	C.S.

Item No.	Name	Q'ty	Type	Material
U4201	Dryer Unit	1		
U4202	N_2 Gas Generator	1	Cold Box	
E4201	Ammonia Converter	1	Vertical	C.S.

7.3 Utilization of By-products and Anti-pollution Measures

7.3.1 Utilization of By-products

As shown in Figure 7-1-1 (1/2)(2/3), approximately 73,590 ton/yr of slag, 1,670 ton/yr of ferrophosphorous, and $2.3 \times 10^7 Nm^3$/yr of carbon monoxide gas (from the phosphoric acid plant) will be produced as by-products in the Paraguayan fertilizer project (Scenario 1 and 2). From the standpoint of saving of energy and resources, these by-products must be used in a constructive manner. Following is an outline of uses for each of these by-products.

1) Carbon monoxide gas

This by-product is a valuable fuel capable of generating 3,020 kcal/Nm^3 (2,420 kcal/kg). In this project, carbon monoxide gas produced in the electric furnace of phosphoric acid plant will be scrubbed and used as fuel for calcination of the phosphate rock raw material.

2) Slag

The slag produced in the electric furnace is composed mainly of lime (CaO) and silicon oxide (SiO_2), in the form of calcium silicate ($CaSiO_2$). In Japan, this slag is put to good use as silicate fertilizer containing soluble silica and alkaline. These fertilizers not only provide silicon (Si) and calcium (Ca) essential for plant growth, but also help to neutralize soils because of their alkaline content.

In the Paraguayan fertilizer project, some of the slag by-product will be used as filler (approximately 15,000 ton/yr), while half of the remaining 58,590 ton/yr will be packaged in 50 kg bags and sold as silicate fertilizer with the following percentages.

soluble silicic acid (as SiO_2): 35%
alkaline content: 40%

3) Ferrophosphorous

The ferrophosphorus by-product produced in the electric furnace has a phosphorus content of 20-26%, and in Japan is used as a ferro-alloy for removing acidity during steel manufacture. In Paraguay, however, there is at present no use for this material, so the by-product will be stored outdoors near the plant until some use for it is found.

7.3.2 Anti-pollution Measures

Environmental pollution is an important aspect of operation, and numerous preventive measures will be taken to protect the environment from plant discharges.

1) Control of atmospheric pollutants

In this project, potential air pollutants in the exhaust gases are fluorine, sulphur dioxide, ammonia and dust. Following are the maximum allowable amounts of these pollutants as specified in Paraguay, according to tentative SENASA regulations, compared to Japanese stanards.

	SENASA	JAPAN
P_2O_5(mist or fume)	0.15%	(dust) 150 mg/Nm^3
fluorine	20 mg/Nm^3	15 mg/Nm^3
sulfur dioxide	0.03%/V/V	K value limitation

Limits for the Paraguayan fertilizer plant are based on both the SENASA and Japanese regulations. Following is a list of potential pollutants according to the point where they will be discharged.

(1) exhaust gases from the phosphoric acid plant
... fluorine, dust, SO_2

(2) exhaust gases from the fertilizer plant
... fluorine, ammonia, dust

(3) exhaust gases from the FMP plant
... fluorine, dust

(1) Exhaust gases from the phosphoric acid plant

These exhaust gases originate primarily in the pellet calcination kiln and while tapping of the electric furnace. The fluorine content can be reduced to meet the present specifications by scrubbing with lime milk.

(2) Exhaust gases from the fertilizer plant

These gases are generated mostly in the granulator, neutralizer tank, dryer and product cooler. With the exception of gases from the product cooler, these all contain ammonia gas, and will first be scrubbed with phosphoric acid to recover the ammonia. Next all gases, including the product cooler exhaust, will be scrubbed with water to bring the fluorine content down to acceptable levels before being discharged into the atmosphere.

(3) Exhaust gas from the boiler

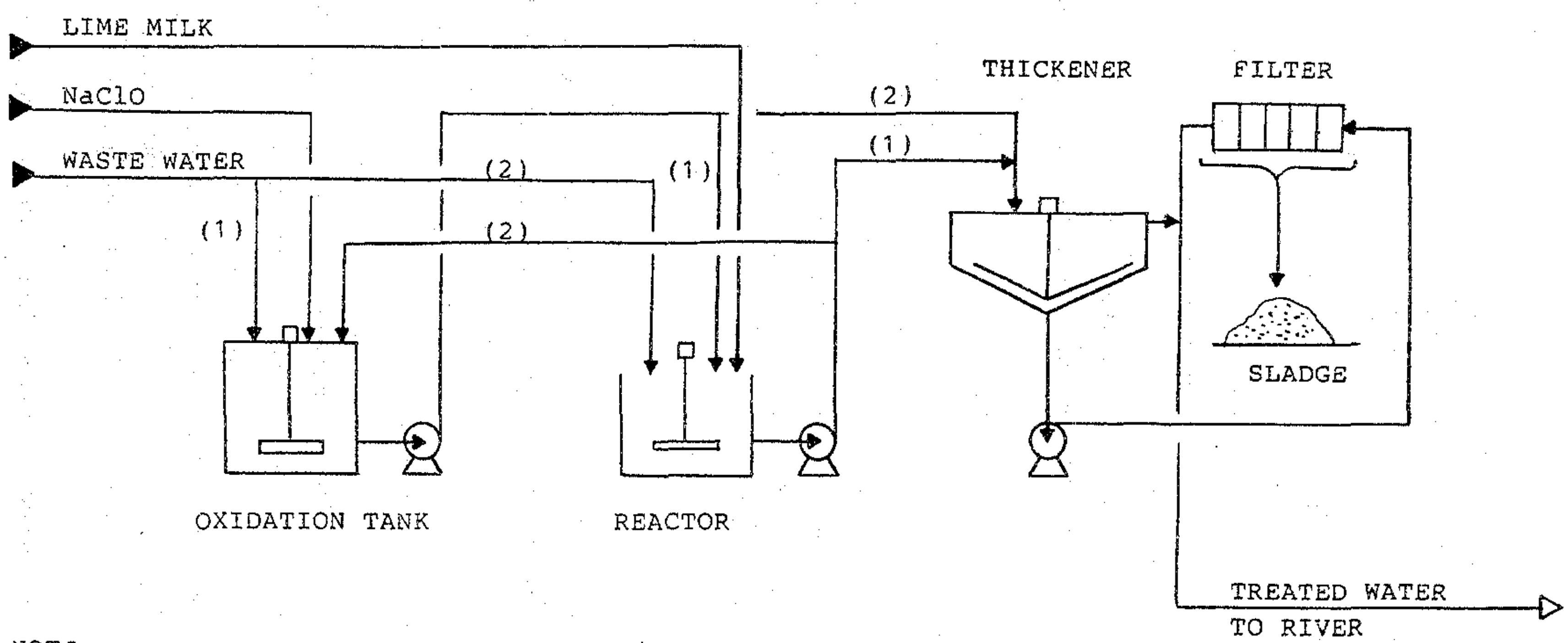
If fuel oil containing 1% sulphur is used in the boiler, the tentative SENASA standards listed above will be difficult to comply with. In this case, preventive measures, similar to those commonly used in Japan, will involve raising the height of the discharge stack in order to minimize concentrations of SO_2 at ground surface level.

(4) Exhaust gases from the FMP plant

These exhaust fumes contain HF and SO_2 that originate inside the electric furnace, and will be scrubbed with lime milk to bring the concentrations of fluorine down below the SENASA standards.

2) Control of water pollution

Control of pollutants in the water discharge, the process for which is diagrammed in Figure 7-3-1, will be according to the following Japanese standards:



NOTE (1) PROCESS LINE FOR SCENARIO-1/2
(2) PROCESS LINE FOR SCENARIO-3

FIGURE 7-3-1 TYPICAL FLOW SHEET OF WASTE WATER TREATMENT

cyanide : 1 mg/l
pH : 5.8 ~ 8.6
COD : 160 mg/l (daily average of 120 mg/l)
BOD : 160 mg/l (daily average of 120 mg/l)
fluorine : 15 mg/l

(1) Scenario 1 and 2

Waste water will be treated before being discharged from the phosphoric acid plant. In the electric furnace, some nitrogen reacts with carbon to form a cyanide compound, which is absorbed into the water in the condenser. In addition, the waste water contains fluorine and substantial amounts of COD.

The cyanide compounds and the COD are dissolved and oxidized with NaClO in an oxidation tank and rendered harmless. The fluorine is treated with lime milk in a reactor tank and fixated as calcium fluoride, which has a very low solubility in water. The solid CaF_2 is then precipitated from the water and removed with a filter, and the treated water discharged into the river.

(2) Scenario 3

Scenario 3 which involves treatment of waste water from the FMP plant, cyanide compounds are not present. The fluorine and COD are treated as described above.

(3) Notification to SENASA

When the factory is constructed in Paraguay, the following documents should be issued to SENASA.

- Schedule and plan of construction
- Anti-pollution measures
- Contract to specify the limits of pollutants

These documents mentioned above will be prepared by the project owner.

7.4 Plant Layout and Operation

The scheme of plant facilities as conceived of in the present plan is presented in Figure 7-4-1. The most important of these facilities are listed below.

1) Process plant

Scenario 1:
- Phosphoric acid plant
- Fertilizer plant

Scenario 2:
- Phosphoric acid plant
- Ammonia plant
- Fertilizer plant

Scenario 3:
- Fused magnesium plant

2) Utility facilities

- Water treatment
- Package boiler
- Fuel oil storage
- Power receiving
- Air supply system

3) Off-site facilities

- Raw materials storage
- Bulk products storage
- Product bagging and bagged product storage
- Product shipping
- Slag handling

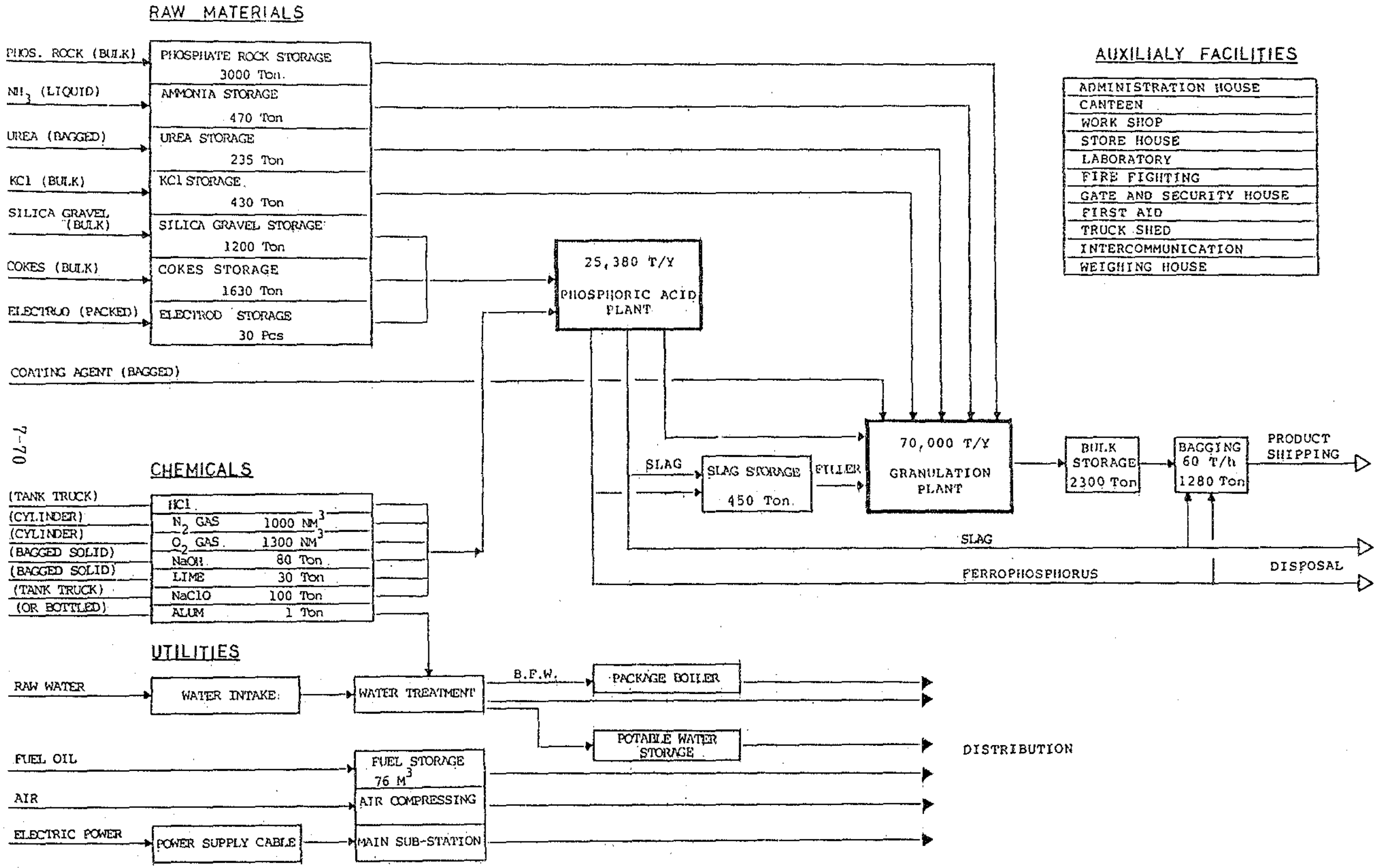


FIGURE 7-4-1 (1/3) OVERALL PROJECT SCHEME (SCENARIO 1)

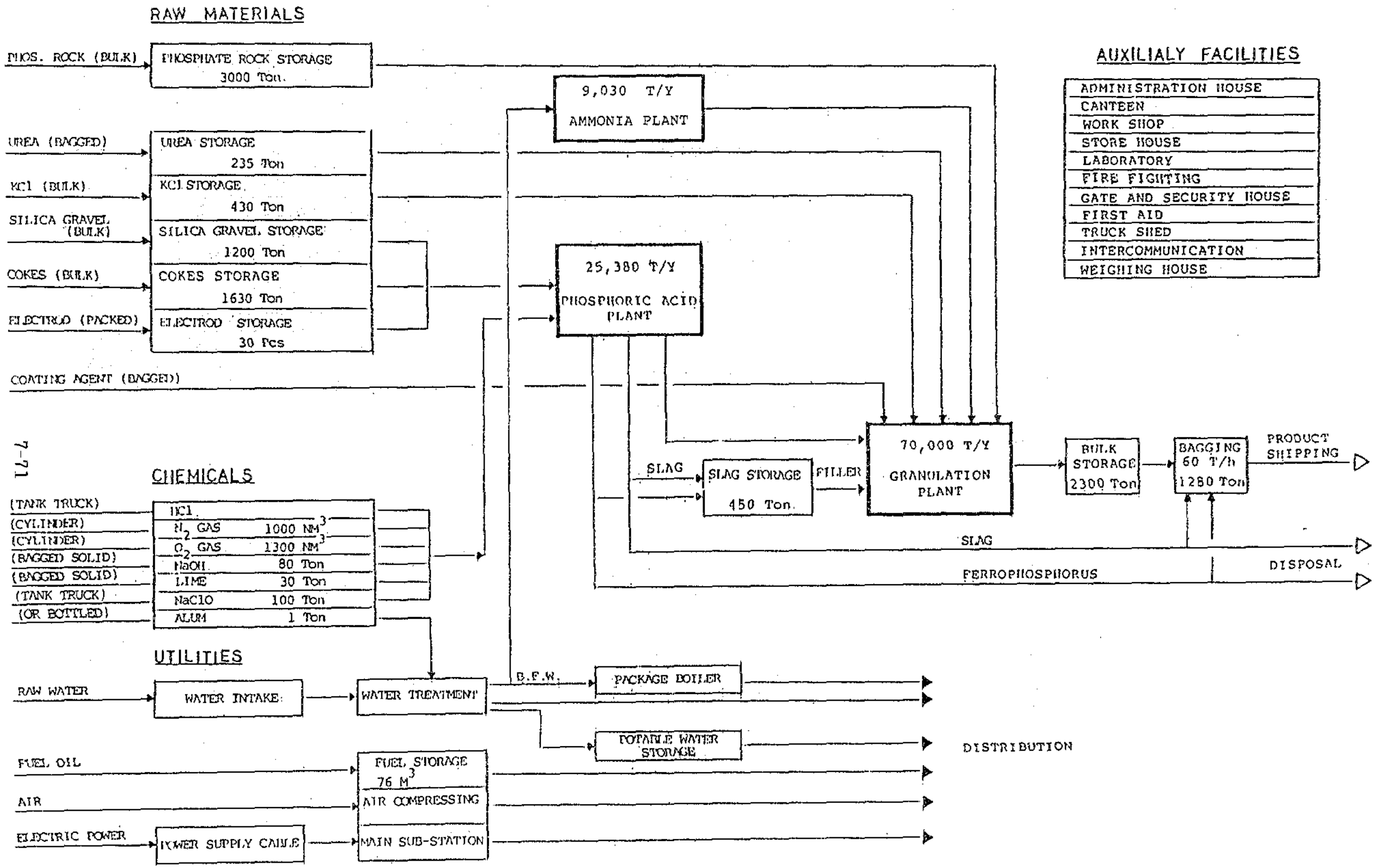


FIGURE 7-4-1 (2/3) OVERALL PROJECT SCHEME (SCENARIO 2)

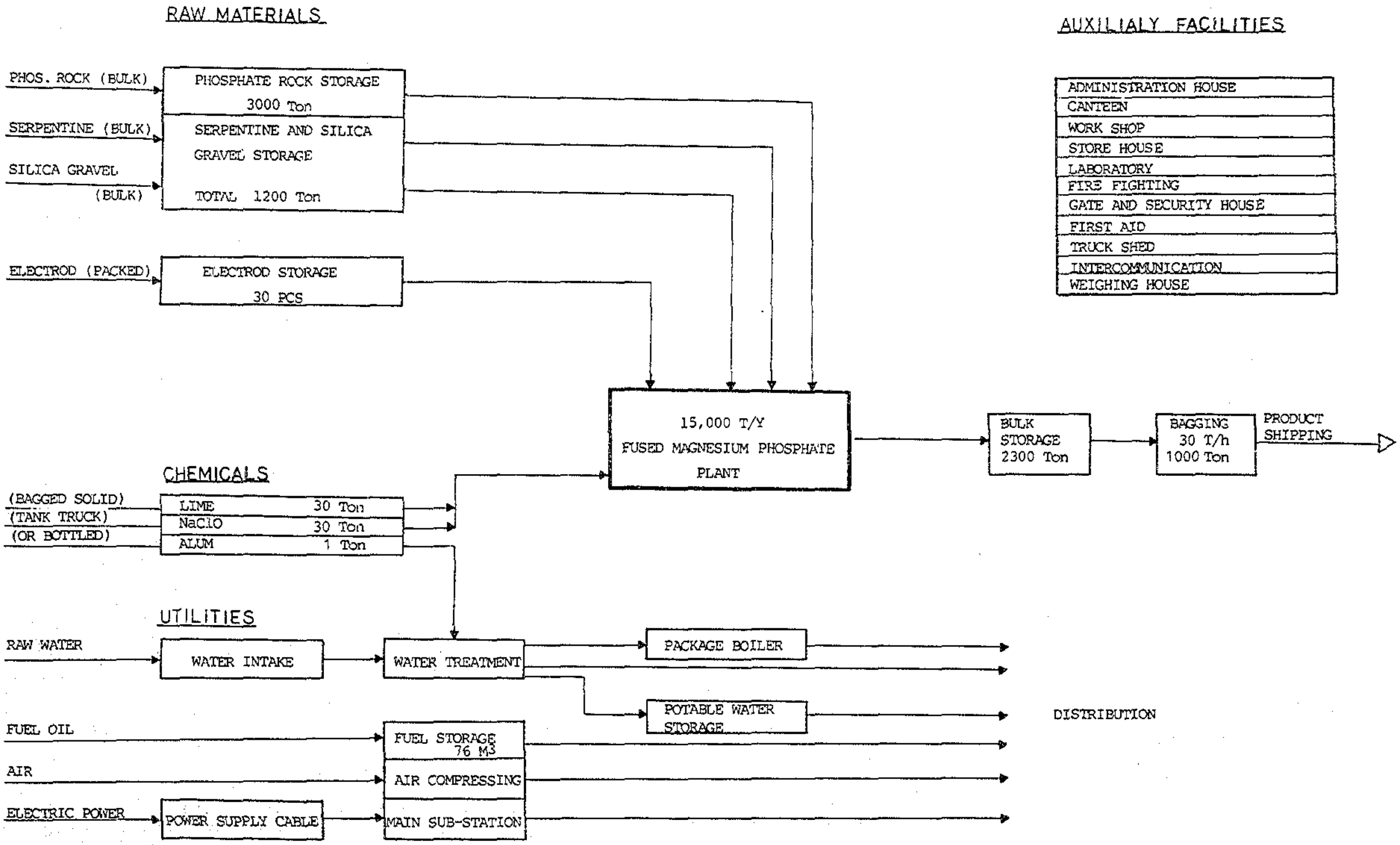


FIGURE 7-4-1 (3/3) OVERALL PROJECT SCHEME (SCENARIO-3)

4) Auxiliary facilities

- Administration house
- Canteen
- Workshop
- Store house
- Central laboratory
- Fire fighting
- Gate and security house
- Car shed
- First aid
- Intercommunication
- Weighing house

7.4.1 Plant Site

1) Location

The plant site should be chosen on the basis of availability of electric power and industrial water supply, convenient transportation for bringing the raw materials in and shipping the product fertilizer out, and easy access for construction vehicles and for installing and removing the plant machinery. After consideration of all these factors, a candidate site in the vicinity of Itaipu Power Station was determined to be most desirable, and Hernandarias, the city in the department of Alto Parana, was researched as a prospective choice.

As can be seen from the map presented in Figure 7-4-2, Hernandarias is located close to the city of Pte. Stroessner, along National Highway 7. Hernandarias has a population of 50,000 (30,000 within the city limits and 20,000 engaged in agriculture). The main crop is soybeans, with 23 storage silos for agricultural product. In addition, the city has 8 junior high schools and 20 timber factories.

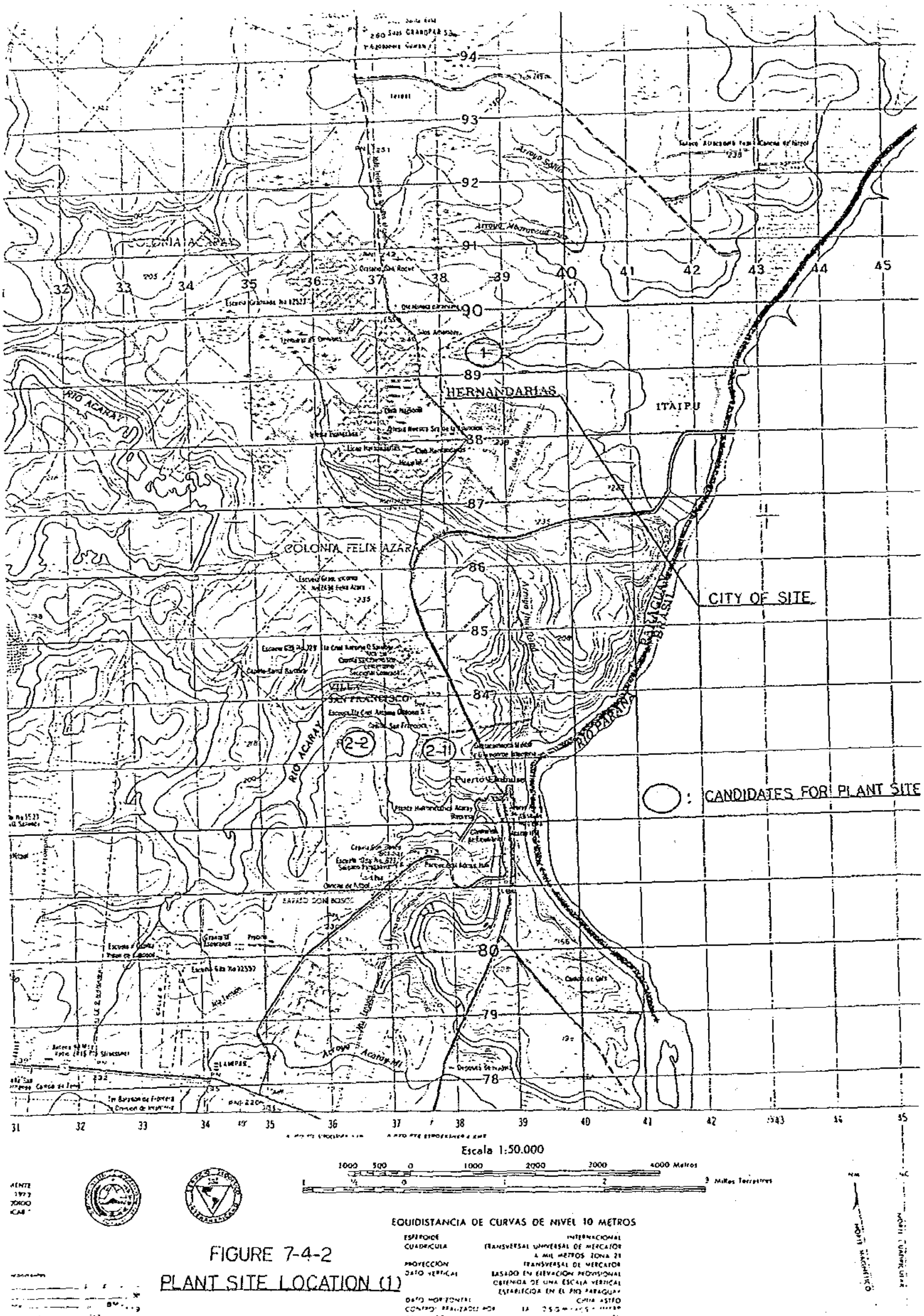


FIGURE 7-4-2
PLANT SITE LOCATION (1)

This field survey mission investigated two candidate plant sites at Hernandarias, one above Itaipu Dam and the other above Acaray Dam. The location of these is shown in Figure 7-4-3. A comparison of these two sites, based on the factors listed in Table 7-4-1, showed the former to be the most suitable.

Table 7-4-1 Comparison of candicated Plant Site

Aspect	Place-1 (The up stream of Itaipu Dam)	Place 2-1, 2-2 (The up stream of Acaray Dam)
Land preparation	o	x
Water intake	o	x
Power receiving	(*1)	o
Access to site	o	x
Raw material receiving	o	x
Product shipping	o	x

Note:

1) Mark "o" is better than mark "x."
   Mark "x" does not mean necessarily insuitable place.
2) *1: There is a local airport near Place-1. Therefore, some consideration for power receiving cable will be required in order to keep from disturbing the landing and taking off of airplanes.

2) Geology

During the field survey of June 1986, no data was collected on the geology of the candidate site. Interviews, however, based mostly on the experience of Compania de Construcciones Civiles S.A., indicate that the area around the site has ground strength ranging from 12-15 ton/m^2. As plans for the fertilizer plant

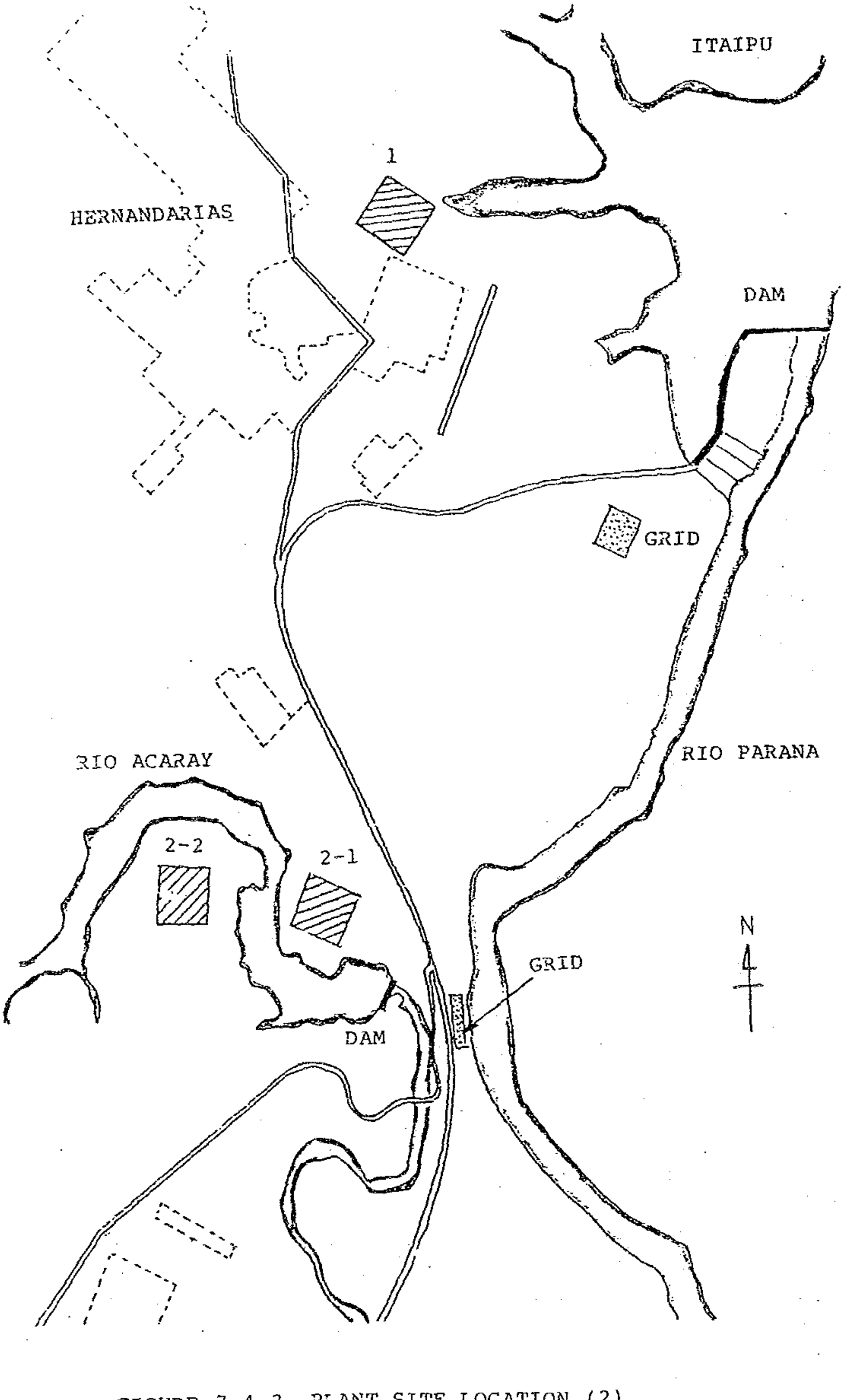


FIGURE 7-4-3 PLANT SITE LOCATION (2)

stipulate a minimum ground strength of 12 ton/m^2, no problems should be expected in this area. Once construction is decided on, however, a detailed geological analysis of the site should be necessary.

3) Meteorology

Basic meteorological data for Pte. Stroessner City is presented below, and more detailed data is given in Table 7-4-2.

(1) Air temperature

annual average : 22°C

maximum record : 38.8°C (1971-1982)

minimum record : -3.0°C (1971-1984)

(2) Humidity

annual average : 77% @22°C

(3) Wind velocity

maximum : 18 m/s (max during 10 years: 25 m/s)

maximum over ten year period

: 25 m/s

(4) Rainfall

maximum rate : 117 mm/24 hr

annual : 2,637 mm

(5) Atmospheric pressure

annual average : 743 mmHg

(6) Water level of Rio Parana (measured at Franco)

maximum : 20.7 m

minimum : 13.2 m

(7) Earthquake activity

No earthquakes have been recorded

Table 7-4-2 Climatic Condition

Measuring place : Pte. Stroessner

Latitude 25°32', Longitude 54°19'

Elevation 196 m

(1) Atmospheric Temperature (°C)

(a) Average Temperature

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANN. (AVE)
1971/80	25.7	25.9	24.6	20.8	17.8	16.1	16.4	17.2	19.1	21.5	23.3	25.0	21.1
1981	26.4	26.1	24.8	22.4	21.2	14.6	15.0	17.1	19.9	21.6	24.6	24.3	21.5
1982	26.1	25.5	25.0	22.6	18.7	17.1	18.4	20.0	21.1	22.4	23.0	17.0	21.4
1983	26.8	26.1	23.8	22.2	20.0	14.4	16.7	17.4	17.3	22.3	22.8	26.3	21.3
1984	26.8	27.6	25.1	20.4	20.0	17.5	17.8	15.8	19.6	25.0	23.9	24.2	22.0

(b) Maximum Temperature

1971/80 : 38.8

1981 : 36.0

1982 : 36.0

(c) Minimum Temperature

1971/80 : -3.0

1981 : 0.6

1982 : 5.4

1983 : 4.6

1984 : -1.0

(2) Relative Humidity (%)

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANN. (AVE)
1971/80	76	76	79	80	83	84	80	80	76	75	72	74	78
1981	79	79	74	75	80	85	72	71	71	75	74	79	76
1982	67	78	75	-	76	87	81	78	76	75	85	74	71
1983	78	77	77	84	88	86	87	75	78	74	74	69	79
1984	76	74	78	82	82	83	78	79	68	70	78	72	77

(3) Wind of Direction (degree)* /Maximum Velocity (m/s)

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1984	060/ 17	300/ 18	330/ 15	030/ 11	060/ 11	250/ 12	030/ 13	260/ 11	220/ 17	210/ 8	250/ 10	210/ 9
1985	210/ 13	259/ 9	130/ 10	240/ 10	180/ 9	320/ 9	330/ 11	260/ 9	340/ 10	310/ 9	030/ 9	350/ 8

Note: * Refer to Figure 7-4-4.

(4) Rainfall

(a) Maximum Rainfall (mm/24 hrs)

	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1984	67.0	31.2	117.0	53.6	21.0	45.7	39.8	70.6	47.1	43.1	62.4	99.2
1985	46.1	52.1	47.0	45.1	35.0	34.9	30.2	13.0	15.0	49.4	14.0	24.5

(b) Rainfall (mm/month)

1983					
JAN	FEB	MAR	APR	MAY	JUN
189.4	268.2	192.5	288.0	339.5	198.8

1983						
JUL	AUG	SEP	OCT	NOV	DEC	ANN.
355.4	12.1	299.8	180.8	233.0	79.4	2,636.9

(5) Atmospheric Pressure (mmHg)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN. (AVE)
1984	740.9	741.5	741.6	744.6	743.3	745.2	744.8	745.9	743.9	742.0	741.7	740.4	743.
1985	740.0	741.2	740.8	742.9	744.7	747.2	747.5	745.2	744.1	741.9	741.9	740.1	743.

(6) Maximum and Minimum Level (m) of Water of Parana River at Pte. Franco in 1985

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MAX	15.55	20.67	19.04	18.19	17.75	15.25	14.40	15.05	17.25	18.25	19.70	18.70
MIN	13.55	17.00	16.29	16.04	15.25	13.75	13.15	14.20	14.15	14.55	17.35	16.80

REPUBLICA DEL PARAGUAY
MINISTERIO DE DEFENSA NACIONAL
DIRECCION DE METEOROLOGIA

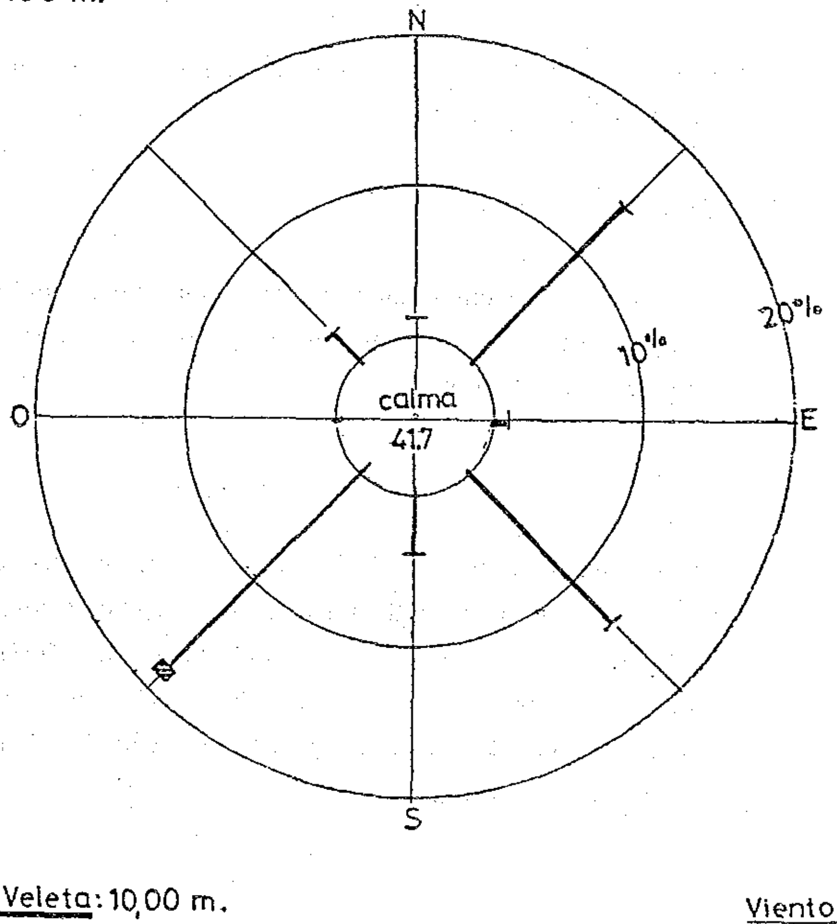
FIGURE 7-4-4

FRECUECIA DE DIRECCION Y VELOCIDAD DEL VIENTO

Pdte. STROESSNER

1980/83

Lat : 25° 32'
Long: 54° 36'
Alt : 19.6 m.



Altura Veleta: 10,00 m.

Viento en Km/h.

2 ≤ V < 25
25 ≤ V < 50
50 ≤ V

4) Plant layout

The area required for this project and proposed plant layout are shown in Figure 7-4-5. The required area for each scenario is as follows:

Scenario 1:	Approx.	290 m x 200 m
Scenario 2:	Approx.	290 m x 200 m
Scenario 3:	Approx.	200 m x 200 m

7.4.2 Outline of the Process Plants

1) Scenario 1

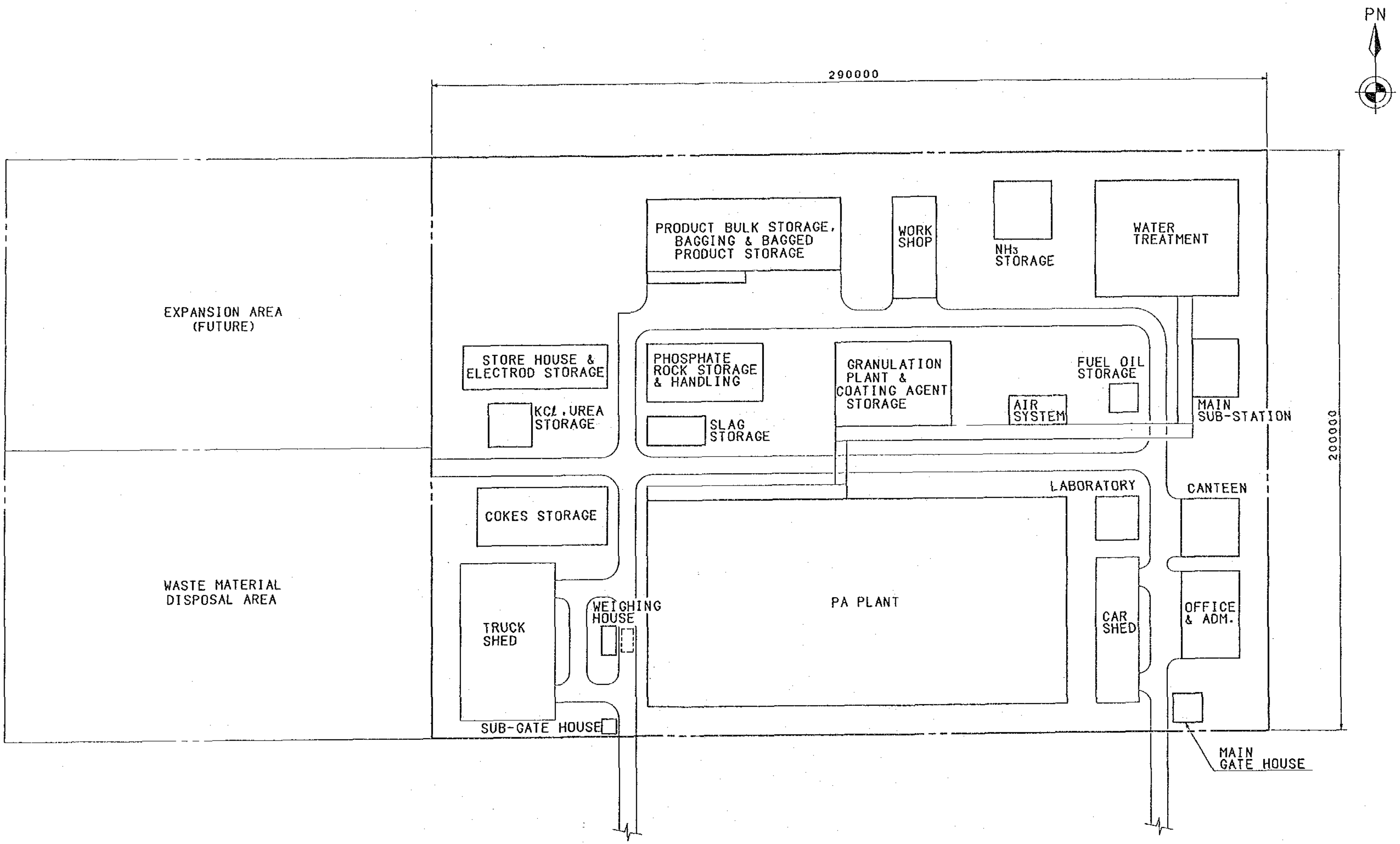
In case of Scenario 1, ammonia is imported and process plants consist of following plant:

(1) Phosphoric acid plant

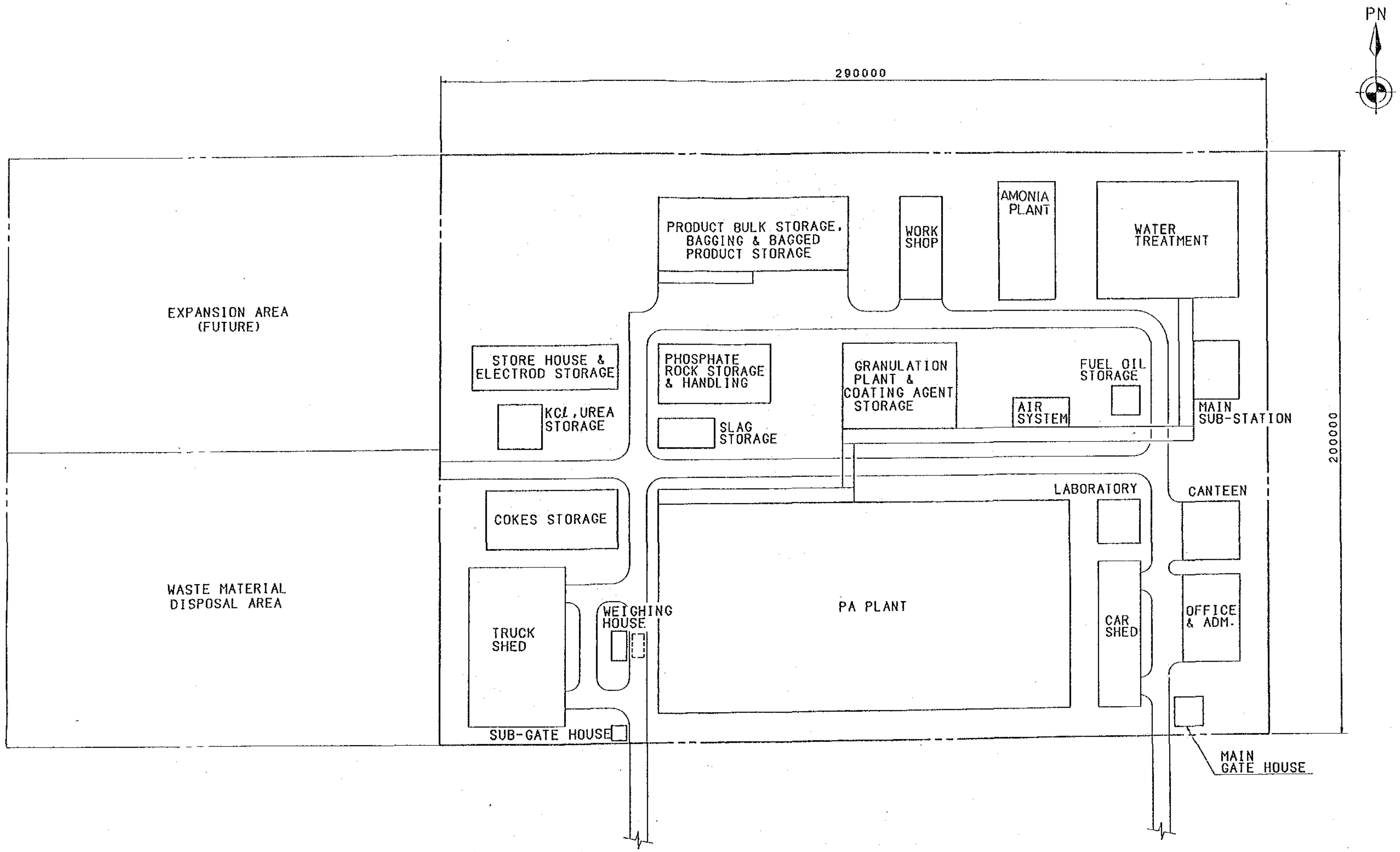
As was mentioned earlier, the phosphoric acid plant will employ the electric furnace (dry) process, and will have a capacity of 85 ton/d.

(2) Fertilizer plant

The fertilizer plant will employ the slurry process discussed in previous and will be capable of switching production among the various grades and types of fertilizers listed below. For each type of fertilizer, the daily capacity depends on the amount of raw material and recycle ratio required for granulation.



FIGUR 7-4-5 (1/3) OVERALL PLOT PLAN (SCENARIO 1)
(BATTERY LIMITS : 290m x 200m)



FIGUR 7-4-5(2/3) OVERALL PLOT PLAN (SCENARIO 2)
(BATTERY LIMITS : 290m x 200m)

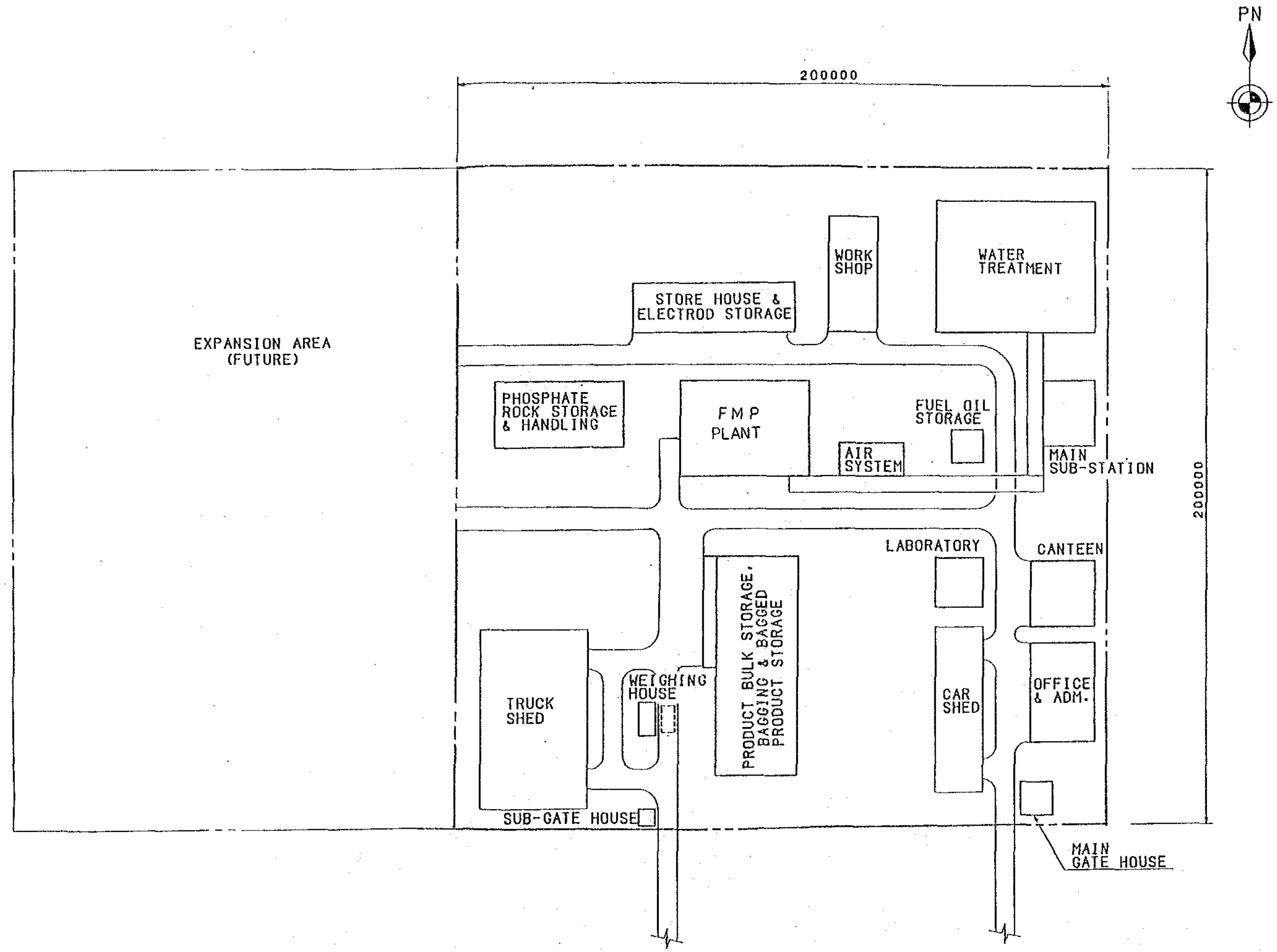


FIGURE 7-4-5 (3/3) OVERALL PLOT PLAN (SCENARIO 3)
(BATTERY LIMITS : 200m x 200m)

Production Capacity

Grade	Daily Capacity t/d	Operation day/y	Yearly Capacity t/y
DAP (18-46-0) :	212	137	29,000
NPK (6-30-10) :	255	125	32,000
NPK (15-15-15):	212	19	4,000
TSP (0-46-0) :	127	39	5,000
Total		320	70,000

2) Scenario 2

In case of Scenario 2, ammonia plan is erected in addition to the Scenario 1.

(1) Ammonia plant (Scenario 2)

As described 7.2.2, ammonia is produced from hydrogen and nitrogen. Hydrogen is produced by the process of water electrolysis and nitrogen is separated from air by the cryogenic process. The capacity is 30 t/d.

3) Scenario 3

(1) Fused magnesium phosphate plant

As was indicated in an earlier section, the FMP plant will utilize an electric furnace and be capable of producing 50 tons/d.

7.4.3 Utilities

Following is a brief outline of the plant facilities connected with utilities.

1) Water treatment
(Supply, filtration and purification of industrial water)

The system for supplying and filtering industrial water is flow charted In Figure 7-4-6, and described briefly below.

(1) Water intake

Raw water will be pumped approximately 100 m from Itaipu Dam or Acaray Dam and stored in a reservoir at the plant site. Some of this water will be used for water quenching for FMP.

(2) Filtration

The raw water will be filtered with a sand filter and stored in a reservoir tank. This water will be used as process water in the various plants.

(3) Purification

Some of the filtered water obtained as described in (2) above will be purified with alum (a coagulant) and used in the boiler and for drinking purposes.

(4) Boiler feed water

Some of the purified water will be treated through ion exchange resin and supplied to the boiler. When necessary, this water will also be de-carbonated.

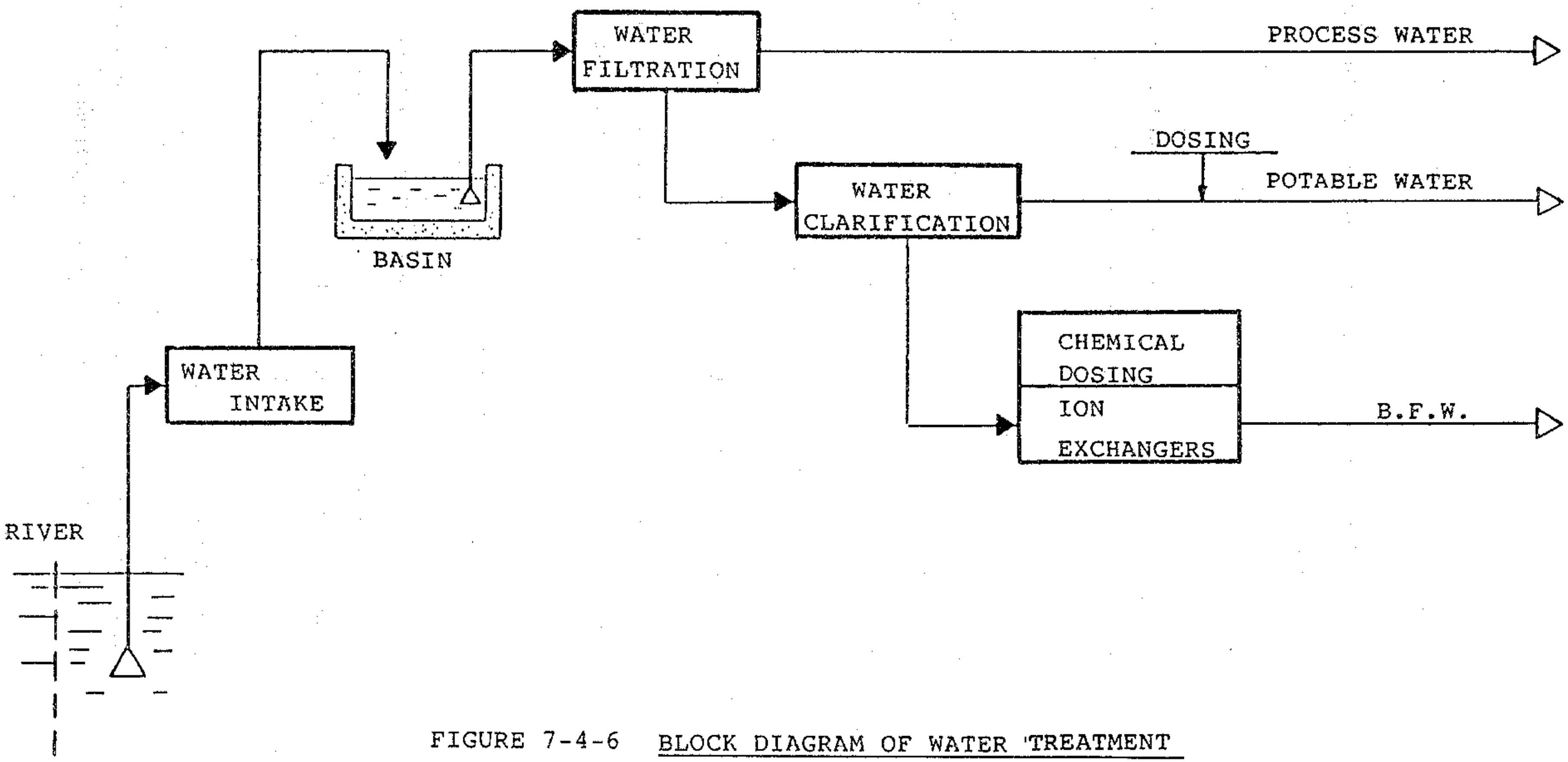


FIGURE 7-4-6 BLOCK DIAGRAM OF WATER TREATMENT

(5) Drinking water

Some of the filtered water will be chlorinated and used for drinking purposes.

2) Steam

Steam for use in the manufacturing process and for maintenance of the plants will be generated in a package boiler.

3) Fuel oil storage

Fuel oil will be delivered to the plant by tank lorry and stored in a tank before use. The facilities involved are diagrammed in Figure 7-4-7.

4) Facilities for receiving electric power

(1) Transmission from Itaipu Station to the plant site

Electric power will be transmitted from Itaipu Station to the plant receiving facilities via cable approximately 5 km in length.

(2) Receiving and distribution at the plant site

The 220 kV power from Itaipu will be received at facilities within the plant and transformed down to 3.3 kV, which will be sent to substations and reduced to the voltage levels needed for various purposes.

5) Air supply system

Facilities will be provided for supplying air for instruments in the manufacturing plants and for maintenance purposes.

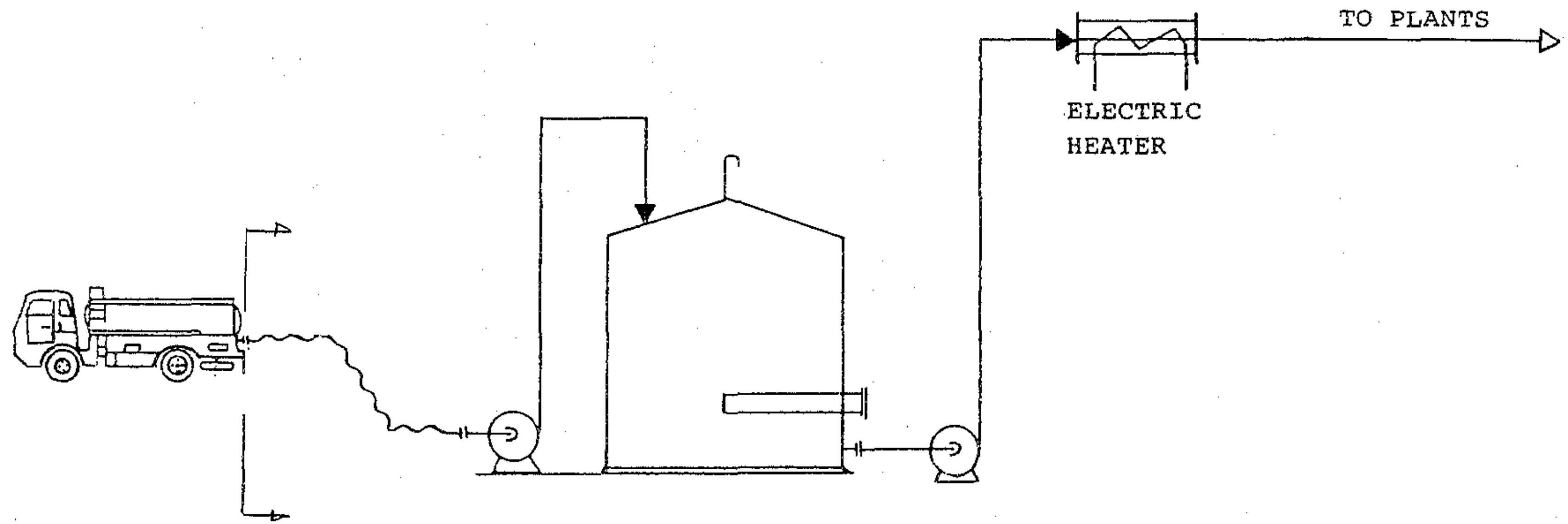


FIGURE 7-4-7 BLOCK DIAGRAM OF FUEL OIL SYSTEM

Table 7-4-3 Outline of Specification of Utility Facility

	SCENARIO		
	1	2	3
(1) Water Treatment			
Intake Capacity (m^3/h)	600	600	100
Filter Capacity (m^3/h)	150	200	75
Clarificaiton Capacity (m^3/h)	8	12	4
Boiler Feed Capacity (m^3/h)	1.6	4.5	1.1
Potable Water Capacity (m^3/d)	65	65	65
(2) Steam Boiler Capacity (t/h) (10 kg/cm^2G)	1.5	1.5	1
(3) Fuel Oil Storage Capacity (m^3)	76	76	76
(4) Electric Power Receiving			
Cable Length (approx. km)	5	5	5
Capacity (kVA)	30,000	48,000	3,200
(5) Air Supply System			
Capacity of Air Compressor (Nm^3/h)	350	400	120

6) Specifications of facilities

Specifications for plant facilities relating to utilities for each Scenario are listed in Table 7-4-3.

7.4.4 Off-site Facilities

The major off-site facilities are described in brief outline form below.

1) Storage of raw materials

All raw materials will arrive at the plant site via truck and be received and stored in the manner indicated below.

(1) Phosphate rock (Scenario 1, 2 and Scenario 3)

Phosphate rock will be imported from Brazil and stored in a hopper as diagrammed in Figure 7-4-8. In Scenario 1 and 2, a storage shed and two hoppers will be utilized. Depending on the size distribution of the phosphate rock size, some of the rock will be used directly for TSP production without grinding. In Scenario 3, the phosphate rock will be inputted directly from the storage shed to the processing plant.

(2) Silica gravel (Scenario 1, 2 and Scenario 3)

Domestically available silica gravel will be used in the production acid and FMP. Silica gravel destined for use in Scenario 1 and 2 will be stored near the phosphoric acid plant, and for Scenario 3 near the FMP plant. Some will also be stored in the phosphate rock shed and fed to the plant with a shovel loader.

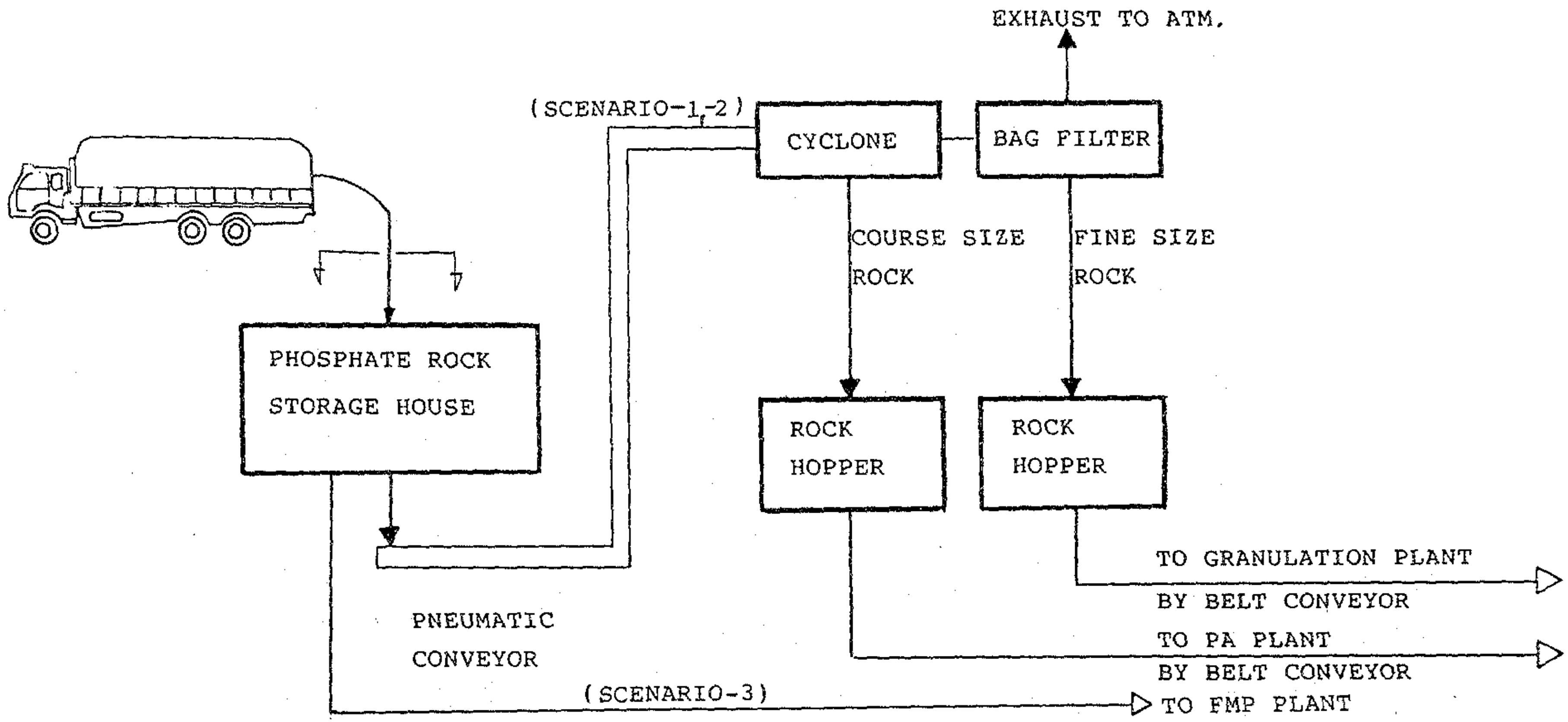


FIGURE 7-4-8 <u>PHOSPHATE ROCK STORAGE SYSTEM</u>

(3) Potassium chloride and urea (Scenario 1, 2)

Potassium chloride required for production of NPK fertilizers will be purchased in bulk from North America, offloaded at Santos Port in Brazil, then transported to the plant site via truck. Bagged urea will be imported from Brazil. These two raw materials will be stored together in a warehouse and supplied to the plants by shovel loader or fork lift.

(4) Coke (Scenario 1, 2)

Coke will be stacked and fed to the phosphoric acid plant via shovel loader.

(5) Liquid ammonia (Scenario 1 only)

Liquid ammonia will be imported from Brazil via tank lorry, then pumped into a spherical storage tank and stored under pressure.

(6) Coating agents (Scenario 1, 2)

Bagged powdered diatomaceous earth will be used as a coating agent in production of NPK fertilizers, and will be stored inside the fertilizer manufacturing plant.

(7) Electrodes (Scenario 1, 2 and Scenario 3)

Electrodes will be imported and stored in an auxiliary warehouse.

(8) Serpentine (Scenario 3 only)

Domestically available serpentine will be used as a raw material in production of fused magnesium phosphate. This material will be stored near the FMP plant, and some will also be stored with the phosphate rock, to be supplied to the FMP plant with a shovel loader.

2) Bulk storage of manufactured fertilizer products (Scenario 1, 2 and Scenario 3)

In case of DAP and NPK production, granulated fertilizer products will leave the plant via a belt conveyor and move to the product warehouse, where they will be unloaded and stacked with a tripper-type belt conveyor. TSP fertilizers will be cured while stored in this product warehouse. The bulk fertilizer will then be transported to the packaging facilities via a shovel loader, belt conveyor and bucket elevator.

3) Packaging facilities and bagged product fertilizer storage (Scenario 1, 2 and Scenario 3)

Packaging facilities, consisting of measuring, bagging and sealing equipment, will be under the same roof as the bulk storage, but separated by a wall partition.

4) Shipping of product fertilizers (Scenario 1, 2 and Scenario 3)

The bagged products will be loaded by fork lift and portable conveyor into trucks at a loading platform inside the product storage warehouse.

5) Facilities for handling of slag (Scenario 1, 2)

Slag and ferrophosphorous will be produced as by-products in the phosphoric acid plant. Some of the slag will be used as filler in the product fertilizer, while half of remaining slag will be packaged in 50 kg bag. The system for handling these by-products is mapped in Figure 7-4-9.

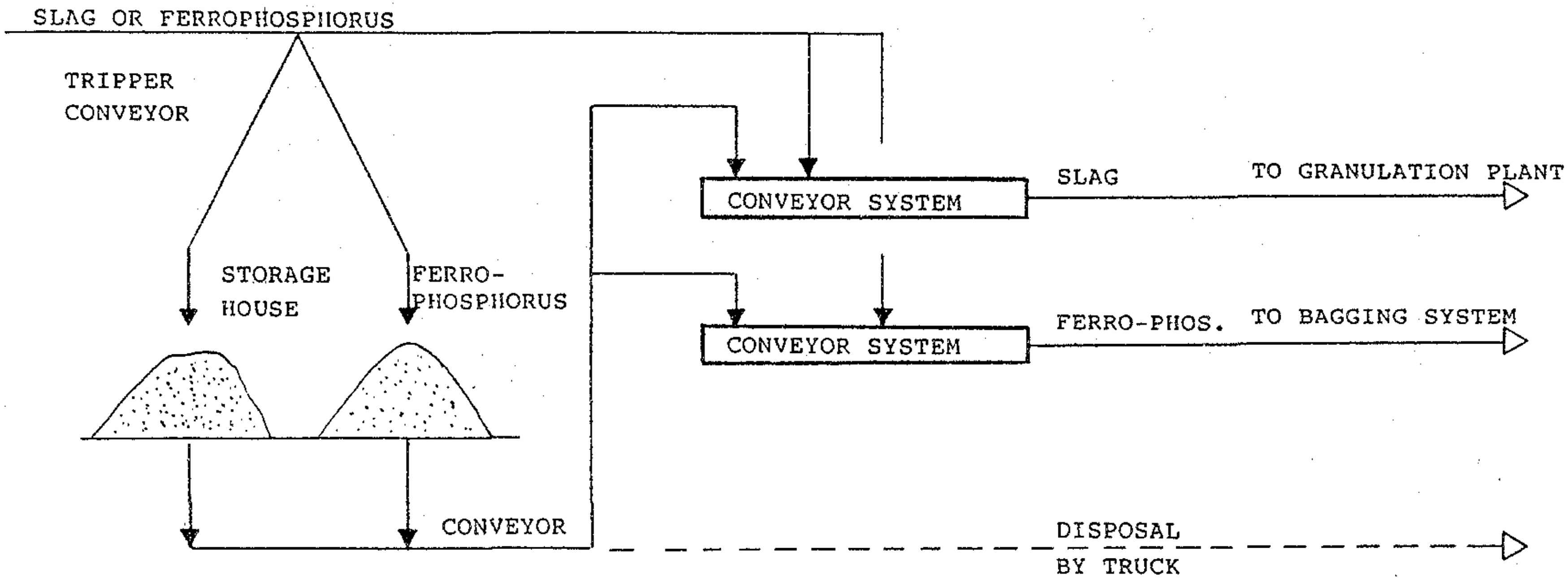


FIGURE 7-4-9 BLOCK DIAGRAM OF SLAG HANDLING
(SCENARIO 1, 2)

6) Specifications of off-site facilities

Outline specifications for the off-site facilities described above are listed in Table 7-4-4.

7.4.5 Auxiliary Facilities

Auxiliary facilities called for under the project plan are listed in Table 7-4-5.

Table 7-4-4 Outline of Specification of Off-Site Facility

	SCENARIO 1	SCENARIO 2
	Phosphoric Acid Plant Granulation Plant	Phosphoric Acid Plant Granulation Plant Ammonia Plant
(1) Raw Materials Storage		
(a) Phosphate Rock Storage		
Storage capacity	3,000t	3,000t
(b) Gravel Storage		
Storage Capacity	1,200t	1,200t
(c) Potassinm Chloride/ Urea Storage		
Storage Capacity		
Potassium Chloride	430t	430t
Urea	235t	235t
(d) Cokes Storage		
Storage Capacity	1,200t	1,200t
(e) Liquid Ammonia Storage		
Storage Capacity	470t	—
(f) Coating Agent Storage		
Storage Capacity	20t	20t
(g) Electrode Storage		
Storage Capacity	30 pcs	30 pcs
(h) Serpentine Storage		
Storage Capacity	-	-
(2) Bulk Product Storage		
Storage Capacity	2,300t	2,300t
(3) Product Bagging/Storage		
Bagging Capacity	50 Kg/Bag x 30t/h x 2 lines	50 Kg/Bag x 30t/h x 2 lines
Product Storage	1,280t	1,280t

	SCENARIO 1	SCENARIO 2
	Phosphoric Acid Plant Granulation Plant	Phosphoric Acid Plant Granulation Plant Ammonia Plant
(4) Product Shipping		
Fork Lift	30∿60 t/h	30∿60 t/h
Portable Conveyor	30∿60 t/h	30∿60 t/h
(5) Slag Treatment		
Storage Cap. for filler	450t	450t
Bagging Facility	Included in (3)	Included in (3)

SCENARIO 3

	FMP Plant
(1) Raw Materials Storage	
(a) Phosphate Rock Storage	
Storage capacity	3,000t
(b) Gravel Storage	
Storage Capacity	COMMON USE FOR SERPENTINE
(c) Potassinm Chloride/ Urea Storage	
Storage Capacity	
Potassium Chloride	-
Urea	-
(d) Cokes Storage	
Storage Capacity	-
(e) Liquid Ammonia Storage	
Storage Capacity	-
(f) Coating Agent Storage	
Storage Capacity	-
(g) Electrode Storage	
Storage Capacity	30 pcs
(h) Serpentine Storage	
Storage Capacity	1,200t
(2) Bulk Product Storage	
Storage Capacity	2,300t
(3) Product Bagging/Storage	
Bagging Capacity	50 Kg/Bag X 30 t/h X 1 line
Product Storage	1,280 t

	SCENARIO 3
	FMP Plant
(4) Product Shipping	
Fork Lift	30~60 t/h
Portable Conveyor	30~60 t/h
(5) Slag Treatment	
Storage Cap. for filler	-
Bagging Facility	

Table 7-4-5 Outline of Auxiliary Facility

The auxiliary Facilities relating the project are summalized in this table.

1) Administration House

- Dimension of House	:	Approx. $20m^W \times 30m^L \times 10m^H$
- Furniture	:	Required furniture will be decided at the stage of project execution.

2) Canteen

- Capacity	:	50 ∿ 70 persons
- Dimension of House	:	Approx. $20m^W \times 20m^L \times 3.5m^H$
- Apparatus	:	Required apparatus will be decided at the stage of project execution.

3) Work Shop

- Main Function	:	General repair and maintenance works of equipment. (Repair of cars/trucks is not included)
- Dimension of House	:	Approx. $15m^W \times 35m^L \times 3.5m^H$
- Machine, Tool, Crane	:	1 lot

4) Store House

- Main Function	:	Storage of consumable chemicals, lubricant and Spare parts.
- Dimension of House	:	Approx. $15m^W \times 45m^L \times 3.5m^H$
- Shelf	:	Required shelves will be decided at the stage of project execution

5) Laboratory (central)

- Main Function	:	General chemical analysis, such as raw materials, products and process materials. Local laboratory will also be provided in each process plants.
- Dimension of House	:	Approx. $15m^W \times 15m^L \times 3.5m^H$
- Apparatus	:	1 lot

6) Fire Fighting

- Equipment	:	Water Pump, hydlant, water piping loop will be required.
- Fire Engine	:	The fire engine of local Fire Devision will be used.

7) Gate and Security House

- Dimension of House

Main Gate	:	Approx. $10m^W \times 10m^L \times 3.5m^H$
Sub-Gate	:	Approx. $5m^W \times 5m^L \times 3.5m^H$

8) Truck Shed

- Area	:	Approx. 30m x 75m

Note: Car (automobile) Shed is also provided.

9) First Aid

First aid room will be provided in the administration house.

10) Intercommunication

- Number of telephone	:	50 sets
- Telex Machine	:	1 set
- Paging and silen	:	each one set

Cont'd

11) Weighing House (Truck Scale)

- Dimension of House : Approx. $5m^W \times 10m^L \times 3.5m^H$
- Weighing Capacity : 50 tons (Load Cell)

7.5 Plant Management and Operation

1) Production plan

Scheduled production and operation load are shown in Table 7-5-1. These projected figures are based on results of market research in Paraguay.

Table 7-5-1 Production Schedule

Year	Scheduled Operation Load	Scheduled Production (T/Y)
1 (1992)	80%	56,000
2 (1993)	90%	63,000
3 (1994)	100%	70,000
15 (1995)	100%	70,000

1) Yearly production plan

As has been explained earlier, DAP, NPK and TSP fertilizers will be produced within the same plant. The annual timing of production of these fertilizer types will coincide with the seasonal demand generated by the Paraguayan agriculture indutry. Table 7-5-2, based on field survey accomplished in June of 1986, lists the main periods for spreading DAP, NPK and TSP fertilizers. Using this data as a timetable, an annual production cycle is calculated as shown in Table 7-5-3.

Table 7-5-2 Fertilizing in Paraguay

Crop	Kind of Fertilizer	Period of Fertilizing
Wheat	DAP, TSP	May - Jun.
Soybean	NPK (6-30-10), TSP	Aug.- Nov.
Vegitable	NPK (15-15-15)	Case by case

In Scenario 3, as fused magnesium phosphate is not presently used in Paraguay, determination of an annual production schedule will have to await the results of experimental research and observation of use patterns once these fertilizations are adopted by the farmers.

2) Factory management

Figure 7-5-1 presents an organizational flow chart for factory management. This chart represents only a general idea of how factory management should be organized, and in actual practice adaptations and additions based on current conditions in Paraguay will be needed for maximum efficiency of operation.

This fertilizer plant will be the first central trunk industry in Paraguay. Thus construction and management will have to be carefully planned and intensively supported. The major goal should be rationalized production of fertilizer of appropriate quality at a reasonable price.

Table 7-5-3 Schedule of Product Shipping and Annual Production

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1)Fertilizing												
DAP/TSP												
NPK(6-30-10)												
2)Shipping				DAP/	TSP				NPK			
3)Production (Day)												
DAP	23	22	23	23	23	23						
TSP	6	4	5	5	6	5	8					
NPK(6-30-10)							21	22	28	29	25	
NPK(15-15-15)								7			3	9
Total Production Day	29 (2)	26 (2)	28 (3)	28 (2)	29 (2)	28 (2)	29 (2)	29 (2)	28 (2)	29 (2)	28 (2)	9 *

(Day) : Maintenance or Product Change

* : The other days are periodical annual maintenance

Based on the organizational flow chart presented in Figure 7-5-1, manpower needs are estimated to be 287 workers for Scenario 1, 348 for Scenario 2 and 244 for Scenario 3. This data is shown in Table 7-5-4, and should be used to calculate labor costs.

NOTE :- IN CASE OF "SCENARIO-2", THE AMMONIA PLANT IS ADDED TO SCENARIO-1.

- IN CASE OF "SCENARIO-3", THE FMP PLANT IS SHOWN IN STEAD OF PA AND GRANULATION PLANTS.

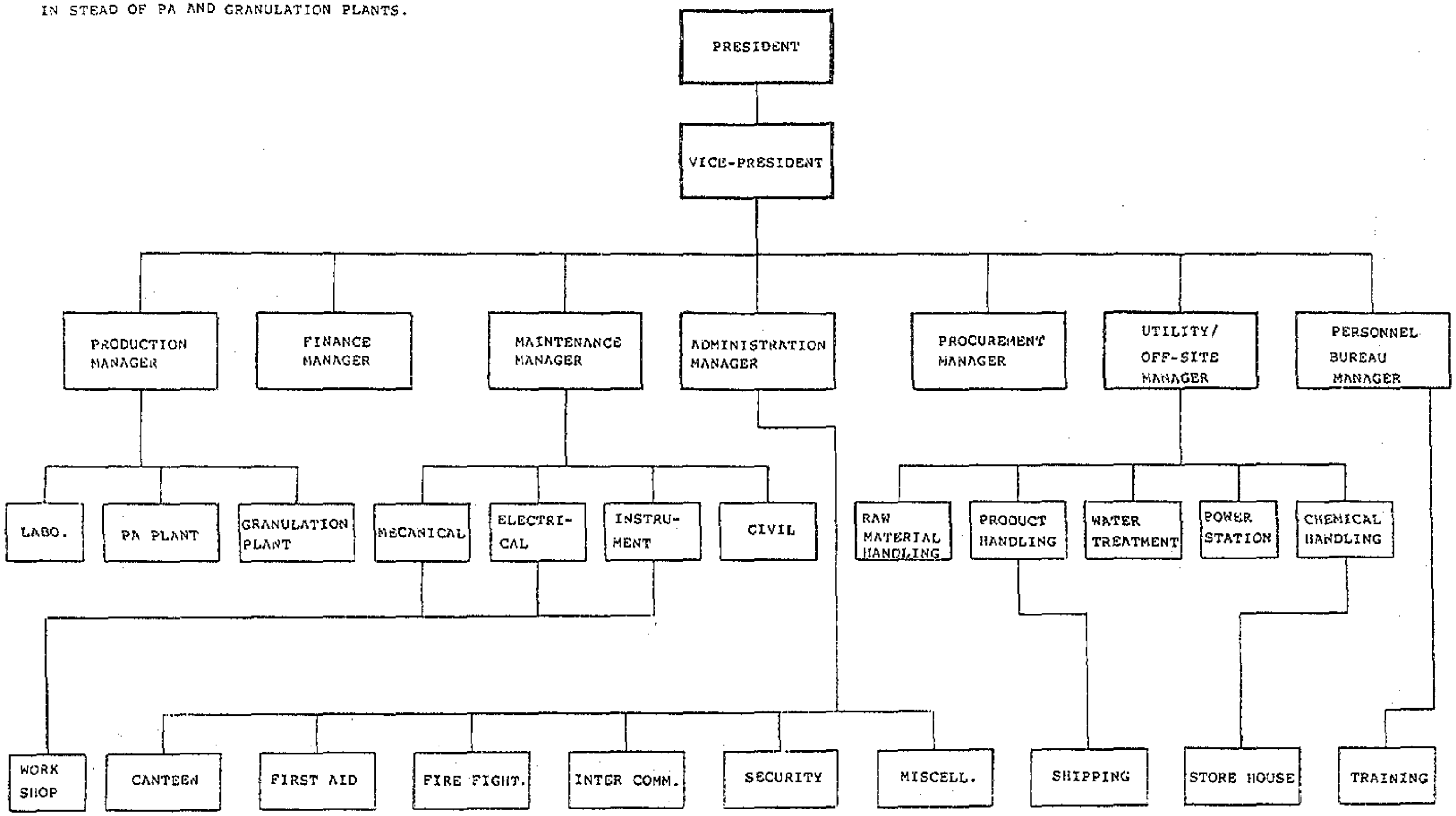


FIGURE 7-5-1 TYPICAL ORGANIZATION FOR FACTORY MANAGEMENT
(SCENARIO 1)

Table 7-5-4 Required Personnel for Factory Management

	Person/Shift	Shift	Total
(a) Management			
-President	1		1
-Vice President	1		1
-Personel Bureau Manager	1		1
-Procurement Manager	1		1
-Finance Manager	1		1
-Administation Manager	1		1
-Production Manager	1		1
-Maintenance Manager	1		1
-Utility & off-site Manager	1		1
-(Secretary)	9		9
(b) Personal Bureau			
-Officer	2		2
(c) Procurement			
-Officer	2		2
(d) Finance			
-Officer	2		2
(e) Administration			
-Superintendent	1		1
-Officer	5		5
-Typist	5		5

	Person/Shift	Shift	Total
-Telephone Exchanger	1	4	4
-Driver	4		4
-Canteen	3	2	6
-First Aid	1	4	4
-Fire Fighting	1	4	4
-Guard Man	2	4	8
-Sweeper	3		3

(f) Production

SCENARIO 1

PA PLANT			
-Superintendent	1		1
-Shift Engineer	1	4	4
-Operator	3	4	12
-Worker	10	4	40
GRANULATION PLANT			
-Superintendent	1		1
-Shift Engineer	1	4	4
-Operator	2	4	8
-Worker	2	4	8
LABORATORY			
-Chemist (central)	2		2
-Chemist (local)	2	4	8

	Person/Shift	Shift	Total
SCENARIO 2			
AMMONIA PLANT			
-Superintendent	1		1
-Shift Engineer	4	4	16
-Operator	2	4	8
-Worker	9	4	36
PA PLANT			
-Superintendent	1		1
-Shift Engineer	1	4	4
-Operator	3	4	12
-Worker	10	4	40
GRANULATION PLANT			
-Superintendent	1		1
-Shift Engineer	1	4	4
-Operator	2	4	8
-Worker	2	4	8
LABORATORY			
-Chemist (central)	2		2
-Chemist (local)	2	4	8
SCENARIO 3			
FMP PLANT			
-Superintendent	1	4	4
-Shift Engineer	1	4	4
-Operator	4	4	16

	Person/Shift	Shift	Total
-Worker	4	4	16
LABORATORY			
-Chemist (central)	1		1
-Chemist (local)	1	4	4

(g) Maintenance

	Person/Shift	Shift	Total
MECHANICAL			
-Superintendent	1		1
-Shift Engineer	1	4	4
-Trchnician	3	4	12
-Worker	2	4	8
ELECTRICAL			
-Shift Engineer	1	4	4
-Technician	1	4	4
INSTRUMENT			
-Shift Engineer	1	4	4
-Technician	1	4	4
CIVIL			
-Civil Engineer	1		1
WORK SHOP			
-Superintendent	1		1
-Technician	2	4	8
-Welder	1	4	4
-Worker	1	4	4

	Person/Shift	Shift	Total
(h) Utility and Off-Site Facilities			
RAW MATERIAL HANDLING			
-Operator	1	4	4
-Driver	3	4	12
-Worker	1	4	4
PRODUCT HANDLING			
-Operator	1	4	4
-Driver	2	1	2
-Worker	2	1	2
WATER TREATMENT			
-Superintendent	1		4
-Operator	3	4	12
-Worker	1	4	4
POWER STATION			
-Engineer	1		1
-Operator	1	4	4
CHEMICAL HANDLING			
-Engineer	1		1
-Worker	1		1
SHIPPING			
-Operator	2	1	2
-Worker	8		8
STORE HOUSE			
-Officer	1		1
-Worker	2	3	6

Total Personnel

SCENARIO 1=287
SCENERIO 2=348
SCENARIO 3=244