JAPAN INTERNATIONAL COOPERATION AGENCY

CENTRAIS ELETRICAS DO SUL DO BRASIL S.A.
COMPANHIA ESTADUAL DE ENERGIA ELETRICA-RS

THE STUDY ON EVALUATION OF ENVIRONMENTAL QUALITY IN REGIONS UNDER INFLUENCE OF COAL STEAM POWER PLANTS IN THE FEDERATIVE REPUBLIC OF BRAZIL

FINAL REPORT

September 1997

SUURI-KEIKAKU CO., LTD.
TOKYO ELECTRIC POWER ENVIRONMENTAL ENGINEERING CO., INC.

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PREFACE

In response to the request from the Government of the Federative Republic of Brazil, the Government of Japan decided to conduct the Study on Evaluation of Environmental Quality in Regions under Influence of Coal Steam Power Plants in the Federative Republic of Brazil and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent to Brazil the Study Team, led by Mr. Masaaki Noguchi of Suuri-keikaku Co., Ltd. (SUR) and organized by SUR and Tokyo Electric Power Environmental Engineering Co., Inc., to Brazil five times from June 1995 to July 1997.

The Team held discussions with the officials concerned of the Governments of Brazil and of related States, and conducted field surveys. After returning to Japan, the Team conducted further studies and compiled the final results in this report.

I hope this report will contribute to the future evaluation of environmental quality and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Federative Republic of Brazil and the States of Santa Catarina and Rio Grande do Sul for their close cooperation throughout the Study.

September 1997

Kimio Fujita
President
Japan International Cooperation Agency

September 1997

Mr. Kimio Fujita
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir:

We have pleasure of submitting to you the Final Report of "The Study on Evaluation of Environmental Quality in Regions under Influence of Coal Steam Power Plants in the Federative Republic of Brazil". This report presents the monitored and evaluated influence by the three coal steam power plants located in the state of Santa Catarina or Rio Grande do Sul upon ambient air of the regions within 20 km of the plants, and proposes countermeasures drawn from the evaluation.

The report consists of the summary and the main volumes. The summary volume gives essences of the study results, and the main volume contains all the methods employed and results obtained. The main volume is attached with necessary information such as the detailed data, analytical and evaluative methods, etc.

On this occasion, we would like to express our deep appreciation and sincere gratitude to all those who extended their kind assistance and cooperation to the Study, in particular the officials from Centrais Electricas do Sul do Brasil S.A., Companhia Estadual de Energia Eletrica - RS, Fundacao do Meio Ambiente - SC, Fundacao Estadual de Protecao Ambiental - RS, Agencia Brasileira de Cooperacao, and Ministerio de Minas e Energia. We also would like to extend our acknowledgments to the officials of your agency, the Ministry of Foreign Affairs, the Ministry of International Trades and Industries, the Japanese Embassy in Brasilia, and the Japanese Consulate General in Porto Alegre.

We hope the report will realistically contribute to the development of the Brazilian coal steam power plants and Brazil itself.

Sincerely yours,

Masaaki Noguchi
Study Team Leader

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LIST of ABBREVIATIONS

ABC	Agencia Brasileira de Cooperacao
A-P	Precipitation
B/T	Brazilian Counterpart Teams
CEEE	Companhia Estadual de Energia Eletrica - RS
CMB	Chemical Mass Balance
CONAMA	National Environmental Council
C/P	Counterpart(s)
De-NOx	Nitrogen Oxides Removal Plant or Process
De-SOx	Sulfur Oxides Removal Plant or Process
DF/R	Draft Final Report
ELETROSUL	Centrais Eletricas do Sul do Brasil S/A
EC	Electro-conductivity
EIA	Environmental Impact Assessment
EP or ESP	Electrostatic Prepicitator
FATMA	Fundacao do Meio Ambiente-SC
FEPAM	Fundacao Estadual de Protecao Ambiental-RS
FGD	Flue Gas Desulfurization
FLP (or FLN)	Florianopolis - SC
F/R	Final Report
GOJ	Government of Japan
HC	Hydrocarbons
IBAMA	Brazilian Institute for Environment and Renewable Natural Resources
IC/R	Inception Report
I/M	Inspection and Maintenance
IT/R	Interim Report
JICA	Japan International Cooperation Agency
JIS	Japan Industrial Standards
J/T	JICA Study Team
MMA	Ministry of Environment, Water Resources and Legal Amazon
MME	Ministry of Mines and Energy
n.a. or na	not available
NETR	Net Radiation
NOx	Nitrogen Oxides (NO & NO_2)
OJT	On the Job Training
OS	Operation System
PM	Particulate Matter
PM10	PM under 10 microns
POA	Porto Alegre - RS
PTIO	2-phenyl-4,4,5,5-tetramethylimidazoline-3-oxide-1-oxyl
RIMA	Environmental Impact Statement
ROM	Run of Mine
RS	State of Rio Grande do Sul
SC	State of Santa Catarina
SOx	Sulfur Oxides (SO_2 & SO_3)
SPM	Suspended Particulate Matter
SUN	Solar Radiation
S/W	Scope of Work
TEA	Triethanolamine
TSP	Total Suspended Particulates
U or u	Unit (usually with a numeral - indicating the plant unit number, ex. 3u)
WB or W/B	World Bank
WHO	World Health Organization
¥	Currency unit of Japan: U.S.A. $ 1.00 = ¥120 in this Report

CHAPTER 1 INTRODUCTION

1.1 Background

This is the Draft Final Report of the Study on Evaluation of Environmental Quality in Regions under Influence of Coal Steam Power Plants in the Federative Republic of Brazil (the Study). Coal power plants in Brazil have been concentrated in its southern states, Santa Catarina and Rio Grande do Sul. The Ministerio das Minas e Energia (Brazil) has planned to expand coal power plants in the future to compensate for the gradually decreasing availability of hydraulic sources. The Ministerio solicited assistance **(Appendix 1-1)** from the Government of Japan (GOJ) in evaluating the air quality of the regions surrounding the coal power plants.

In response to this request, GOJ appointed the Japan International Cooperation Agency (JICA) as the executing agency. It concluded the Scope of Work for the Study **(Appendix 1-2)** in January, 1995, with the Brazilian executing agencies, Centrais Electricas do Sul do Brasil S/A (ELETROSUL) and Companhia Estadual de Energia Eletrica (CEEE).

JICA set up the JICA Team composed of members from the private sector, for implementation of the Study. The JICA Team commenced the Study by joining the Brazilian side in discussion of its Inception Report in June, 1995.

The Brazilian governmental policies of privatization, pollution prevention, and natural gas utilization in relation to power generation have become clear during the course of the Study. Accordingly, the expansion plan of the Candiota III Coal Steam Plant was cut back from 2100 MW to 350 MW. Construction at the Jacui I Plant is still under suspension. Meanwhile, the one remaining expansion plan of Jorge Lacerda IV was completed during the Study at the end of 1996 and has been in operation since then.

The Report is composed of the Executive Summary and the Main Report. The latter is separated into the main body and Appendices: documents, data, methodologies, etc. prepared in relation to the Study. Quoted sources of data, literature, information, etc. are identified with a # number in parentheses in the Report and listed in the References section.

1.2 Study Overview

1.2.1 Objectives

The objectives of the Study were to evaluate the environmental quality of air in regions under influence of coal steam power plants, and to contribute to the planning for development of coal steam power plants by transferring related technologies to Brazilian personnel.

1.2.2 Study Regions and Pollutants

The power plants concerned were Jorge Lacerda, Charqueadas, and Candiota as in **Fig. 1.2.1**. Individual units in the plants are listed in **Table 1.2.1** including the known future plan.

Table 1.2.1 Units in Power Plants Studied

Name of Power Plant (Operator)	Unit Code	Rated Capacity	Year in Operation
Jorge Lacerda	A Ⅰ-1	50 MW	1961
(ELETROSUL)	A Ⅰ-2	50	1963
	A Ⅱ-3	66	1972
	A Ⅱ-4	66	1972
	B Ⅲ-5	125	1977
	B Ⅲ-6	125	1977
	Ⅳ	350	12/1996
Charqueadas	1	18	1956
(ELETROSUL)	2	18	1956
	3	18	1956
	4	18	1968
	Jacui 1	350	12/1999
Candiota (CEEE)	Ⅱ A-1	63	1974
	Ⅱ A-2	63	1974
	Ⅱ B-1	160	1986
	Ⅱ B-2	160	1986
	Ⅲ	350	(9/2003)

The study regions encompassed roughly 20 km around each of the three plants. The pollutants that the Study concentrated on were sulfur dioxide, nitrogen oxides, and particulate matter in ambient air and stack gases. Also the main ion ingredients and acidities of rain and soluble dry precipitation were monitored at one point in each region, and as well as in Acegua although it was located more than 20 km from the Candiota Power Plant. Eight elements in particulate matter, air and stack gases, were analyzed under subcontract to a local laboratory.

1.2.3 Task Organizations

Members of the JICA Study Team are listed in **Table 1.2.2**. The names and roles of the members of the two Brazilian teams, and the sections they belong to are given in **Table 1.2.3**. The supervision of the CEEE Team was altered from the middle of 1996.

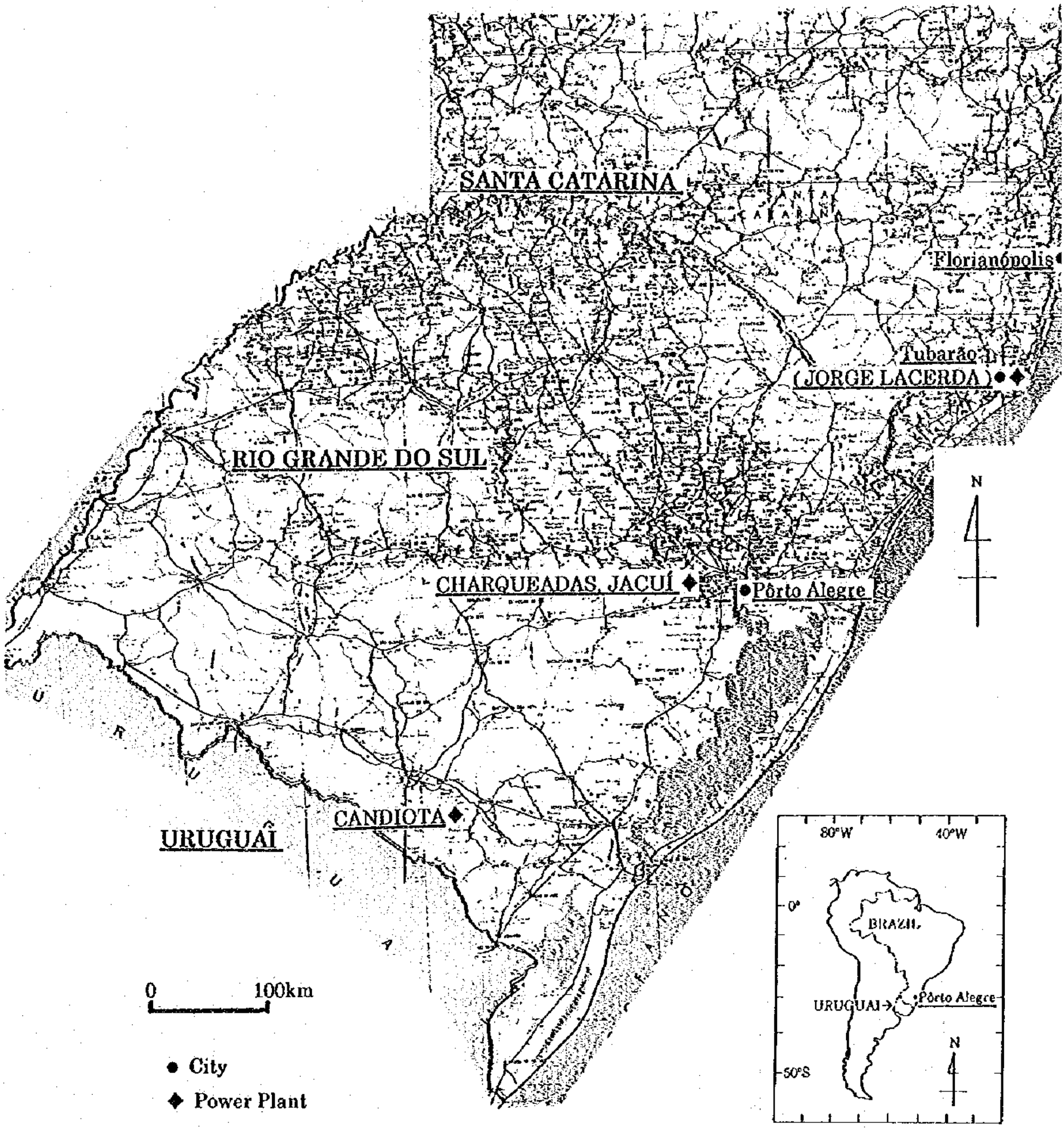


Fig. 1.2.1 Location of Power Plants in the Study

Table 1.2.2 JICA Study Team

NAME	MAJOR ROLE
Masaaki Noguchi	Supervision
Takeo Akizawa	Assistant Supervision, Control Measures, Power Plant
Haruo Kikuchi	Air Quality Evaluation, & Air Quality Monitoring Plan
Kenji Takahama	Air Quality Monitoring
Tamiki Umezawa	ditto
Toshiki Nagasawa	Stack Gas Monitoring & Its Plan
Yoshifumi Zama	Stack Gas Monitoring & Its Plan
Toshio Nakajima	Chemical Analysis
Akeo Fukayama	Numerical Analysis

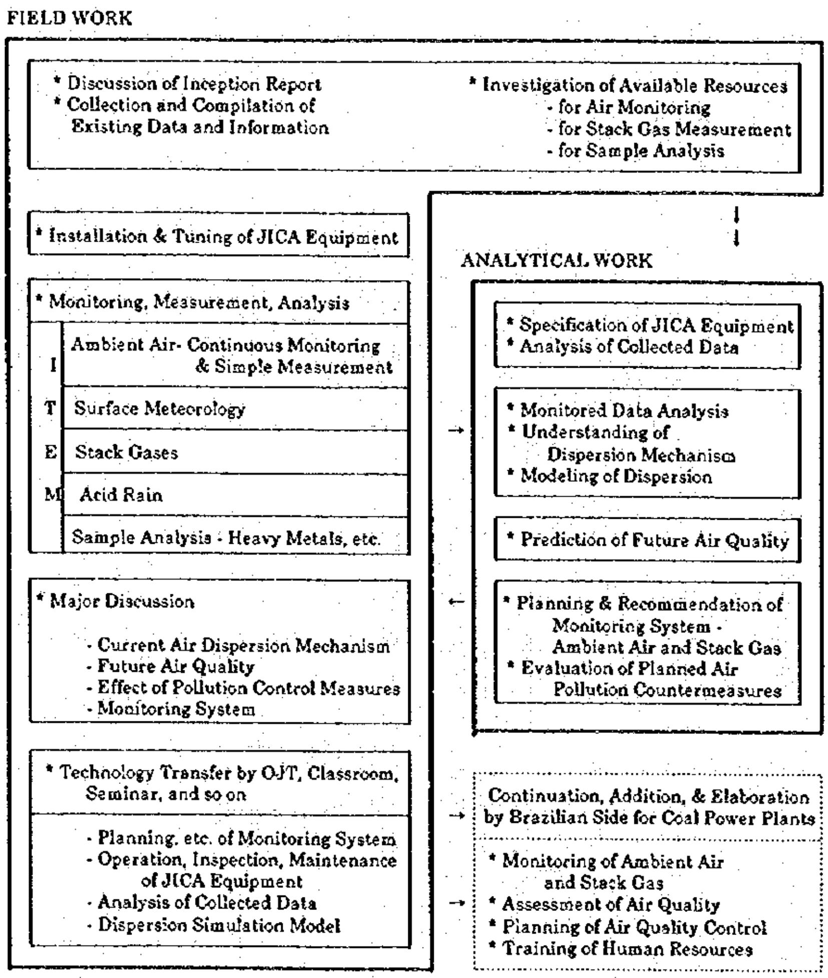


Fig. 1.2.2 Outline of Study

Table 1.2.3 Brazilian Study Teams

ELETROSUL Team

	Major Role	Name	Position
1	Supervision	Edison Pereira de Lima	Gerente de Meio Ambiente - FLP
2	Air Quality Evaluation and Monitoring Plan	Ligia Bittencourt da Silva	Planejamento - FLP
		Maristela B. Mendes	Setor Engenharia Ambiental - FLP
3	Stack Gas Monitoring Plan	Jose Lourival Magri	Planejamento - FLP
		Christiane R. Coelho	Setor Engenharia Ambiental - FLP
4	Air Quality Monitoring	Ligia Bittencourt da Silva	Planejamento - FLP
		Maristela B. Mendes	Setor Engenharia Ambiental - FLP
		Alexandre Thiele	Chefe Laboratorio - Jorge Lacerda
		Etilio Tuiscon Kich	Chefe Laboratorio - Charqueadas
		Paulo Vinicius Lima	Laboratorio - Charqueadas
		Amaro Vaz Machado	Laboratorio - Charqueadas
		Daniel Aguiar	Laboratorio - Jorge Lacerda
		Wherinton Cavalcanti	Laboratorio - Jorge Lacerda
5	Stack Gas Monitoring	Jose Lourival Magri	Planenamento - FLP
		Christiane R. Coelho	Setor Engenharia Ambiental - FLP
		Alexandre Thiele	Chefe Laboratorio - Jorge Lacerda
		Etilio Tuiscon Kich	Chefe Laboratorio - Charqueadas
		Luiz Henrique Lague	Laboratorio - Charqueadas
		Sergio Rios Martins	Laboratorio - Charqueadas
		Claudio Ludke Konradt	Laboratorio - Jorge Lacerda
		Jose Antonio da Rosa	Laboratorio - Jorge Lacerda
		Daniel Rolim Rodrigues	Laboratorio - Jorge Lacerda
6	Chemical Analysis	Alexandre Thiele	Chefe Laboratorio - Jorge Lacerda
		Etilio Tuiscon Kich	Chefe Laboratorio - Charqueadas
		Sergio Rios Martins	Laboratorio - Charqueadas
		Simone Menezes	Laboratorio - Charqueadas
		Rita Tissot	Laboratorio - Charqueadas
		Mozart Antunes Maciel	Laboratorio - Jorge Lacerda
		Gisan Vitoria da Costa	Laboratorio - Jorge Lacerda
7	Numerical Analysis	Jose Lourival Magri	Planejamento - FLP
		Alex Dias de Azevedo	Planejamento - FLP
		Christiane R. Coelho	Planejamento - FLP
		Ligia Bittencourt da Silva	Planejamento - FLP

CEEE Team

	Major Role	Name	Position
1	Supervision	Sergio Ladniuk	Coordenador de Meio Ambiente - POA
		Claudio Krebs	ditto
2	Air Quality Evaluation and Monitoring Plan	Antonio Carlos Rossato	Coordenadoria de Meio Ambiente - POA
		Luiz Henrique Mengatto	Secao de Planejamento - Candiota
		Francisco Porto	Secao de Meio Ambiente - Candiota
		Plinio Slomp	Secao de Hidr. e Meio Ambiente - POA
3	Stack Gas Monitoring Plan	Francisco Porto	Secao de Meio Ambiente - Candiota
		Marines Ceolin	Secao de Meio Ambiente - Candiota
4 5	Air Quality and Stack Gas Monitoring	Ciro Vitoria Pinto	Secao de Meio Ambiente - Candiota
		Plinio Slomp	Secao de Hidr. e Meio Ambiente - POA
		Aquiles Indurski	Secao de Hidr. e Meio Ambiente - POA
		Lazareno Cardoso	Secao de Meio Ambiente - Candiota
		Marines Ceolin	Secao de Meio Ambiente - Candiota
		Eloa Maria Dhiel	Secao de Meio Ambiente - Candiota
		Renato Ferraz	Secao de Meio Ambiente - Candiota
6	Chemical Analysis	Francisco Porto	Secao de Meio Ambiente - Candiota
		Jose Manuel C. Pinheiro	Laboratorio Central - POA
		Harry Breier	Laboratorio Central - POA
		Nadir Salete Rodrigues	Laboratorio Central - POA
7	Numerical Analysis	Claudio Krebs	Coordenadoria de Meio Ambiente - POA
		Plinio Slomp	Secao de Hidr. e Meio Ambiente - POA
		Aquiles Indurski	Secao de Hidr. e Meio Ambiente - POA

1.2.4 Work

The Study progressed as scheduled (**Table 1.2.4**). It consisted of field work and analytical work as in **Fig. 1.2.2**, these being respectively divided into five and four stages. The major tasks of each stage were as follows:

1) First Field Work	Discussion of the Inception Report, and collection of data & information for inception of the Study
2) First Analytical Work	Preparation for specifications of the JICA Equipment
3) Second Field Work	Commencement of air and stack gas monitoring
4) Second Analytical Work	Preparation of the Interim Report (IT/R)
5) Third Field Work	Discussion of the IT/R and continuation of monitoring
6) Third Analytical Work	Preparation of air dispersion model
7) Fourth Field Work	Checking of the JICA Equipment and technology transfer of the dispersion model
8) Fourth Analytical Work	Preparation of Draft Final Report

1.2.5 JICA Equipment

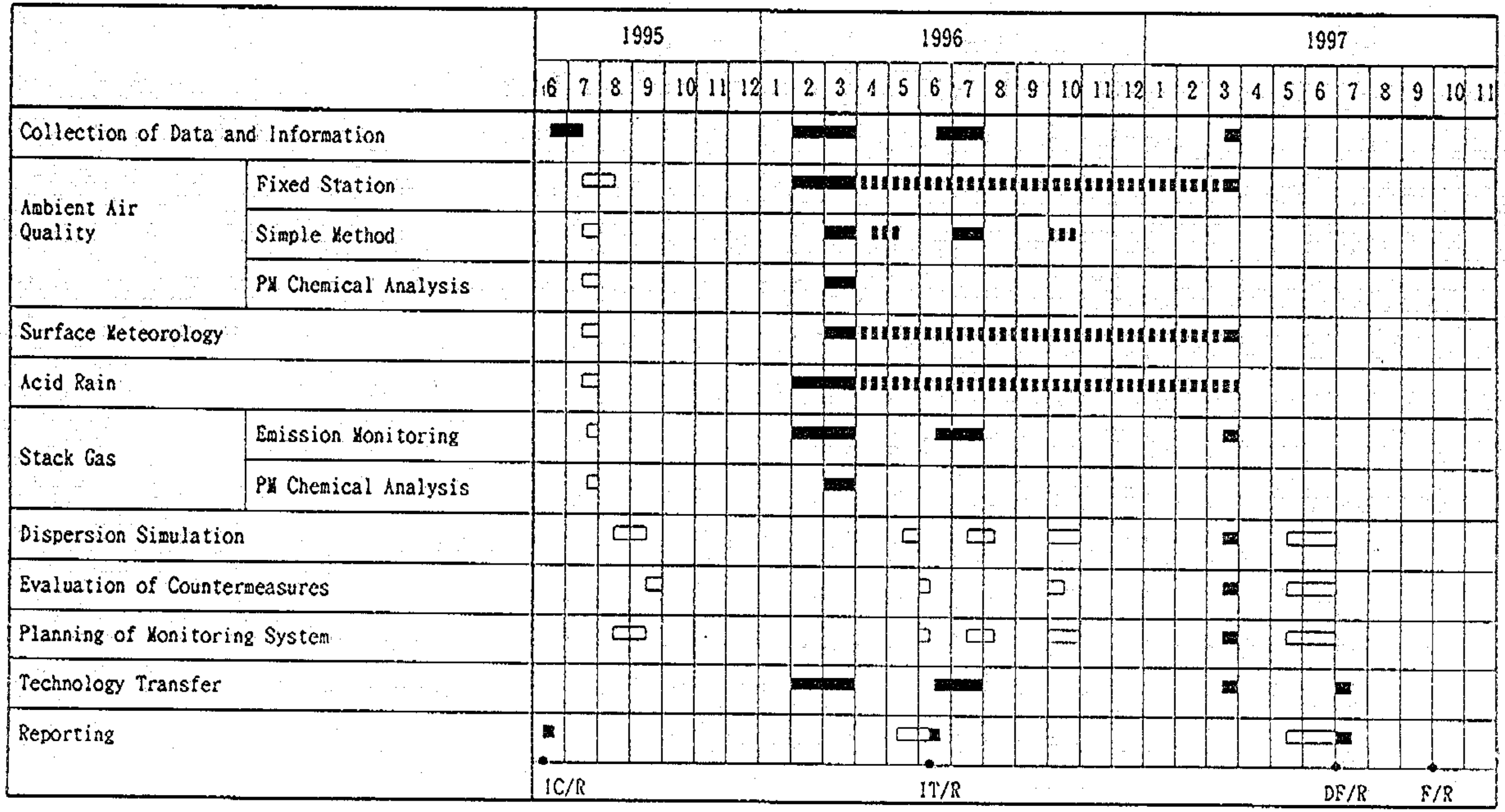
The Study utilized equipment possessed by the Brazilian side (**Appendix 1-3**) and supplied by JICA in accordance with the requisites stipulated by the JICA Team (**Appendix 1-4**). Some of the equipment was purchased in Brazil by JICA.

Among the JICA Equipment, the ambient air automatic SO_2 analyzers had troubles with their optical filters after around six months of operation. The manufacturer investigated the reasons for the malfunction and supplied newly designed filters. During the investigation, data was not taken for one to three months at several monitoring stations. Also one pitot tube velocity meter had its sensor broken for some unknown reason. The JICA Team repaired it in Japan and brought it back to Brazil. Other equipment was mobilized in place of the velocity meter during the repairs.

1.2.6 Technology Transfer

All the measurements and monitoring at the sites were carried out with the cooperation of the Brazilian Teams. The JICA Team transferred necessary technologies to the Brazilian side before commencement of the monitoring by lectures, and at the sites by on-the-job training working together side by side. Once the transfer was completed, the JICA Equipment was operated and maintained by the Brazilian Teams. The details of the transfer were set forth in **Appendix 1-5**, cited from the Interim Report of June, 1996, and in additional materials.

Table 1.2.4 Overall Work Schedule



Note : ▬ Field work in Brazil
▮▮▮▮ Field work in Brazil by Brazilian Team only
▭ Analytical work in Japan

CHAPTER 2 SOCIOECONOMICAL CONDITIONS PERTAINING TO THE POWER SECTOR

2.1 Current Socioeconomics and Development Plans

2.1.1 Outline of Brazil (#066,#067)

(1) Formal country name : The Federative Republic of Brazil

(2) Location and Area :

Location :	From 05° 16' 20" in north lat. to 33° 44' 32" in south lat.
	From 34° 47' 30" in west long. to 73° 59' 32" in east long.
Area :	8,511,965km^2 (22.5 times as large as Japan)

(3) Geographical Features :

Brazil is roughly classified to the Guiana Highland, the Brazilian Plateau, the Amazon Plain, the Paraguay Plain and the seaside plain. About 60% of the country is at or higher than 200 meters above the sea level, while the percentage of heights over 900 meters above the sea is only 3%. The highest peak is Mr. Pico da Neblina, 3,014 meters above the sea. The country is blessed with rivers with a plenty of water which are important traffic means. Length of rivers where navigation is possible reaches 44,000km. Among them, the Amazon is a long river ranked the second in the world. Area of this river basin in the country, 4,778,372km^2, accounts for 56% of the territory of Brazil. Total length of the Sao Francisco River is 3,161km and runs between the central heights and the Atlântico heights. The Parana River has many waterfalls such as Iguazu and is rich in water power resources.

(4) Climate :

As the country is vast, climate in each district is different. Climate is that of tropical rain forest in the north section (the Amazon zone etc.), subtropical climate in the central heights and the seaside plain (Brazilia, Rio etc.), semi-desert dry climate in the mountainous zone in the northeast section, and temperate climate in the south section (Sao Paulo and southward). The average annual precipitation ranges from 700mm in the dry area to 3,000mm in the tropical rain forest area.

(5) Population : 159 million (estimated in 1995)

(6) Administration :

The four-year president system is employed. The country is divided to 26 states including the Brazilian Metropolitan area and one federal district. Governors and assemblies are selected by direct election. Two states with the districts covered by this investigation, Santa Catalina and Rio Grande do Sul, are located at the southernmost end.

(7) Language: Portuguese (official language)

(8) Religion :

Brazil is the largest Catholic country in the world. About 90% of the people are Catholics and the percentage of Protestants is approximately 7%.

2.1.2 Economic Summary and Policies for Economic Development

(1)Economic Policies

In December, 1993, the economic stabilizing operation was set out by Cardoso, Finance Minister at that time (the present President). Later, the plan was named the "Real Plan" after the name of new currency. The result has brought a great tuning point in Brazil. The Federal Government acted firmly to maintain monetary stability by credit restriction, the maintenance of high interest rates, change in the exchange rate policy with the creation of currency bands, the limitation of the import of goods, etc. It changed the monetary unit from the Crusado to the Real on July 1, 1994. Notably the policies generate a strong reduction in the market liquidity, cooling of the growth rate of industrial expansion and the control of inflation. Annual inflation rate of 2,668.5 % in 1994 was reduced to 23% at the late of 1995. During the Study, the monetary conversion of one U.S. Dollar has been changed substantially in the small rate from R$ 0.895 in June, 1995 to R$ 1.035 in March, 1997.

(2) Movements after Introduction of New Currency (Real)

Policies for finance and exchange are a key to maintain stability of present Brazilian economy. Backed by rapid increase in domestic demand, the great growth have been maintained after introduction of Real. In the meantime, due to a series of tight-money actions by the Government, decline of production activities became remarkable in the second half of 1995. Although the rate of economic grow in 1995 was 4.2%, uncertainty about the future is still remained.

(3) Characteristics of Brazilian Economy: from the past to the present

① Brazilian economy successfully ranked among middle developed countries in the latter half of 1970 as a result of high economic growth from 1960s to 1970s

② However, the industrial structure became biased, and so-called supporting industry was changing without being mature due to rapid industrialization. In addition, monopolistic and oligopolistic features was formed. For example, the nucleuses of main industrial departments were limited to national enterprises and to a part of large native capitals and foreign-affiliated companies. In addition to payment of obligations to foreign countries, export incentives were required to realize the trade surplus to be used for the payment. Furthermore, public finance had resulted in suffering chronic deficits because financially supplementary payments to national enterprises increased due to the policy of relatively lower public utilities rates regardless of increase in costs.

③ In 1990s, it was decided that what would be aimed at should be policies for liberalization/opening of economy by, for example, placing national enterprises under private management and by liberalizing import. The first organization placed under private management in October 1991 was Usiminas Iron Mill. Organizations in the electric power department are also being placed under private management now.

④ In the electric power sector, a bill to establish the Electric Power Agency was passed in the Lower House and sent to the Upper House in July 1996. The purpose of the Agency is to coordinate problems regarding private management in the electric power sector such as Electric Power Public Corporation (ELETROBRAS). As to ELETROBRAS, it was known that, in late July 1996, a tender was made for consulting works to place five thermal electric power plants, five hydroelectric plants, and Manaus and Bolivista Electric Power Systems under private management. All of them are parts of the ELETROBRAS organization..

⑤ Brazil held the tenth place in the world GNP in 1993, and now takes the position following advanced countries with G7 countries as a center. GNP and GDP of Brazil are shown in **Table 2.1.1.** In consideration of the vast territory, abundant underground resources, plentiful labor etc. there are limitless possibilities regarding its future.

Table 2.1.1 Gross Product in Brazil

(# 046, 055, 056,062)

	Gross National Product	Gross Domestic Product
US million $ in 1993	458,504	507,353
ditto in 1991	442,698	405,771
US$ per capita in 1995	3,640	---------
1993	2,930	3,242
ditto in 1991	2,920	2,677
ditto in 1990	2,680	--------
Average growth in 1983-93	2.6%	2.2%
ditto in 1980-91	2.5%	2.5%

Note: Distribution of Gross Domestic Production (#055)

- Agriculture 11%, Industries 37%,and Services 52% in 1991

2.1.3 Energy and Reserves in Brazil

The energy and reserves in Brazil is shown in **Table 2.1.2**

Table 2.1.2 Energy and Reserves in Brazil (1994) (#050)

	unit	Measured/ Indicated/ Inventoried	Inferred/ Estimated	Total Reserved (T)	Annual Consumpt-ion	Annual Product-ion (A)	Ratio (T)/(A)
Petroleum	10^3 m^3	658,906	349,228	1,008,134	74,418	38,766	26
Natural Gas	10^6 m^3	146,476	86,915	233,391	5,136	7,756	30
Shale Oil	10^3 m^3	445,100	9,402,000	9,847,100	n.a.	n.a.	n.a.
Coal	10^6 t	10,157	22,239	32,396	see below	see below	n.a.
Steam Coal	10^6 t	n.a.	n.a.	n.a.	5.12	5.19	6,242
Metal.Coal[1)]	10^6 t	n.a.	n.a.	n.a.	10.61	0.05	n.a.
Hydraulic	GW year	82.7	51.8	134.5[2)]	n.a.	28	4.8
Nuclear	tons-U^{308}	192,540	108,950	301,490	0	0	n.a.
Peat	10^3 t	129,330	357,960	487,290	n.a.	n.a.	n.a.

Note: 1) Metal. Coal: for metallurgical use, almost imported

2) The largest potential power generated during the worst hydrological period

3) n.a. : not available in the reference

2.2 Electric Sector in Brazil

2.2.1 General Overview of Electric Sector in Brazil

(1) Organization

The electric sector in Brazil has been controlled by Centrals Electricas Brasileiras (ELETROBRAS) subject to the jurisdiction of the Departamento Nacional de Aguas e Energia Eletrica (DNAEE), which is one of organization in the Ministry of Mine and Energy (MME). DNAEE has the rights of controlling and overseeing transmission and distribution of electric power including making plans for generation plants, licensing, setting up electric price, etc. Accordingly, ELETROBRAS makes solid plans and executes the plans, and raises funds for the execution. ELETROBRAS has four regional electric power companies under its direct control; ELETRONORTE, CHESF, FURNAS and ELETROSUL, which cover respectively from the north, northeast, southeast and south of Brazil. The regional companies sell their product to state power companies which sell it to end users in each state. The state power companies can also generate electric power in their own plants. Besides the public power plants controlled by ELETROBRAS, there are plants generate power for self use. **Fig. 2.2.1** shows the organization of the electric sector in Brazil.

ELETROSUL covers for four states, i.e. Parana, Santa Catarina, Rio Grande do Sul and Mato Grosso do Sul. CEEE is for the state of Rio Grande so Sul.

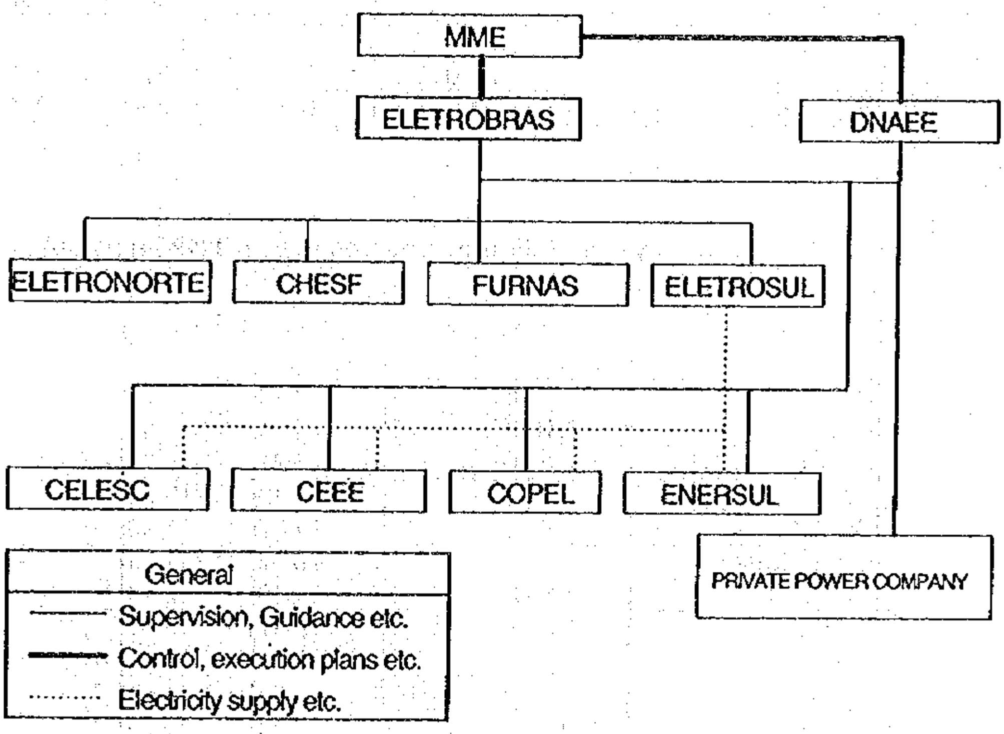


Fig. 2.2.1 Organization of Electric Power Sector in Brazil
(A part of the organization which does not relate to the Study is omitted)

(2) Power Generation

The generated and consumed amounts of electricity and generation capacity by energy sources are respectively shown in **Table 2.2.1** and **2.2.2**. The hydraulic source generates about 93% of all electricity in Brazil. **Table 2.2.3** shows installed capacity of power plants. Again the hydro-power accounts majority of the capacity: 87%.

The Itaipu Plant mentioned in **Table 2.2.3** was the hydraulic power plant constructed cooperatively by Brazil and Paraguay. Brazil has a right to use 50% of the total generation. The Itaipu Plant has a installed capacity of 12,600 MW and generation capacity of 70,000 GWh. The nuclear plant given in **Table 2.2.2** has been in operation from 1984 and the maximum production in the past was 3381 GWh in 1985 which was 59% of the installed capacity. Annual average load factors were 55.5% for hydraulic and 24.7% for thermal, in 1994 in all of the public and private plants.

Table 2.2.1 Electricity in Brazil

Year	Public Power Plants	Private Production Plants	Import	Export	Loss & Adjustment	Total Consumption
1990	210,913	11,907	26,545	-7	-31,701	217,657
1992	228,711	13,020	24,022	-8	-35,273	230,472
1994	245,593	15,089	31,657	-0	-41,830	250,509

Unit in GWh (#050)

Table 2.2.2 Electricity Generation by Sources in Brazil (1994) (#050)

Sources	Public Plants		Private Plants	
	GWh	%	GWh	%
Natural Gas	0		416	2.76
Coal	3,105	1.26	214	1.42
Firewood	0		921	6.10
Bagasse	--		2,348	15.56
Black Liquor	--		1,807	11.98
Other Waste	--		1,752	11.61
Diesel Oil	1,841	0.75	319	2.11
Fuel Oil	1,389	0.57	2,017	13.37
Coke	--		543	3.60
Nuclear	55	0.02	--	--
Hydraulic	239,203	97.40	3,714	24.61
Others	--		1,039	6.88
Total	245,593	100.00	15,089	100.00

(3) Counterpart Power Companies

ELETROSUL is a subsidiary of ELETROBRAS as described before. CEEE is a company owned by the State of Rio Grande do Sul. The electricity generation amounts of

ELETROSUL and CEEE are given in **Table 2.2.4**.

Table 2.2.3 Installed Capacity of Electric Generation in 1994 (#050)

	Thermal	Nuclear	Hydraulic	Total in MW
Public Plants	4,155	657	1)49,304	54,116
Private Plants	2,900	0	624	3,524
Total in MW	7,055	657	49,928	57,640

Note: 1) includes half of Itaipu Plant (total installed capacity 12,600 MW)

ELETROSUL sells its generated power to FURNAS (a subsidiary of ELETROBRAS) and the four southern state companies of Parana, Santa Catarina, Rio Grande do Sul (CEEE) and Mato Grosso do Sul; around 36 % of its production to CEEE. On the other hand, CEEE generate electricity in its own power plants, and distribute and sell it together with the one purchased from ELETROSUL to industrial, commercial, rural and residential customers in almost 98% of Rio Grande do Sul. Its sales amounts was 13,268 GWh in 1993 (#036).

Table 2.2.4 Power Generation by Counterpart Companies

	Installed Capacity in MW (1993)				Generation in GWh		
	Coal	Oil	Hydraulic	Total	Coal & Oil	Hydraulic	Total
ELETROSUL	554	66	2602	3,222	1,787	13,469	15,256
CEEE	446	--	820	1,266	2,483	3,758	6,241

Source:1) Generation data in 1994 for ELETROSUL (#051) and 1993 for CEEE (#036)
2) Installed capacity data from (#036, and 057)

The two companies are the exceptions in Brazil who generate electricity from coal in substantial amounts.

(4) Coal for Power Generation

Coal power generation in Brazil not only shoulders a supplementary role for hydraulic power generation, but also contributes to keeping coal business in this country. Although the coal consumption is still low in terms of the amount of energies supplied in whole of Brazil, being 5%, it is expected that coal will be increasingly used mainly as a fuel for thermal power generation in the future, according to steady growth of electricity demand. **Table 2.2.5** is to show coal reserves and production in Brazil.

Total coal reserves in the whole of Brazil are identified to be about 32.3 billion tons, and of this figure, about 17.1 billion tons have been marginally indicated to be mined for. Coal fields are concentrated in the States of Rio Grande do Sul and Santa Catarina, the southern parts of Brazil. Although there are small mines in the States of Parana and Sao Paulo, their reserves and production are negligibly small. **Appendix 2-1** is to show coal production in Brazil and its sulfur contents.

In 1993, about 4.7 million tons of coal were produced, and all of them were consumed domestically. The Brazilian coal is low grade coal with generally such properties as high ash content, high oxygen, low calorific value and lack of caking. It is used mainly as a fuel. (#046,049)

Table 2.2.5 Coal in Brazil (#053)

State	Measured/ Indicated/	Estimated	Total Reserves		Production in 1993	
	tons 10^6	tons 10^6	tons 10^6	%	tons 10^3	%
Sao Paulo	4.50	4.00	8.50	0.03	n.a.	--
Parana	101.54	2.65	104.19	0.32	155.18	3.3
Santa Catarina	2,321.60	1,041.40	3,363.00	10.42	2,102.63	44.6
Rio Grande do Sul	14,644.14	14,159.30	28,803.44	89.23	2,452.46	52.1
Total Brazil	17,071.78	15,207.35	32,279.13	100.00	4,710.27	100.0

The total energy consumption in Brazil in 1994 was 199,134,000 tons-oil-equivalent (toe), whereas 1,938,000 toe was supplied by coal-power generation, being 1 % or less in 1994 (#050). Coal is expected to be used increasingly as a fuel for power generation in the future, riding along steady increase in electricity demand, in difficulty of hydraulic power source development, and giving security of power supply in shortage of rain. The State of Rio Grande do Sul which has 89% of the coal reserves of Brazil, has expected to increase coal participation in energy generation to be 55%. Coal mining is the major means of living for near-by people.

Meanwhile, the Rio Grande do Sul State Mining Corporation is proposing the partnership with a private sector for the exploitation of the chemical-industrial complex of Candiota (#052). Candiota reserves amount 3.0 billion tons of coal and produces over 200,000 tons/month by open mining.

(5) Gas for Power Generation

The state of Rio Grande do Sul has already agreed with the Argentinean national oil company, YPF, for undertaking a project to construct 440 km gas line to Urguaiana, the border city between Argentina and Rio Grande do Sul. The state government intends to have arranged concessions for the construction and operation of the 316 MW single cycle (or 450 MW combined cycle) gas power station in Urguaiana by private entrepreneurs (#052). Natural gas is also coming from Bolivia through 500 km extension of lines from Sao Paulo to Porto Alegre, the capital of Rio Grande do Sul, for industrial and public uses.

2.2.2 Policy for Power Generation

(1) Generation expansion plan

In 1992, ELETROBRAS set forth a ten-year(1993 to 2002) expansion plan. It was estimated in this plan that the annual growth rate of the electricity consumption would reach 5.5% in 1992 to 1997 and 5.7% in 1997 to 2002, respectively. Although the plan has been promoted enthusiastically, it is delayed considerably because of shortage of funds, influence of suspension of credit granted by international financial institutions, etc.

(2) Privatization

The monopoly in general is no longer in accordance with demands imposed by the economic reality which has market regulated price and quality as a basic competitiveness factor. The federal government begins to privatize various sectors, no exception of the electric sector. It is expected to undergo great changes. The Ministry of Mines and Energy is planning to have international consultants for the services of remodeling the Brazilian electric sector. Actually, ESCELSA (the State of Espirito Santo) was privatized with the transfer of the controlling shares to the private sector.

The legislative assembly of Rio Grande do Sul approved to offer 49% of shares to a private enterprise (# 052). CEEE is now studying the shape of the company, involvement of the state government, etc. With regard to the Candiota III (the new unit), CEEE has been decided that the 33% of its whole shares will be hold by private hands, the 33% by ELETROBRAS and the rest by the state in accordance with the decision of the state congress. The specified time limit for inviting tenders is now postponed because no private company has participated in tender for the consortium (deadline August, 1996) at a present. Following are the scheme CEEE has in mind:

a) One thermal power plant is to be held by divided ownership of private company, MME (ELETROBRAS or ELETROSUL) at the state (CEEE).
b) Three electric power distribution departments : two of them are to be sold to private hands and the remaining one is to be placed under the states' management.

c) One hydraulic power plant and one power transmission department are to be continued operating and their rights of management are to be maintained by holding 51% of shares by public hands and selling 49% the rest to private hands.

ELETROSUL is also looking for a partner of some projected plants' ownership. As for construction of the Jacui plant, ELETROSUL is planning to introduce private funds (U.S. companies etc.) and to purchase electricity from the newly established company (JACUI GENERATING COMPANY) on a 20 years contract.

CHAPTER 3 Environmental Air Regulations

3.1 Environmental Policy in Brazil

Environmental legislation in Brazil dates back to 1973 and was modeled mostly after U. S. law relying heavily on its standards and zoning. At that time, Brazil established a national Special Secretariat for the Environment within the Interior Ministry. Beginning in 1974, some State Environmental Protection Agencies were created.

The national environment management framework has since undergone periodic revision. In 1981, the Government established the National Environment Plan and the National Environment System (SISNAMA) – Law 6.938/1981. In 1984, a National Environment Council (CONAMA) was established to oversee SISNAMA. 1988, the federal agencies were integrated into the Brazilian Institute of Environment and Natural Resources (IBAMA), which maintains a superintendency in each state and focuses mainly on resource management and conservation issues. Immediately after the promulgation of the Constitution, in 1989, while the spirit of mobilizatin in defense of the environment still prevailed, the program "Our Nature" was launched, consisting of a set of proposals for legislative and institutional improvement. In 1994, a National Ministry of Environment, Water Resources and Legal Amazon (MMA) was established of which IBAMA is now a part.

The federal legal framework is designed to provide overall guidance and to set broad ambient quality objectives and minimum compliance requirements. Legislation explicitly recognizes the right of states to set tighter pollution standards or to issue supplemental state legislation. At the national level there are the PROAGUA (national water quality) program and the PRONAR (national air quality control) program. Most of the supervisory and enforcement functions including licensing, monitoring and fines are left to the states; Yet in cases where a state agency cannot assume these responsibilities, the federal agency (IBAMA) must theoretically intervene.

3.2 Environmental Air Quality Standards

3.2.1 Environmental Air Quality Standards

The environmental air quality standards (Regulation No.231 in April, 1976 and Decision No.3 in June, 1990) (#01) stipulated by the federal government is shown in Table **3.2.1**.These are the allowable maximum concentrations of air pollutants, which may affect the human health, safety and welfare of inhabitants, and also may damage the general and habitat environment of animal and plant if one of them would be exceeded.

Table 3.2.1 Environmental Air Quality Standards in Brazil

Pollutants	Averaging Time	Primary Criteria	Secondary Criteria	Measuring Methods: given or equivalent approved by CONAMA
TSP	Annual	80	60	High-volume air sampler
	24 hours*	240	150	ditto
Smoke	Annual	60	40	Reflectance
	24 hours*	150	100	ditto
Inhalant Particulates	Annual	50	50	Inertial separation and filtration
	24 hours*	150	150	ditto
SO_2	Annual	80	40	Para-rosaniline
	24 hours*	365	100	ditto
CO	8 hours*	10,000	10,000	Non-dispersion infrared absorption
	1 hour*	40,000	40,000	ditto
O_3	1 hour*	160	160	Chemiluminescence
NO_2	Annual	100	100	Chemiluminescence
	1 hour	320	190	ditto

Unit in micrograms/m^3 (25°C, 760mmHg)(#01)

Notes:

1) The air quality with * should not exceed the limit shown in the above more than once a year.

2) The primary criteria indicates the maximum concentrations of air pollutants which may affect the human health of inhabitants if exceeded. It is a short and intermediate term target.

3) The secondary criteria indicates the maximum concentrations of air pollutants, under which damages to the welfare of inhabitants, and habitat and general environment of animal and plant are expected to be minimum.

4) Measuring methods should be those shown in the table or equivalents.

Each State has the responsibility to assign the area criteria. Actually, the primary criteria is in vigor. There is no such area assigned as the secondary criteria as of June, 1996. State of Santa Catarina has requested the TSP measurement frequency to be 24 hours in 6 days. There is no such requirement in the Federative.

For reference, the Brazilian air quality standards are compared with those of Japan and the Guidelines of World Bank (WB) and World Health Organization (WHO), in **Appendix 3.1.1.**

The warning levels of air quality are also shown in **Table 3.2.2 (#01)**. The warning means the advent of high concentration in a short time as a result of meteorological conditions unfavorable for the dispersion of pollutants. It will be declared in consideration of such factors not only concentration of respective pollutants, but also meteorological forecast, etc. Three levels are determined to judge the declaration, i.e., caution, alert, and emergency.

The emergency level will be declared when it is expected that meteorological conditions are unfavorable to the dispersion of pollutants for 24 hours or more, and at least one of the conditions in **Table 3.2.2** appears.

Table 3.2.2 Levels for Warning Declaration

Pollutants	Averaging Time	Levels		
		Caution	Alert	Emergency
TSP	24 hours	375	625	875
Smoke	1 hour	250	420	500
Inhalant Particulates	24 hours	250	420	500
SO_2	24 hours	800	1,600	2,100
CO	8 hours	17,000	34,000	46,000
O_3	1 hour	400	800	1,000
NO_2	1 hour	1,130	2,260	3,000
TSP x SO_2	24 hours	65,000	261,000	393,000

Unit:micrograms/m^3 (25°C, 760 mmHg) (#001)

In case the Emergency is declared, in order to improve the air quality, an environmental organization of the state calls for immediate reduction of pollutant emissions to each public corporation and private companies by means of cutting off their production and changing fuel used to high quality one.

3.2.2 Emission Standards

(1) Emission standards in Brazil

The emission standards of pollutants from external combustion sources determined by the federal government (CONAMA008)(Decree No.8, in December, 1990, #02) are summarized in **Table 3.2.3** for newly installed stationary sources. The emission standards are classified with the potential nominal capacity of sources, the category of area, and the fuel burnt, and are determined as the quantity of pollutants emitted per heat input to the source.

The categorized areas are as follows in the Decree No. 5 de junho de 1989 (#03):

Class I - National parks, state parks, ecosystem preservation areas, mineral spring areas, secure areas such as tropical waters, leisure spots, and sightseeing resorts:
Air quality of this area must be kept at a level as closely as possible not to be affected by any human activity.

Class II - Areas where the degradation level of air quality is restricted by the secondary criteria.

Class III: Developmental areas where the degradation level of air quality is restricted by the primary criteria.

Table 3.2.3 Emission Standards of Pollutants (#02)

Fuel	Output MW	Area Classification	TSP g/10^6 kcal	Smoke color % 3) Ringelman Scale	SO_2 g/10^6 kcal	Annual fuel consumption 4)
Coal	<70	I 2)	120	<20 or No. 1	2,000	3,000
		II, III	1,500	<25 or No. 1	5,000	—
	>70 1)	II, III	800	<20 or No. 1	2,000	—
Oil	<70	I 2), 4)	120	<20 or No. 1	2,000	3,000
		II, III	350	<25 or No. 1	5,000	—
	>70 1)	II, III	120	<20 or No. 1	2,000	—

Notes: 1) Sources more than 70 MW are not allowed to install in Area Class I.

2) No economic activity which causes air pollution is allowed in the area where air quality should be preserved. The given emissions are allowed only in the area where air quality should be conserved; such areas as for leisure, tourist attraction, mineral water and hot spring.

3) Except for the cases of cleaning and of maintenance of the source

4) Approval is mandatory from the State Environmental Agency for the annual fuel oil consumption of more than 3,000 tons, and for combustion of other fuels.

(2)Emission Standards for Counterpart Power Plants

CONAMA's emission standards will be applied to new and expanding thermal power plants. Therefore, the existing facilities of three coal power plats in Jorge Lacerda, Charqueadas and Candiota are excluded from the application of CONAMA's emission standards. However, as a condition of operation permission of new and expanding power plants, the power corporations have concluded agreements with FATMA or FEPAM to control emissions of total suspended particulate, nitrogen oxides, and sulfur dioxide from their stacks including the existing facilities, besides new and expanding facilities, under the emission rates specified in the agreements in order to prevent air pollution. The agreed emission rates applied to the above-mentioned power plants are as shown in **Table 3.2.4**.

Table 3.2.4 Emission Allowance Agreed with State

Power Plant		Unit	No	Rated output (MW)	CONAMA's Standards		FATMA,FEPAM 's Allowance			Remarks
					TSP	SO_2	TSP	NOx	SO_2	
Jorge Lacerda	Exist.	A I	1	50	Not Applicable		Total amounts of sulfur in coal at any output rate should be less than the sulfur equivalent to 2.2% contents in average coal at the full rated output.			1/1997
			2	50						
		A II	3	66						
			4	66						
		B III	5	125						
			6	125						
	Exp.	IV*	--	350						
Char-queadas	Exist.	——	1	18	Not Applicable		80mg/m^{3}N	400mg/ m^{3}N	400 mg/ m^{3}N	by the year of 2005
			2	18						
			3	18						
			4	18						
Jacui	Exp.	I *	—	350			140mg/m^{3}N (at 280MW) 85mg/m^{3}N (at 175MW)	680mg/ m^{3}N	1500 mg/ m^{3}N	at the time of operation
Candiota	Exist.	A	1	63	Not Applicable		80mg/m^{3}N	400mg/ m^3 N	400 mg/ m^{3}N	by the year of 2004
			2	63						
		B	1	160			Undecided	680mg/ m^{3}N	2100 mg/ m^{3}N	by the year of 2002
			2	160						
	Exp.	III*	--	350			265mg/m^{3}N (at 280MW) 100mg/m^{3}N (at 158MW)	Undecid ed	2000 mg/ m^{3}N	at the time of operation

(O_2= 6%)

Severer emission allowance rates are applied to the existing units than to new and expanding units in Charqueadas and Candiota, although the existing units have smaller capacities. Small-sized old units require high cost for modification and have lower efficiency than that of large-sized ones. It seems not rational to apply severer emission rates (concentration standards) to the existing units than to the new ones, because the influence of pollutants on surrounding environmental air does not depend on the concentration of emission from stacks but on the amount of emission for an unit time.

In general, even if the concentration is low, the large-sized units influence more, and even if the concentration is high, small-sized units influence less on the surrounding regions. Therefore, it is more advantageous in the aspect of investment cost to apply severer emission standards to new large-sized units and, if doing so, influence on air quality will be able to be reduced.

CONAMA 's standards value, 10^6 Kcal, is equivalent to about 1,600m^3N of the amount of flue gas with residual O_2 concentration of 6%. Accordingly, TSP 800g/10^6 Kcal is equivalent to 500mg/m^3N, and SO_2 2,000g/10^6 Kcal to 1,250mg/m^3N, respectively. The exact amount of flue gas is determined by the composition of fuel coal and the amount combustion air (the amount of residual oxygen).

For reference, a comparison among the emission standards of coal combustion in Brazil, Japan and Guideline of World Bank (WB) is shown in **Appendix 3.2.1**

CHAPTER 4 CURRENT AIR QUALITIES

4.1 Meteorology

4.1.1 Measurement Method

The net-radiation was measured at one station in each region. Data on wind direction, wind speed and solar radiation were obtained through the existing instruments(**Table 4.1.1**). The location of the meteorology monitoring stations are shown along with the location of the automated monitoring stations in **Figure 4.2.1**, and the existing instruments and the list of JICA owned instruments are on **Appendix 1-3** and **1-4**. The measurement was conducted from March 1996 to February 1997, and all observed values are organized as hourly data (**Appendix 4-1**).

Table 4.1.1 Meteorology Monitoring Stations and Measured Items

Power Plant	Net Radiation	Wind Direction, Wind Speed, and Solar Radiation
Jorge Lacerda	Capivari	Power Plant
Charqueadas	DEPREC	Jacui
Candiota	Airport	Airport

Note : Solar radiation values of Airport (Candiota) were abnormal, therefore not used for further analysis.

4.1.2 Meteorology Characteristics

Calm frequency was high (11.5 %) and the average wind speed was 2.0 m/s at Jorge Lacerda. The wind was the weakest at Jorge Lacerda. On the other hand, the wind at Candiota was the strongest, and the calm frequency and the average wind speed were 3.7 % and 3.4 m/s respectively. At Charqueadas, the extent of wind speed was the middle of the other two regions, and the calm frequency and the average wind speed were 7.0 % and 2.3 m/s. The frequency of the most frequently observed wind direction was 12.0% in easterly (E) at Jorge Lacerda, 25.5% in south-easterly (SE) at Charqueadas, and 15.5% in easterly (E) at Candiota. The highest frequency occurred at Charqueads in south-easterly (SE) direction (**Figure 4.1.1**). Wind rose diagram by month is shown on **Appendix 4-2**.

The highest frequency of wind speed class was 1.0 to 1.9m/s in Jorge Lacerda and Charqueadas, and 4.0 to 4.9m/s in Candiota. High frequency observed at high wind speed in

Candiota is a distinctive feature (**Figure 4.1.2**).

The atmospheric stability was determined from data on wind speed, solar radiation and net radiation. However, as the solar radiation data at Candiota showed abnormal values, the stability was determined from wind speed and net radiation. Estimation process of the atmospheric stability is on **Appendix 4-3**. General features of stability in these regions were high frequency of strong stable conditions (G) and strong unstable conditions (A to B). High frequency of strong unstable conditions means the potential high impact from the tall stack of power plants to the ground concentrations. The frequencies of strong unstable conditions were 19.4 % at Jorge Lacerda, 18.3 % at Charqueadas, and 13.3 % at Candiota. The frequency at Jorge Lacerda was the highest (**Figure 4.1.3**).

All three regions have common daily pattern, high values during daytime, for wind speed, solar radiation, and net radiation. No clear seasonal change was observed by monthly pattern of wind speed, but observed high solar radiation in summer and low in winter (**Appendix 4-4**).

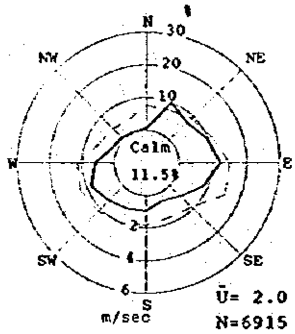
As results from the consideration above, the meteorological conditions at Jorge Laceda with the weakest wind and the highest frequency of unstable conditions tend to cause air pollution, and Candiota has the less possibility of air pollution because of the strong wind and the low frequency of unstable conditions.

4.2 Automated Continuous Air Quality Monitoring

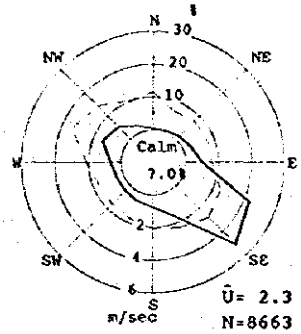
4.2.1 Measurement Method

Each three automated continuous monitoring stations were installed at Jorge Lacerda, Charqueadas, and Candiota. Sulfur dioxide (SO_2) concentrations were monitored at each three stations, and nitrogen oxides (NO_x, NO_2, and NO) concentrations at each one station in each region (**Table 4.2.1, Figure 4.2.1**). Instrument called Infra-red absorption was used to measure SO_2, and chemiluminescence was used to measure NO_x. More details of the measurement instruments are shown in **Appendix 1-4**.

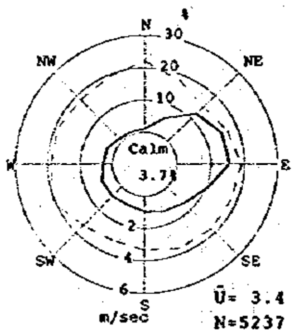
LACERDA



JACUI



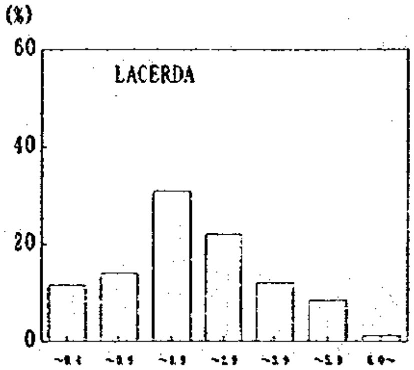
CANDIOTA



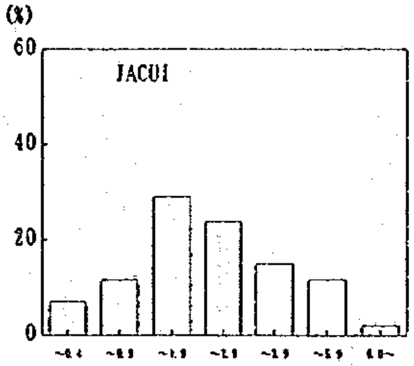
——— Frequency of Wind Direction
– – – Average of Wind Speed
Calm: Less than 0.5 m/sec
Ū=: Ave. of wind speed (m/sec)
N=: Number of sample

Figure 4.1.1 Annual Wind Rose Year: 1996 (Mar. to Feb.)

Jorge Lacerda Power Plant



Charqueadas Power Plant



Candiota Power Plant

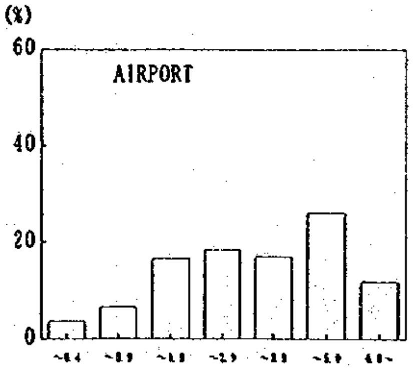
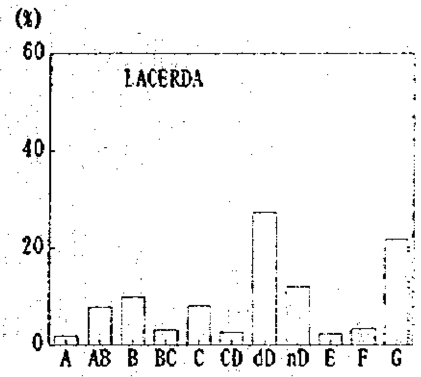
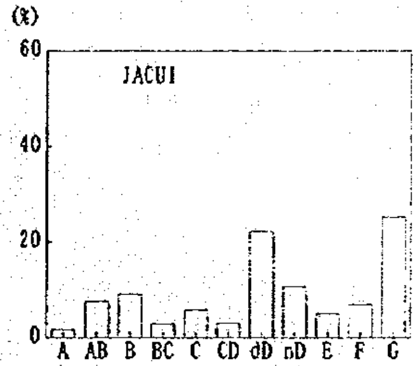


Figure 4.1.2 Frequency by Wind Speed Class Year 1996 Mar to 1997 Feb

Jorge Lacerda Power Plant



Charqueadas Power Plant



Candiota Power Plant

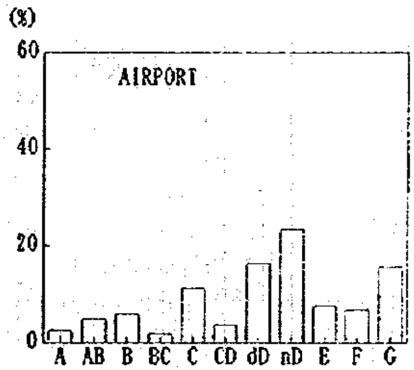
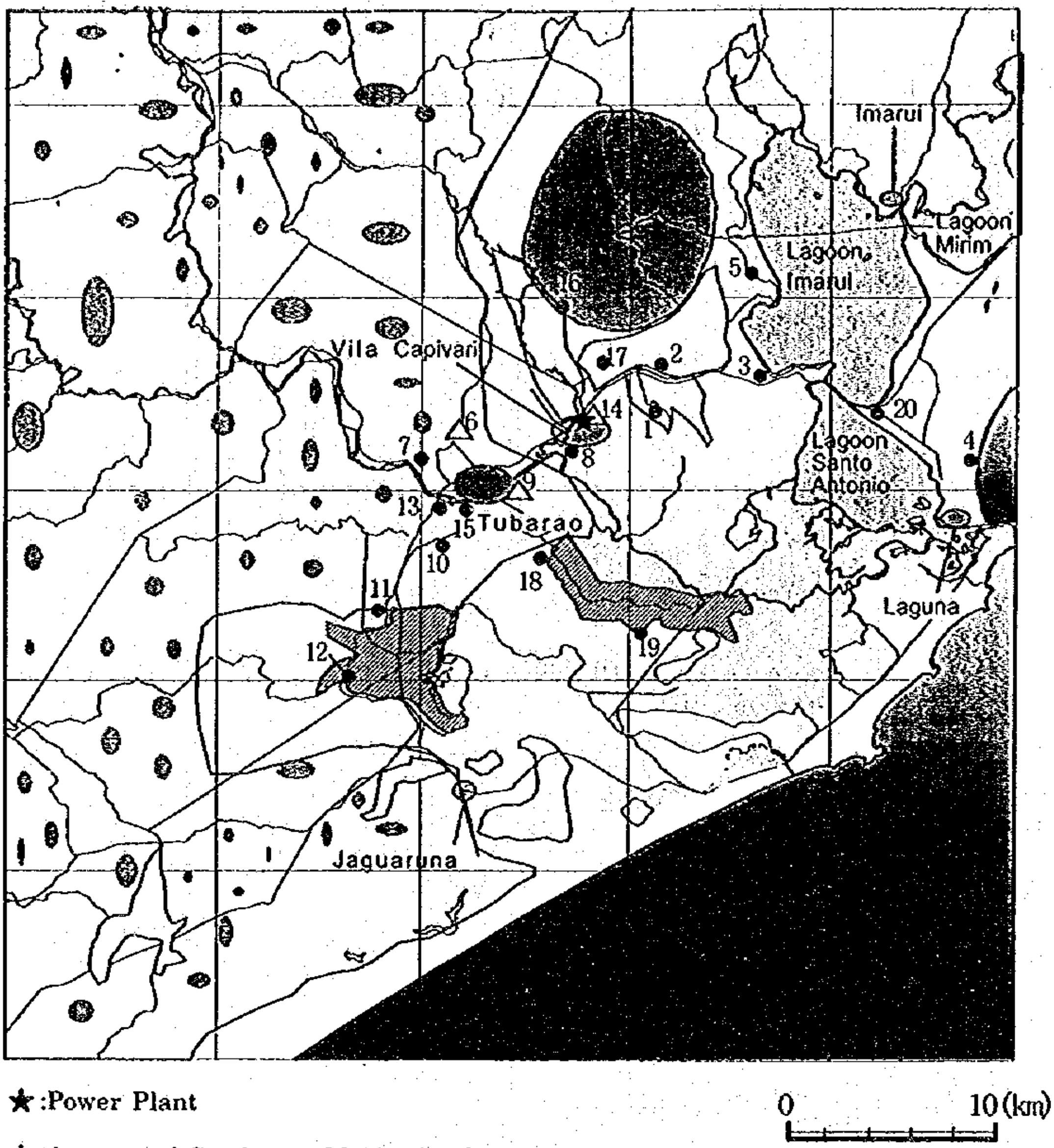


Figure 4.1.3 Stability Frequency Year 1996 Mar to 1997 Feb



★ :Power Plant

△ :Automated Continuous Monitoring Stations

● :Simple Monitoring Stations

Code	Station Name	Code	Station Name
1	Banhado da Estiva	11	Escola Jose Botega
2	Igreja de Sao Sebastiao	12	Estrada Geral Treze de Maio
3	Campo dos Bandeirantes	13	Colegio Gallotti
4	Turist Hotel	***14***	***Capivari***
5	Ribeirao da Pescaria Brava	15	Oficians
6	***Sao Bernardo***	16	Ilhota Grande
7	Domingo Saviatto/Ceramica	17	Cachoeira Segunda
8	Pasto do Gado RFFSA	18	Escola Cristina Avila Wendhausen
9	***Vila Moema***	19	Lactuba
10	Monte Castelo	20	Cabecudas

Note: Stations in bold & italic letters are simply and continuously monitored.

Forest

Agricultural

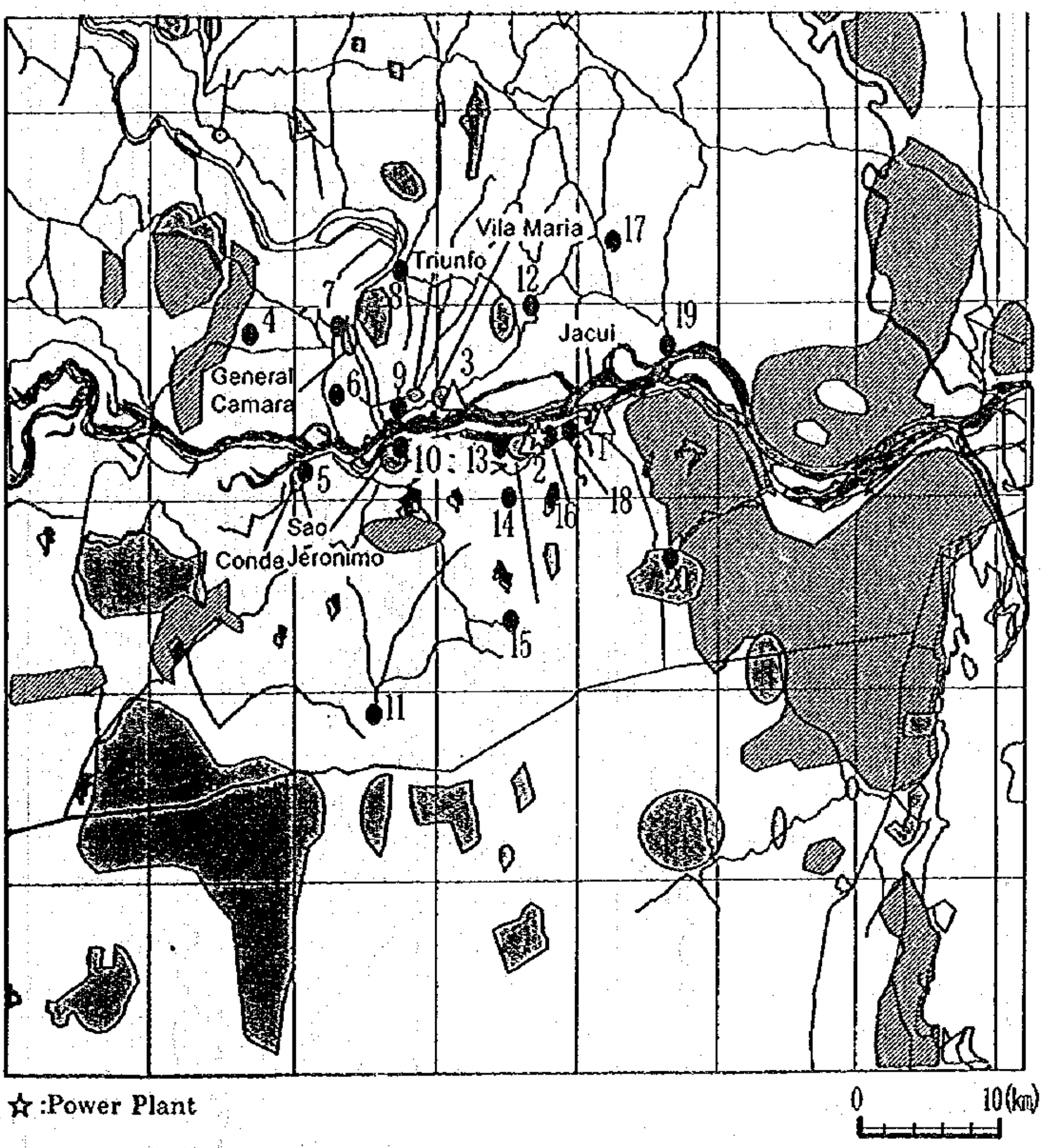
Paddy field

mangrove

marshy area

Village and Town

Figure 4.2.1(1) Monitoring Station Locations (Jorge Lacerda)



☆ :Power Plant

△ :Automated Continuous Monitoring Stations

● :Simple Monitoring Stations

Code	Station Name	Code	Station Name
1	***OBJA (Jacui)***	11	CORSAN
2	***Arranca Toco***	12	Adi Campos Cornelio
3	***DEPREC***	13	Jose Manoel
4	Antonio Camboim	14	Gilberto Kuball
5	Escola Barao do Jacui	15	Fazenda Capororca
6	Otoli Panta	16	COPELMI
7	Escola Vasconcelos Jardim	17	Pedro Ferreira
8	Telomo Machri	18	Penitenciaria Est. do Jacui
9	Escola Afonso M. Coelho	19	Inelio da Rosa
10	Hospital Sao Jeronimo	20	Fernando Kroeff

Note: Stations in bold & italic letters are simply and continuously monitored.

Forest

Paddy field

Fruits farm

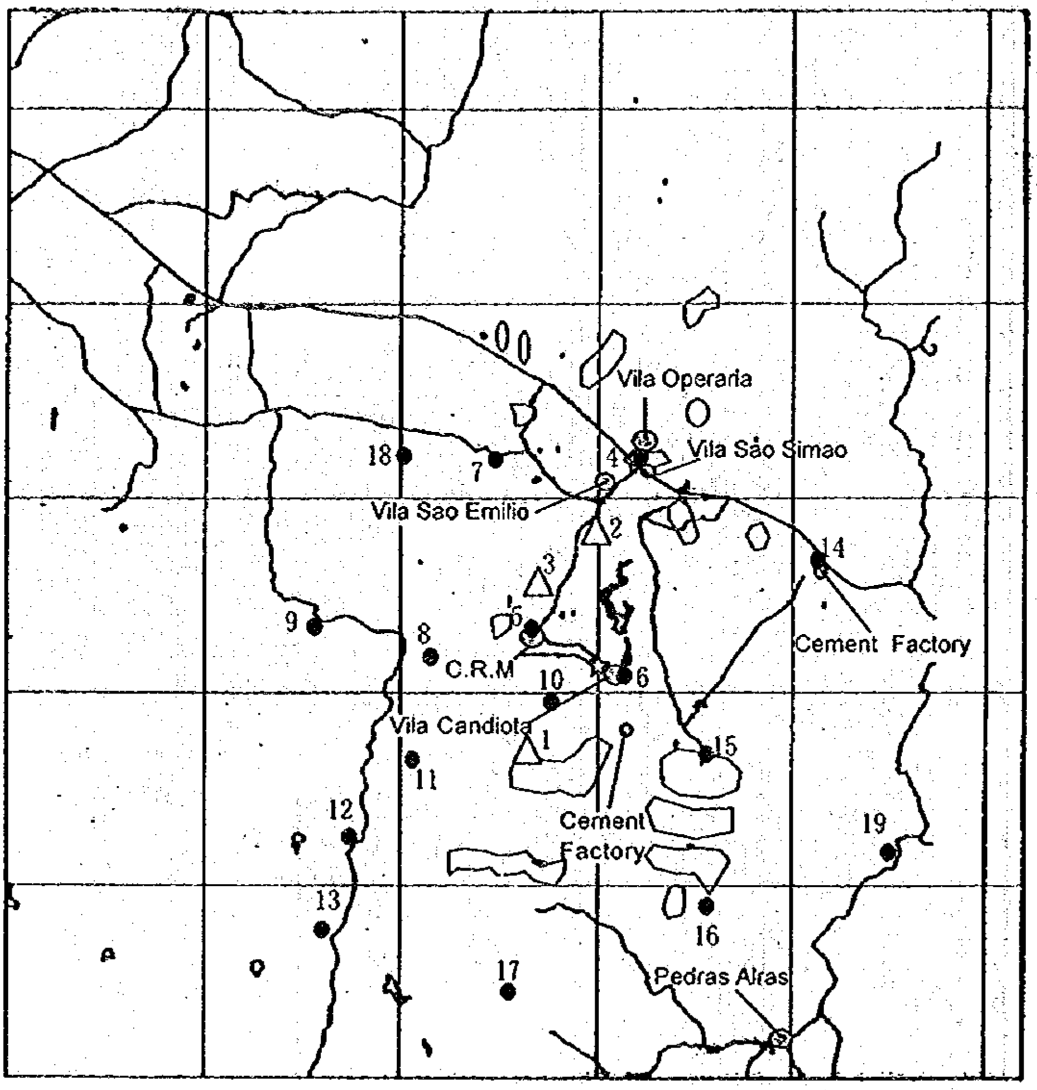
Lake

Rio Jacui

Marshy area

Village and Town

Figure 4.2.1(2) Monitoring Station Locations (Charqueadas)



☆ :Power Plant

△ :Automated Continuous Monitoring Stations

● :Simple Monitoring Stations

0 10 (km)

Code	Station Name	Code	Station Name
1	***Tres Lagoas***	11	Passo do Tigre
2	***Airport***	12	Barao do Itaqui
3	***Candiota III***	13	8 de Agosto
4	Brigada Militar	14	CORSAN
5	Lago	15	Joao Geraldino
6	E.T.A. Colegio	16	Pedras Atlas
7	Igreja	17	D. Pedro II
8	Passo do Arroio	18	Jose Otavio
9	Hulha Negra	19	Pinheiro Machado
10	Tunel	20	Acegua

Note: Stations in bold & italic letters are simply and continuously monitored.

Agricultural

Village and Town

Cement Factory

Figure 4.2.1(3) Monitoring Station Locations (Candiota)

Table 4.2.1 Automated Continuous Monitoring Stations and Measured Items

Power Plant	Station	Item
Jorge Lacerda	Capivari	SO_2, NO_x
	Vila Moema	SO_2
	São Bernardo	SO_2
Charqueadas	DEPREC	SO_2, NO_x
	Jacui	SO_2
	Arranca Toco	SO_2
Candiota	Airport	SO_2, NO_x
	Candiota III	SO_2
	Tres Lagoas	SO_2

4.2.2 Characteristics of Pollutant Concentration by Automated Continuous Monitoring of Air Quality

(1) Comparison with National Criteria

Annual average values of SO_2 and NO_2 are shown in **Table 4.2.2**, and maximum of daily average values and hourly values, also, cumulative distribution of each monitoring stations and each items measured are shown in **Appendix 4-5.**

Table 4.2.2 Results of Automated Continuous Monitoring

Item / Station	SO_2			NO_2		
	Average	Daily Max.	Hourly Max.	Average	Daily Max.	Hourly Max.
Capivari	6.1	35	336	5.7	11	44
Vila Moema	8.0	54	322	-	-	-
Sao Bernardo	5.2	63	438	-	-	-
DEPREC	1.9	11	120	3.0	11	37
Jacui	3.7	18	108	-	-	-
Arranca Toco	6.1	39	173	-	-	-
Airport	3.5	17	182	1.4	7	20
Candiota III	4.5	27	113	-	-	-
Tres Lagoas	4.2	16	129	-	-	-
Standard	30.56	139.44	-	53.15	-	170.08

Unit: ppb

All the values were much lower than the National Primary Criteria for annual average ($80ug/m^3$=30.56 ppb) and 24 hours average ($365ug/m^3$=139.44 ppb). The annual average concentrations of SO_2 at Vila Moema of Jorge Lacerda was the highest among others to be 8.0

ppb. The maximum concentration of SO_2 daily averages was the highest at Sao Bernardo. Generally, SO_2 concentrations of Jorge Lacerda are higher than the ones in the other regions.

The annual average concentration of NO_2 and the maximum concentration of NO_2 hourly values were the highest at Capivari of Jorge Lacerda. The NO_2 concentrations in Jorge Lacerda and Charqueadas were almost in the same range, and the concentrations in Candiota were lower than the others. Maximum values of NO_2 were also much lower than the Primary Criteria for annual average (100 ug/m^3=53.15 ppb) and hourly value (320 ug/m^3=170.08 ppb).

TSP measurements were carried out using with existed high volume samplers at each three points in Jorge Lacerda and Charqueadas, and one point in Candiota. Only at Capivari of Jorge Lacerda, its concentration exceeded the Primary Criteria of 24 hours average (240 ug/m^3) by three times in one year span. Measured values of each regions are shown in **Appendix 4-6**.

(2) Analysis of Diurnal Change

Diurnal changes of SO_2 showed one peak during the daytime, and this phenomenon would be caused by the tall stacks of power plants because the atmosphere is unstable in the daytime by solar radiation. Accordingly, the effect from the tall stack could reach to the ground level, but contributions from ground-level sources like automobiles are weakened by dilution. Other low altitude emissions such as vehicle exhaust, may have influenced the small peak of Vila Moema at early evening (**Figure 4.2.2**).

On the contrary, diurnal changes of NO_x had two peaks in the morning and the evening which indicated the pattern to be related with traffics. The contributions from power plants to NO_x concentrations might be relatively low. This characteristics are especially observed in Capivari (**Figure 4.2.3**).

Common characteristics of monthly change of SO_2 were not observed (**Appendix 4-7**), but NO_x was high concentration in winter. The result also prove the low altitude emissions as the major pollutant source for NO_x(**Figure 4.2.4**).

(3) Analysis of Relation with Meteorology

To analyze the relation of ambient air quality and meteorology, average concentration by wind direction, and average concentration by stability were used.

The analysis of average concentrations by wind directions at Candiota showed good coincidence between high concentration directions and upward directions of the power plant, although the concentrations were low (**Appendix 4-8**). This indicates that the contributions from the power plant to the stations is relatively high at Candiota. Such kind of coincidence was not clear at Jorge Lacerda. Many other pollutant sources except the power plant would be there to contribute the pollutant concentrations at Jorge Lacerda.

The average SO_2 concentrations were relatively high under unstable conditions. The tall stacks would be the reason (**Figure 4.2.5**). The average NO_x concentrations were relatively high under stable conditions and may be caused by automobiles. However, the NO_x concentrations at Capivari also increased under unstable conditions and some contributions from the tall stacks should be considered (**Figure 4.2.6**).

(4) Current Condition of Ambient Air Quality

As results, SO_2 and NO_2 concentrations are much below the criteria and not problematic at present. The power plants could contribute to SO_2 concentrations in all regions, and the contributions from the power plants to NO_x concentrations are relatively small compared with the ones from automobiles. The contributions from the power plants to TSP concentrations will be discussed based on the simulation results later.

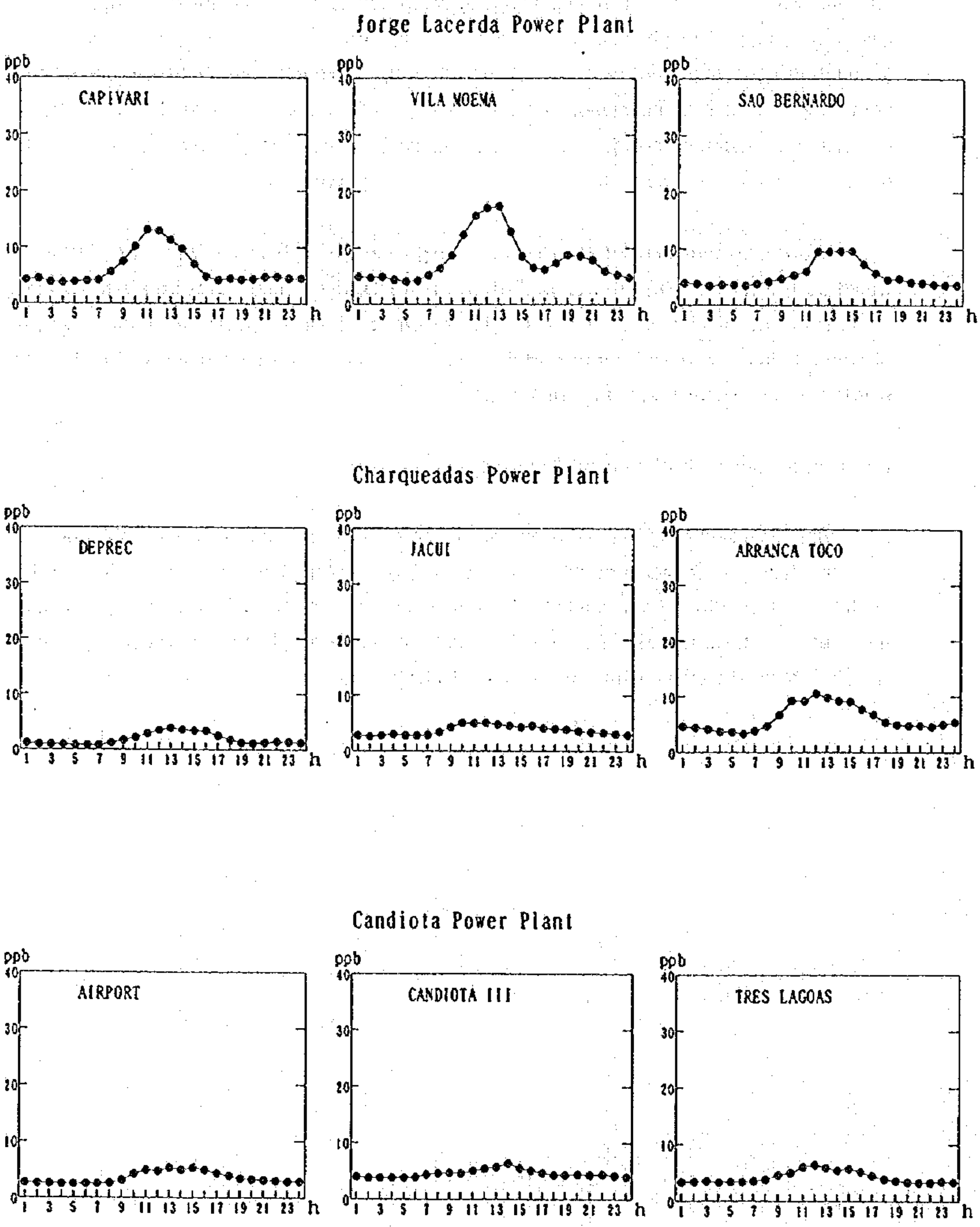
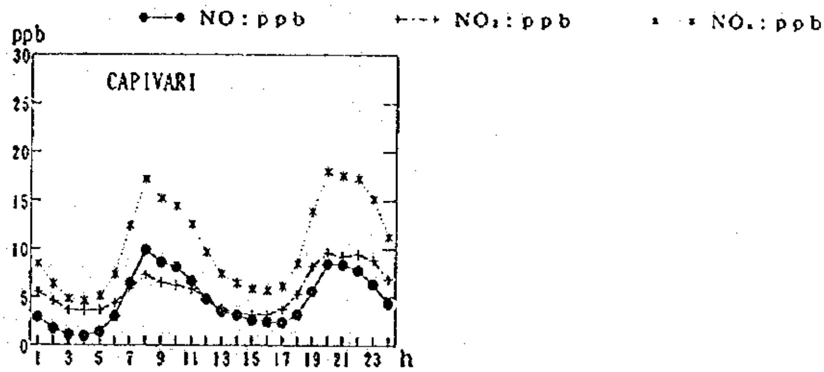


Figure 4.2.2 Diurnal Change of SO_2

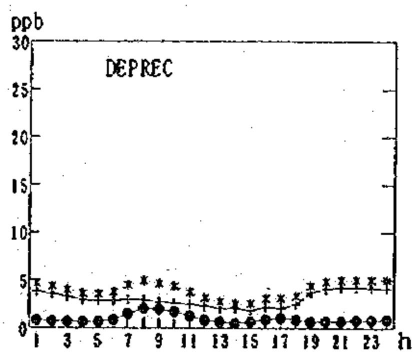
Year 1996 Mar to 1997 Feb

*SO_2: 1ppb=2.617 $\mu g/m^3$ at 25 ℃

Jorge Lacerda Power Plant



Charqueadas Power Plant



Candiota Power Plant

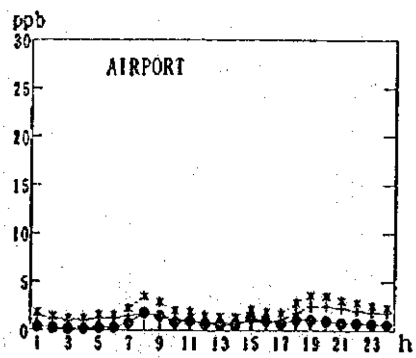


Figure 4.2.3 Diurnal Change of NO_x Year 1996 Mar to 1997 Feb

*NO_2: 1ppb=1.881 $\mu g/m^3$ at 25 ℃

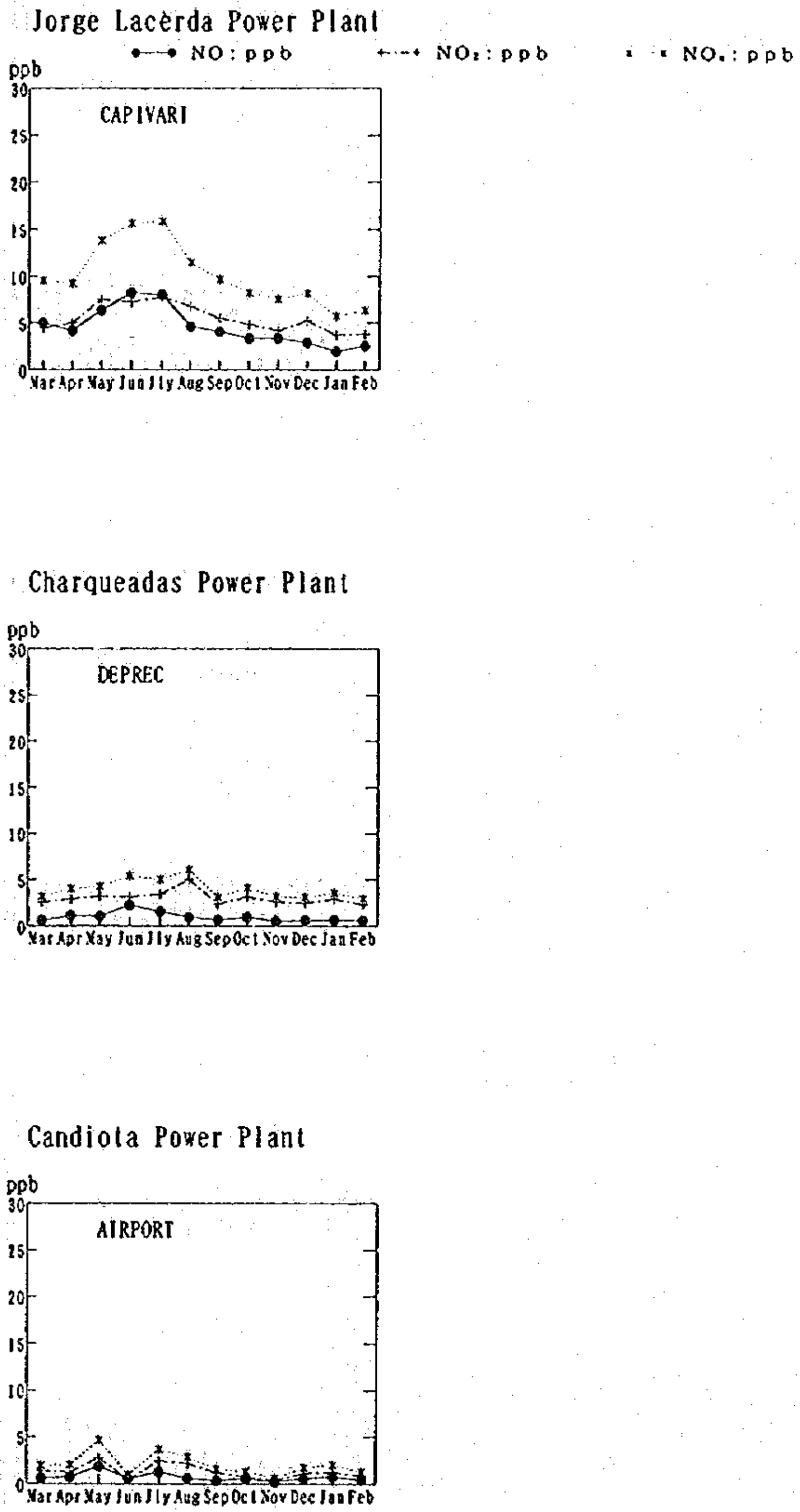
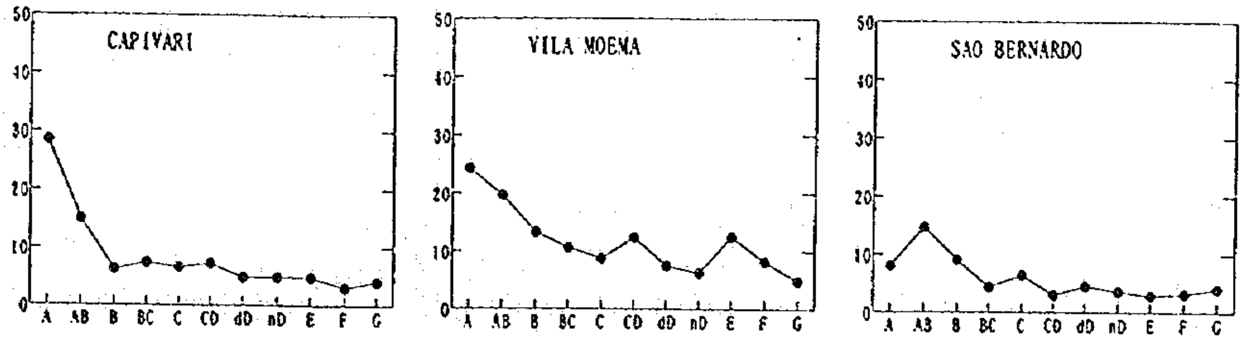


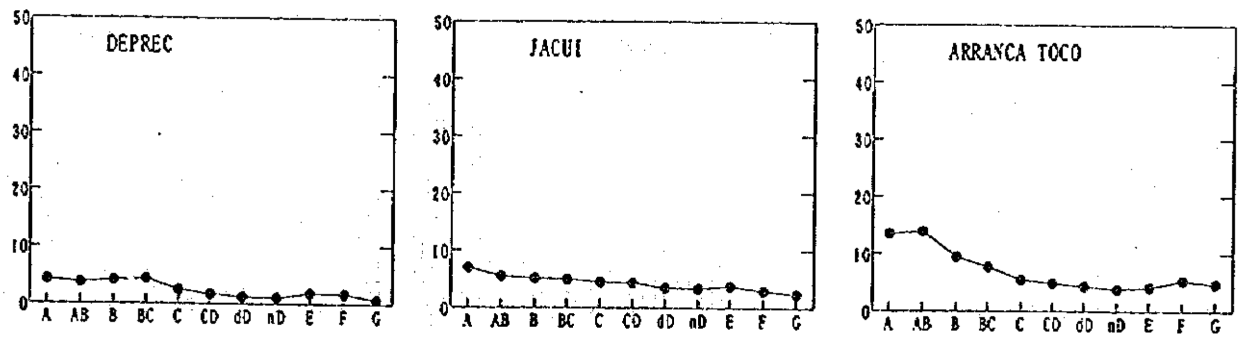
Figure 4.2.4 Monthly Change of NO_x Year 1996 Mar to 1997 Feb

*NO_2: 1ppb=1.881 $\mu g/m^3$ at 25 ℃

Jorge Lacerda Power Plant



Charqueadas Power Plant



Candiota Power Plant

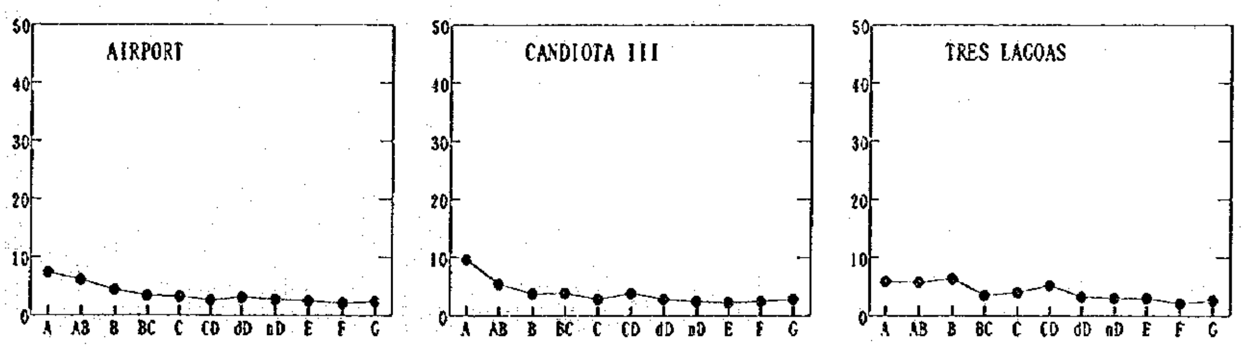
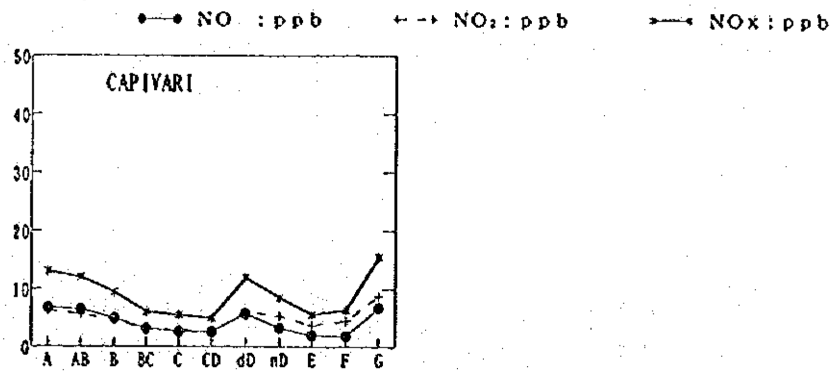
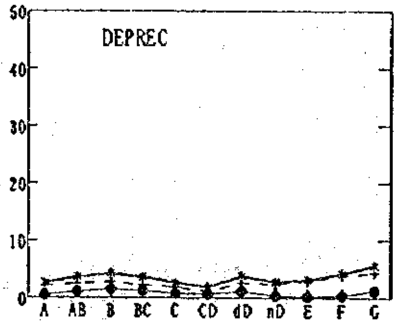


Figure 4.2.5 Concentration by Stability (SO_2)

Jorge Lacerda Power Plant



Charqueadas Power Plant



Candiota Power Plant

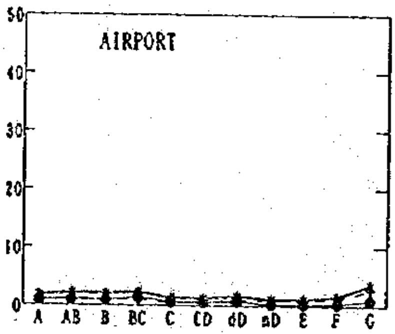


Figure 4.2.6 Concentration by Stability (NO_x)

4.3 Simple Measurement

4.3.1 Measurement Methods

In order to supplement monitoring of the ambient air with the fixed automated continuous analyzers, absorption methods were employed in 20 sampling points around each power plant. Equipment used are listed in **Appendix 1-4** and analysis methods are shown in **Table 4.3.1.**

Table 4.3.1 Simple Measurement Methods

Substance	Absorbent - Analysis Method
SO_2 and NO_2	tri ethanol amine - ion chromatography method
NO_x	tri ethanol amine +PTIO - ion chromatography method

In the regions concerned, SO_2 in the atmosphere had been measured by the PbO_2 method (minimum limit of determination : 6.25mg / exposure time).' As its concentration was so low, the method could not detect it at all. In the Study, used is the ion chromatography method which is 1,000 times more sensitive than the PbO_2 method for detecting SO_2. The minimum limits of determination in this method are shown as follows:

SO_2 : 0.005mg / exposure time
NO_2 : 0.004mg / exposure time
NO_X : 0.004mg / exposure time

However, after the actual measurement, it was found that the concentration of the measured substances was lower than these minimum limits. Therefore, the measurement was performed with 5 times more sensitivity by increasing the amount of sample in the ion-chromatography. The minimum limits of determination of this measurement are shown as follows.

SO_2 : 0.001mg / exposure time
NO_2 : 0.0008mg / exposure time

NO_X could not be measured because its peak overlapped that of sampling matter by PTIO due to the higher sensitivity obtained. NO_X concentration was also very low and it was not detected by the measurement with 0.004mg / exposure time as the minimum determination limit. In the end, the measurement was performed only for SO_2 and NO_2. In light of the need to prevent the column's deterioration of the ion chromatography, it is believed that these minimum limits of determination are the limitation of the analysis. Even with these minimum limits, there were few measuring points where the measured substances were detected over 7 days of exposure time as originally determined. Therefore, the exposure time was elongated to one month not only to obtain the data, but also to improve the accuracy of the measurement. The results are tabulated in **Appendix 4-9A**.

4.3.2 Regional Concentration Distribution

The absorption amounts at the automated continuous stations were compared with the average concentrations of SO_2 and NO_2 during the same periods to obtain regression equations (**Appendix 4-9B**). The absorption amounts of the samples were converted to annual average concentrations of pollutants. However, because the correlation coefficients for SO_2 were very low, SO_2 absorption amounts were directly evaluated.

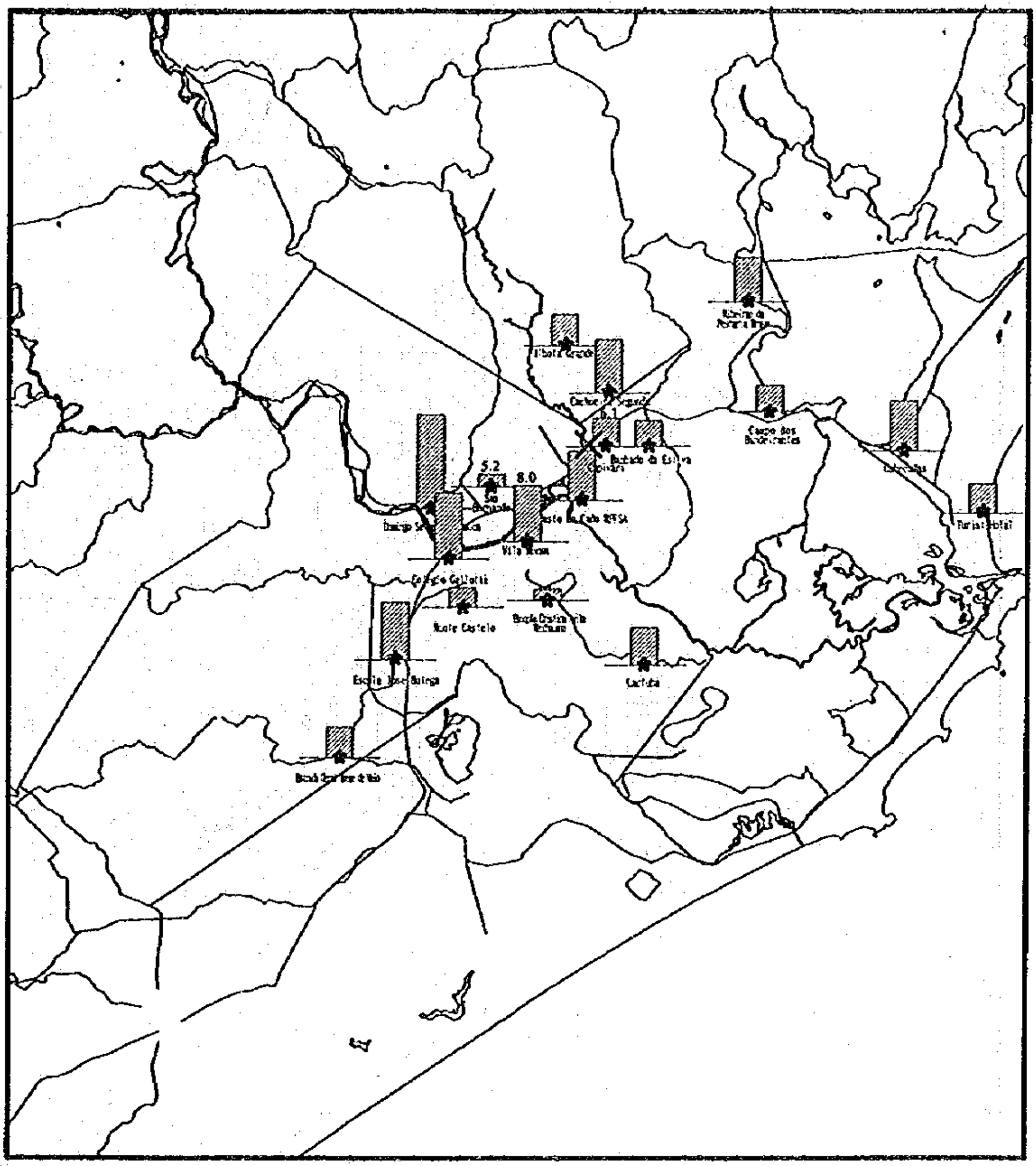
Figure 4.3.1 shows the annual average absorption amount of SO_2 and annual average concentration of NO_2 of each station.

The regions with high SO_2 absorption amounts (0.4 ug per month) spread in WSW to SW and with the distances of 5 km to 15 km from the power plant at Jorge Lacerda. Adding to that, the wind frequency of E to NNW were high and the potential influence by the power plant should be considered. The regions with high NO_2 concentrations (more than 5 ppb) were located at SW and E to NNW from the power plant.

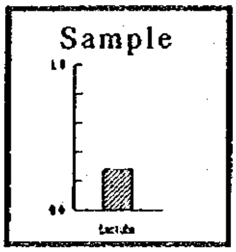
The regions with high SO_2 absorption amounts were in two locations of Charqueadas. One was located at NW to W with distance of 10 km to 15 km from the power plant, and the other at E to ENE with the distance of 1 km to 10 km. The former regions may be influenced by the power plant because the main wind directions were SE to ESE. NO_2 concentrations at only one point near the power plant were high.

In Candiota, the regions with high SO_2 absorption widely spread in S with the distances of 1 km to 20 km from the power plant, and NW to N with the distances of 5 km to 15 km. The other unknown SO_2 sources can be suspected. NO_2 concentrations were generally low.

Some of the local regions may be influenced by the power plants and the other pollutant sources may also be affecting ambient air qualities. Pollutant sources should be considered for locations of monitoring stations, if the new network is planned for the air quality monitoring.



Jorge Lacerda
SO_2(ug)



Stations where Concentration is zero

Igreja de Sao Sebastiao
Oficinas

* :Station
X :Power Plant

Figure 4.3.1(1) Regional Concentration Distribution by Simple Method (SO_2, Jorge Lacerda)

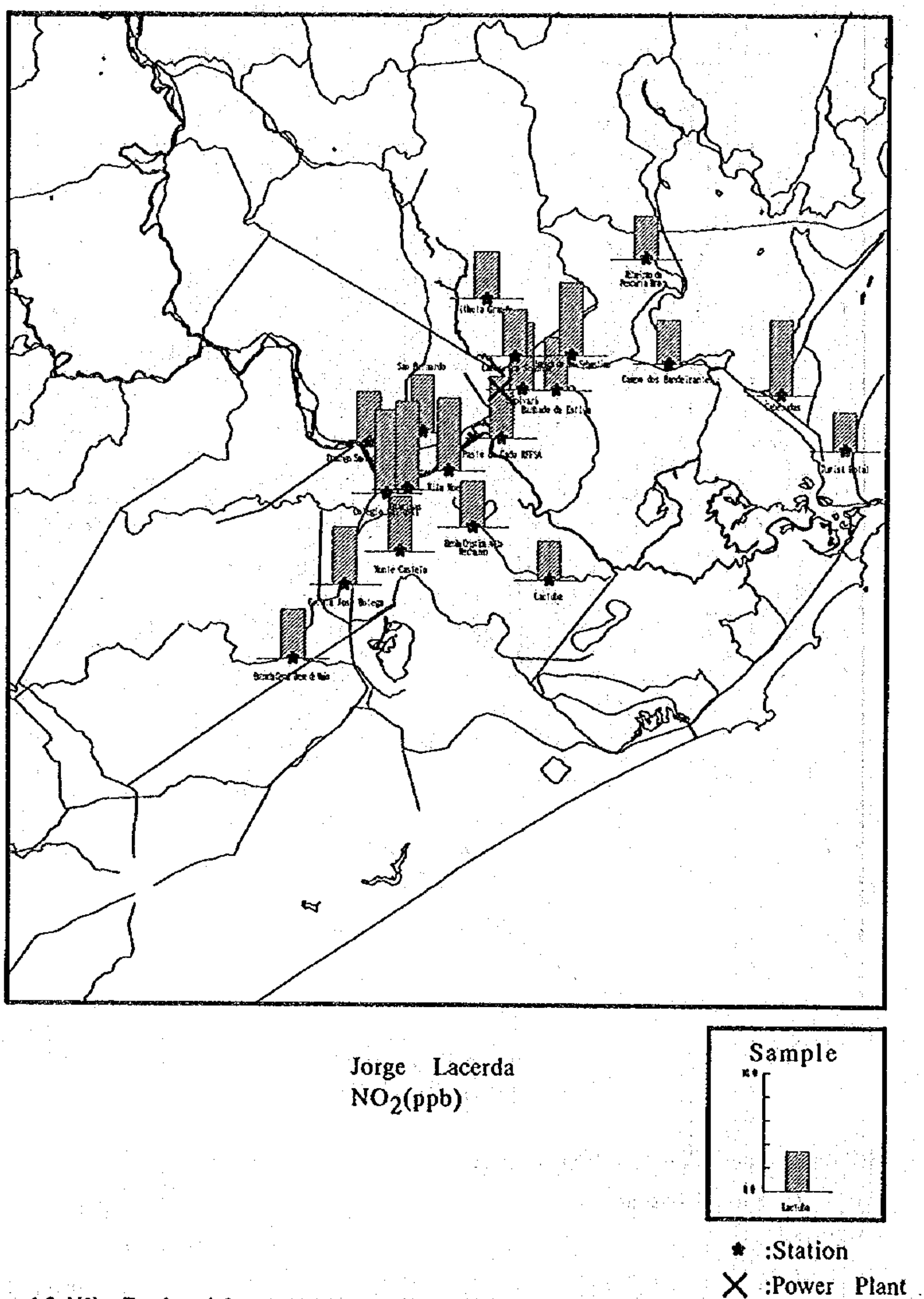
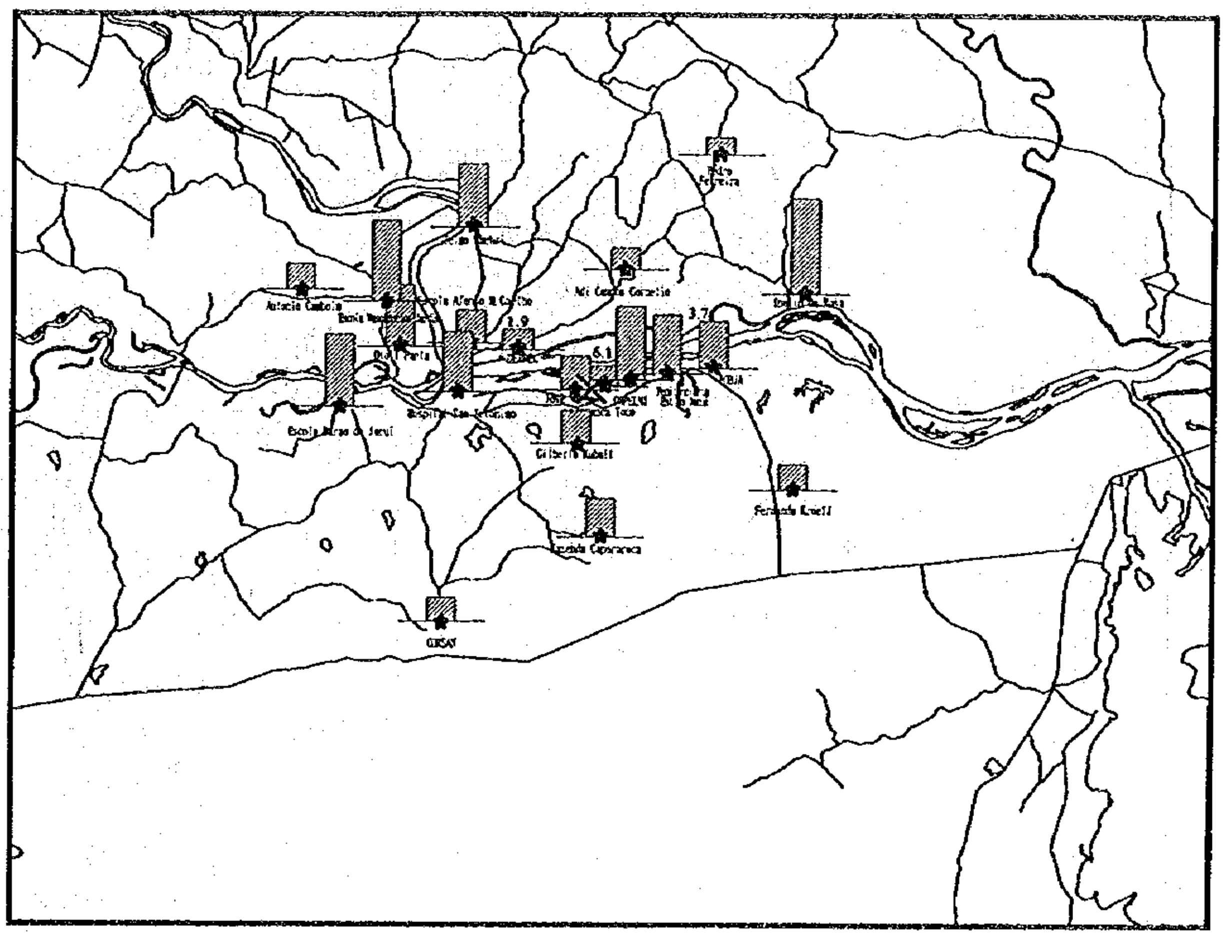
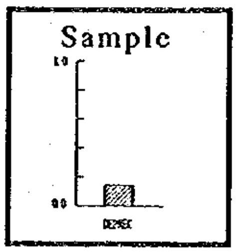


Figure 4.3.1(2) Regional Concentration Distribution by Simple Method (NO_2, Jorge Lacerda)



Charqueadas
SO_2(ug)



★ :Station
✕ :Power Plant

Figure 4.3.1(3) Regional Concentration Distribution by Simple Method (SO_2, Charqueadas)

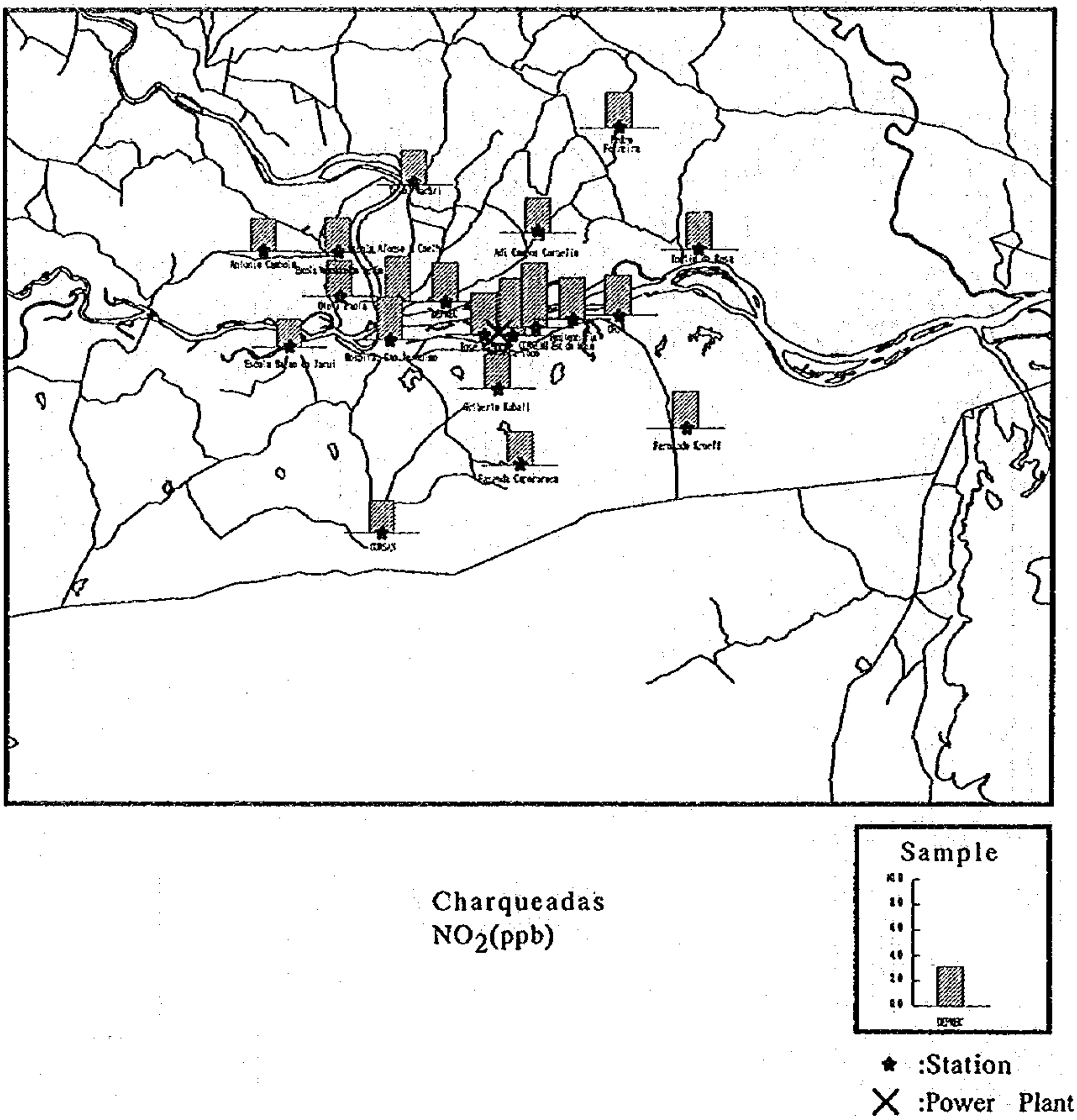


Figure 4.3.1(4) Regional Concentration Distribution by Simple Method (NO_2, Charqueadas)

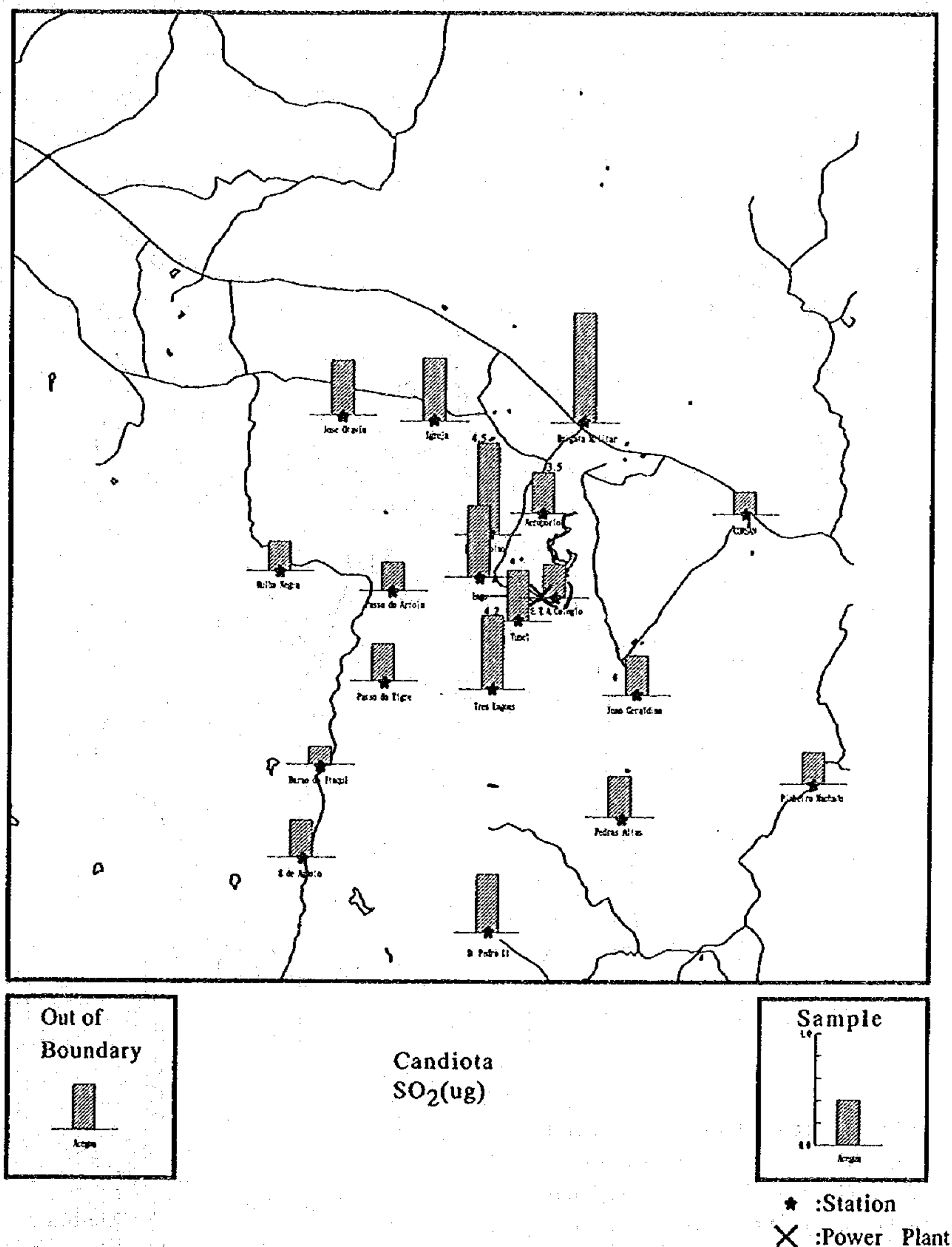
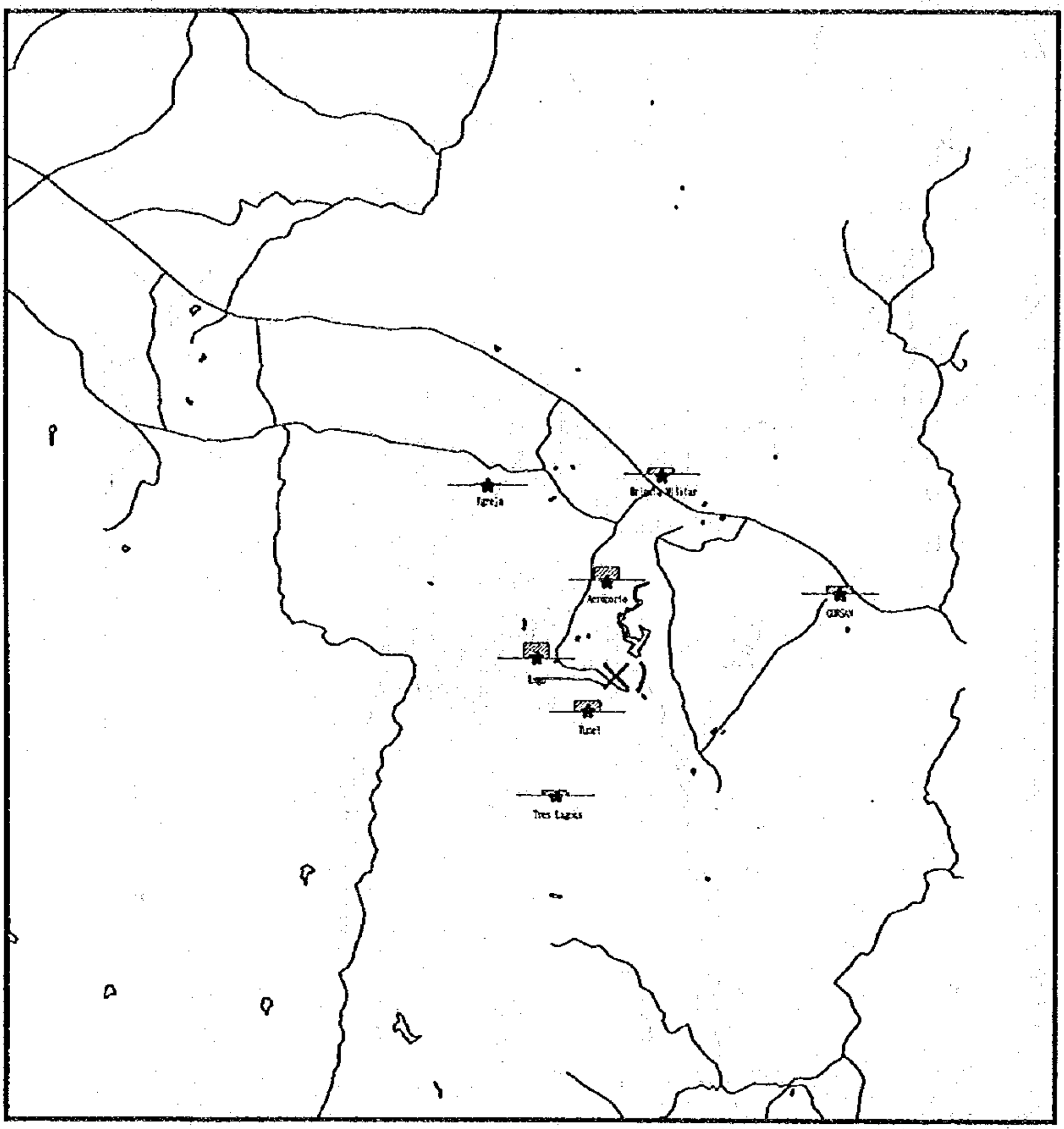
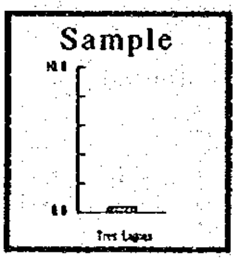


Figure 4.3.1(5) Regional Concentration Distribution by Simple Method (SO_2, Candiota)





Candiota
NO_2(ppb)

<u>Stations where Concentration is zero</u>

Candiotao	8 de Agosto
E.T.A. Colegio	Joao Geraldino
Passo do Arroio	Pedras Altas
Hulha Negra	D. Pedo II
Passo do Tigre	Jose Otavio
Barao do Itaqui	Pinheiro Machado
	Acegua

* :Station
X :Power Plant

Figure 4.3.1(6) Regional Concentration Distribution by Simple Method (NO_2, Candiota)

4.4 Chemical Analyses

4.4.1 Analysis Methods

In addition to the ion-chromatography analyses for the simple air monitoring, several chemical analyses were applied at the Charqueadas plant laboratory. The elemental analyses were entrusted to a local research institute after six similar laboratories were investigated for their instrument in possession, capability, etc. The analyses and equipment used were as shown in **Table 4.4.1** and **Appendix 1-3** and **1-4**.

Table 4.4.1 Chemical Analysis Methods

Measured Item	Chemical Analysis Method
Anions and Cations in rain water and dry precipitation	Ion-chromatography method (Dry precipitation after being dissolved unto 500 ml water)
pH of rain and dry precipitation	pH meter (glass electrode method)
Electric conductivity of ditto	Electro-conductivity meter
Elements in airborne dust and stack gas particulate	Atomic absorption

4.4.2 Samples

One sample of air borne particulates and one sample of stack gas particulate (dust or fly ash in the Report) were collected at each power plant. Twice a month for one year, each one sample of rain water and dry precipitation were collected at the following sites.

a)	Jorge Lacerda	Weather Station
b)	Charqueadas	OBJA
c)	Candiota	Aeroporto and Acegua

4.4.3 Results and Evaluations

For rain and dry precipitation, **Appendix 4-10** (analytical data) and **4-11A & B** (Data correlation) were prepared. Also **Appendix 4-12** was done for the elemental analyses. Following are the evaluation of the data.

(1) Rain Water and Dry Precipitation

Ion balance (ug equivalent/l) and theoretical pH value (pHc) were calculated from the results of analyses for rain water and dry precipitation, and each correlation between 1) pH and pHc, 2) anions and cations, and 3) total ions and electric conductivity (EC) was examined by correlation coefficients (r^2). Also the correlation between Na and Cl was examined.

The data which are obviously out of the regression lines are regarded as abnormal values. The correlation coefficients (r^2) excluding these abnormal data are also shown in **Appendix 4-11 B.**

a) Rain Water

Cation (including hydrogen ion to balance the measured pH) and anion ratio of rain water is one index for accuracy of chemical analysis, and the ratio should be between 0.8 and 1.2 according to the Japanese guideline of acid rain measurement (**Appendix 4-11 C**). The samples satisfying the guideline were only 4 out of 25 at Jorge Lacerda, 1 out of 25 at Charqueadas, 2 out of 26 at Candiota, and 1 out of 24 at Acegua. The number of the samples were too small to represent the annual averages of acidity of rain.

By enlarging the range of the Cation/Anion ratios to 0.5 and 1.5, there remain 17 at Jorge Lacerda, 9 at Charqueadas, 2 at Candiota, and 4 at Acegua as acceptable data, of which annual average pH with rain volume weighted were 4.51, 5.22, 5.31, and 5.91. The acidity levels were similar with those in Japan (pH 4.3 to 5.2 during fiscal 1988 to 1990) as **Appendix 4-11 D**. Continuation of the measurement with accurate methods and well maintained equipment is highly recommended.

pH and pHc were not correlated for any of the 4 sampling points nor for the 4 sampling points as a whole. In terms of ion balances, the amount of cations generally exceeded that of anions (distributed around the upper part of the correlation graphs (see **Appendix 4-11 A**)) and pHc was calculated as alkaline, while measured pH this time showed acidity on almost every point. However, the anions which should cause the acidity were not detected. Pure water's pH is about 5.6 in an ordinary state, with a stable equilibrium of CO_2 in the atmosphere. However, that of rain water is affected by pH buffer actions due to acid gases, alkaline dust like sand particulates, and the salts contained. The results of this measurement can be considered to be affected by these reactions.

Anions and cations were strongly correlated for each of the 4 sampling points and for the 4 sampling points as a whole. The 2 data for NH_4 at the Charqueadas plant were abnormal values for the 4 sampling points as a whole.

Total ions and EC were also strongly correlated for each of the 4 sampling points and for the 4 sampling points as a whole. The 2 data for NH_4 as mentioned above, and EC at the Charqueadas plant were abnormal values, and the EC had abnormal values for the 4 sampling points as a whole.

b) Dry Precipitation

pH and pHc were not correlated for any of the 4 sampling points or for the 4 sampling points as a whole as was the case with rain water, and it was also believed that the results were affected by pH buffering actions due to salts.

Anions and cations were correlated but not strongly. There were points at which their correlation was strong, excluding abnormal values, but considering the 4 sampling points as a whole, the relation between anions and cations was not established with dispersion.

Total ions and EC were not correlated for the Candiota plant (No. 20 Acegua). In this area, measurement errors tend to occur because of the low total ion concentration and low EC. It is believed that it causes this dispersion. The 2 data for EC at the Charqueadas plant were abnormal values for the 4 sampling points as a whole.

c) Correlation between Na and Cl

They were strongly correlated in rain water for each of the 4 sampling points except for 1 piece of data. It is believed that microscopic sea salt and rock salt particles containing NaCl were scattered widely into the atmosphere and were caught by rain water.

They were not correlated in dry precipitation except near the Jorge Lacerda plant. It is believed that particles of sea salt and rock salt etc. big enough to be captured as dry precipitation were not scattered wide enough to reach the sampling points.
It seems that the results for Jorge Lacerda were affected by sea salt particles because

of its seaside location.

(2) Elements in Airborne and Dust

The results of the analysis conducted by the local research institute are shown in **Appendix 4-12 (1)** with the original reports. Pb and F were detected from almost every sample, but other elements were scarcely detected. It was quite strange that the coal fly ash contained too much of Pb, and Ni low to the detection limit of the atomic absorption spectrometry.

Therefore, coal fly ash samples from the 3 thermal power plants taken in the 3rd Field Study period were analyzed in Japan to confirm the previous results. It was found that all of these samples contained less Pb and more Ni (see **Appendix 4-12 (2)**) than the previous results. Again, the samples, the counterpart trainee (Ms. Rita Tissot) brought, were analyzed in Japan. The results were also given in **Appendix 4-12 (3)**. It was indicated that the substantial amounts of Ni were contained in the fly ashes. Pb contents in the fly ashes were one order lower than those in the airborne samples. The local analytical results of Pb contents in the airborne samples were in the same order with those carried out in Japan.

Surface layer of the silicate shell of the earth contains chemical elements in the following numbers in average according to Clarke et. al. (Source: Chronological Scientific Tables, Japanese National Astronomical Observatory, 1995):
Pb (13 mg/kg), Ni (75 mg/kg), Co (25 mg/kg), Be (2.8 mg/kg), and Fe (50,000 mg/kg).

In comparison with the above so called Clarke Number, airborne Pb in the analyzed samples seems probably from unnatural sources. World Health Organization set up the guideline of Pb contents in the air to be 0.5 to 1.0 $\mu g/m^3$. Pb contents in **Appendix 4-12 (3)** are in the range of 0.019 to 0.156 $\mu g/m^3$, indicating lower than the WHO guideline.

Airborne Co and Fe come probably from soil, except Fe in Arranca Toco sampled on 18 May, 96.

CHAPTER 5 CURRENT STACK GAS QUALITES

5.1 Coal Steam Power Plants

5.1.1 Location of the Power Plants

The Jorge Lacerda and Charqueadas plants of ELETROSUL are respectively located in the State of Santa Catarina and of Rio Grande do Sul. The Candiota plant of CEEE is in the State of Rio Grande do Sul. All the plants are mine-mouth operations. **Fig. 1.1.1** indicates locations of all the three plants.

5.1.2 Specifications of Existing Plants

Table 5.1.1 gives the general specification of existed power plants. The plants fire low grade coal excavated near-by mines. All the units in the plants are equipped with electrostatic precipitators. However, there are no other facilities installed in the plants to remove SO2 nor NOx.

5.1.3 Operating Situation of Existing Power Generation Facilities

(1) Pulverized Coal Firing Method

Pulverized coal firing method is employed at all the units in the three plants. In this process fuel coal is pulverized with mill, then blew into a furnace together with carrier air by burner, and combusted. As pulverized coal is combusted by suspension firing with pulverized coal burner, ignition and combustion time is extremely shortened. It makes coal possible to burn in the very similar form to oil or gas combustion. In comparison with fire grate incineration (Stoker), pulverized coal firing has advantage shown as follows;

- Requires a small quantity of excess air and results high combustion efficiency
- Easy to adjust firing rates and conditions, possible to ignite and extinct in a short time
- Easy to operate with automatic control
- Possible to burn coal with liquid or gas fuel

Table 5.1.1 Specifications of Existed Coal Steam Power Plants

Power	Plant	Unit	Rated MW	Amount Coal Burnt (t/h)	Stack Gas (m^3N/h)	Stack Gas Temperature (°C)	Stack Height (m)	Stack Diameter	EP Efficiency (%)	Cooling Tower	Startup
Jorge Lacerda	A I	1	50	30.23	238,000	150	150	5.9	99	Forced Cooling	1961
		2	50	30.23	238,000	150			99		1963
	A II	3	66	34.23	260,000	160			99		1972
		4	66	34.23	260,000	160			99		1972
	B III	5	125	74.7	480,000	180	100	4.6	99	Forced Cooling	1977
		6	125	74.7	480,000	180	100	4.6	99		1977
Total		6	482								
Charque-adas		1	18	20.7	96,000	180	62	5.0	99.5	Forced Cooling	1956
		2	18	20.7	96,000	180			99.5		1956
		3	18	20.7	96,000	180			99.5		1956
		4	18	20.7	96,000	180			99.5		1968
Total		4	72								
Candiota	A	1	63	69.3	246,000	130	150	5.05	99	Forced Cooling	1974
		2	63	69.3	246,000				99		1974
	B	1	160	206.67	910,000	162	150	5.05	99	Dry Natural Ventilation	1986
		2	160	206.67	910,000	162	150	5.05	99		1986
Total		4	446								

(2) Coal Combustion Control

For complete combustion of fuel, it is required to add a proper quantity of excess air depending on the state of fuel, in addition to theoretically required air volume. In case of pulverized coal, more excess air (air ratio of around 1.3) is necessary than that of burning oil or gas fuel. Residual oxygen concentration is usually around 5 - 6 %.

According to the monitored data, the residual oxygen concentrations were 8 - 11% at Jorge Lacerda (excluding O_2=19.2%, a measured value on February 23, 1996), 7 - 10% at Charqueadas, 10 - 16% at Candiota, respectively. High value was obtained in all cases. This indicates that the excess air was fed and, as a result, it causes a lowering of comprehensive thermal efficiency of the power plant. It is considered that the reason is combustion with a large quantity of excess air due to low heat value of fuel and to high ash content of around 50%. Also it is possible that air is leaked from the air heater or else.

(3) Annual Availability Ratio of Existing Facilities

The annual availability ratio of each power plant from March of 1996 to February of 1997 was as follows; at Jorge Lacerda power plant, 45.8% of Unit A1, 45.2% of Unit A2, 42.6% of Unit A3, 40.8% of Unit A4, 59.9% of Unit A5, 67.0% of Unit A6 and 53.8% of power plant as a whole; at Charqueadas power plant, 52.4% as a whole; and at Candiota power plant, 9.8% of Unit A1, 35.1% of Unit A2, 35.3% of Unit B1, 31.9% of Unit B2 and 30.5% as a whole. The availability ratio of Candiota power plant is extremely low.
Though the availability ratios of Jorge Lacerda and Charqueadas power plant are different in their level, both are high in winter season (from May to October) and low in summer (from November to April). As for Candiota A Line, the availability ratio is high in winter season and low in summer, and Candiota B Line vice versa.

(4)Environmental Measures for Existing Facilities

Almost all the existing electrostatic precipitators (EPs) are retrofitted to the plant in order to remove particulate emission with high collection efficiency. Other are installed gradually implementing additional measures at every time of expansion.

It seems that maintenance and check of facilities, and repairing and mending are not carried out enough in all three thermal power plants. Moreover, it is considered that the performances of electrostatic precipitators are fairly low, judging from the situation of stack gas, though the collection efficiencies of all EPs are more than 99% in their specifications. This tendency is remarkable at Charqueadas and Candiota power plants. It also can be judged from scattering of fly ash on and off power plant premises, as well as from leakage of flue gas from flue.

Although coal is stored as open air storage at coal yard without any device for preventing measures such as wind break net, water spray system, etc., coal's effects on surrounding area are slight, comparing to that of fly ash.

5.1.4 Coals in Power Plants

(1) Properties of Coals

Coals burnt at the three power plants have low heating values, high ash contents, high oxygen. **Table 5.1.2** lists the coal properties used as the design basis. The sulfur contents are rather low. However, because of low heating values, SO2 emission in the stack gas becomes higher than expected. **Appendix 2.1** gives locations of mines, production rates, sulfur contents as mined and after washed in the states of the southern Brazil.

Table 5.1.2 Properties of Coal Used in Power Plants

Item (Unit)	Power Plants			
	Jorge Lacerda	Charqueadas	Jacui	Candiota
Caloric Value (Kcal/kg)	4300 - 4700	2945-3255	3600-3800	3027-3572
Fixed Carbon (wt%)	33-40	FC/VC<1.2	FC/VC<1.6	24.5-28.1
Volatile Component (wt%)	20-26	--	--	21.5-23.5
Ash (wt%)	39-44	53-56	45-48	49.1-53.5
Total Carbon (wt%)	43-50	--	--	28.0-30.0
Hydrogen (wt%)	2.7-3.1	--	--	1.8-2.4
Sulfur (wt%)	1.8-2.3	<1.3	0.7	0.8-1.5
Nitrogen (wt%)	1.0-2.1	--	--	0.4-0.7
Oxygen (wt%)	3.5-8.0	--	--	6.7-10.0
Water (wt%)	6-10	12-15	<15	10.0-18.4

(2) Coal Transportation to Power Plant

The Jorge Lacerda plant receives coal by rail road from mines 60 to 70 km apart. The coal is stock piled at storage capacity of 1,000,000 tons in the plant site. Coal to the Charqueadas plant is shipped by tracks from mines 30 km apart. A belt conveyer is used to transport coal to the Candiota plant at the rate of 600 t/hr from the distance of 2.5 km. The Candiota plant have a coal storage of 300,000 tons which is equivalent to 30 days consumption.

5.2 Stack Gas Monitoring

5.2.1 Monitoring Methods

Stack gases of all units of three power plants were monitored of their pollutant emissions. Monitoring instruments employed are listed in **Appendix 1-4** as SO_2 analyzers, NO_x-O_2 analyzers and dust analyzer systems. Their principles of analyses are summarized in **Table 5.2.1.** Locations of measuring points for each stack gas emission and monitoring points in the measuring profile are shown in **Appendix 5-1.**

Table 5.2.1 Principles of Stack Gas Monitoring Methods

Analyzer		Method	Standard Applied
SO_2		Infrared absorption (Portable automatic analyzer)	JIS-B7981-84
NO_x		Chemiluminescence (Portable automatic analyzer)	JIS-B7982-88
O_2		Zirconia (Portable automatic analyzer)	JIS-B7983-94
Dust	Concentration of dust	Dynamic pressure balance (Cylinder filter-paper method) (Dust sampler)	JIS-Z8808-92
	Water content	$CaCl_2$ absorption	
	Velocity of flow	Pitot tube	
	Temperature	Thermocouple	

5.2.2 Monitoring Data and Evaluation

(1) Summary

Stack gas monitoring was carried out once to four times at each unit depending on its availability. The monitored data at all power plants are shown in **Appendix 5-2**. By plotting SO_2, NO_x and dust emission rates per outputs on each monitoring day in **Appendix 5-3,** abnormal values are eliminated from further studies. Velocity and temperature distributions of exhaust gas, and dust distribution maps are shown in **Appendix 5-4.**

In **Appendix 5-3,** excluding abnormal values, the amount of dust emissions was 0.4~12.4 Kg/h·MW, that of SO_2 was 19.9~52.4 Kg/h·MW and that of NO_x was 1.1~4.5 Kg/h·MW. The range of the amount of dust emissions is very wide. It is believed that this is because ash contents in coal change greatly or because EP operations are different from expected.

Appendix 5-5 shows the various correlation plots between such as 1) power generation output and the amount of fuel use, 2) output and the amount of exhaust gas, and 3) output and the amount of SO_2 emissions. As the amount of fuel use was calculated on the basis of known output values using the data from the power plant side, it is natural that the correlation between output and the amount of fuel use is plotted on a linear. However, it was not found at Charqueadas. At Jorge Lacerdas, a good correlation of output-exhaust gas and output-SO_2 emission was found as in **Figure 5.2.1**, and the reliability of the monitoring data was demonstrated. Because there was no difference in output at the Charqueadas plant, and data at only two outputs were obtained at the Candiota plant, their correlation curves are straight. From now on it is desirable to monitor at different outputs. If these correlation curves can be established, they will be used for forecast of the amount of pollutant generated as well as for checking of monitored values.

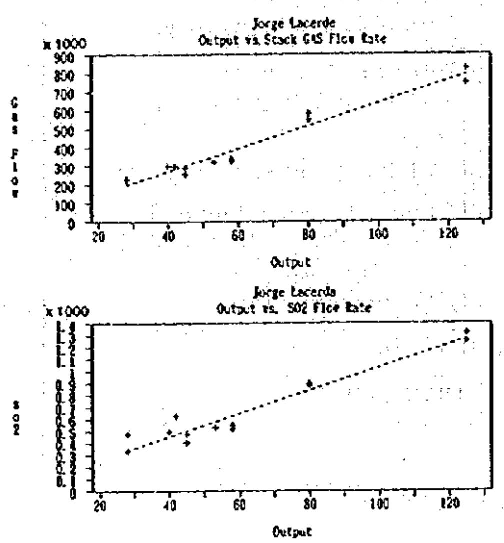


Fig. 5.2.1 Output MW vs. Stack Gas & SO_2 Flow Rates

The percentages of the calculated stack gas or the theoretical SO_2 emission rates to the measured values are shown in **Table 5.2.2**. Relatively good coincidence was found as shown in the table, with 66.5~134% in the case of stack gas and 59.6~136% in the case of SO_2. This proves that measurements were carried out with high accuracy. The calculation details are given in **Appendix 5-6**.

As to the amount of NO_x generated from power plants, low values were generally obtained at all the units of all the plants, possibly because boiler combusting temperature is low due to a great deal of combustion air, etc. As shown in **Figure 5.2.2** (#058), the rate of NO generation to temperature increases sharply when the temperature reaches 1,600℃ or higher.

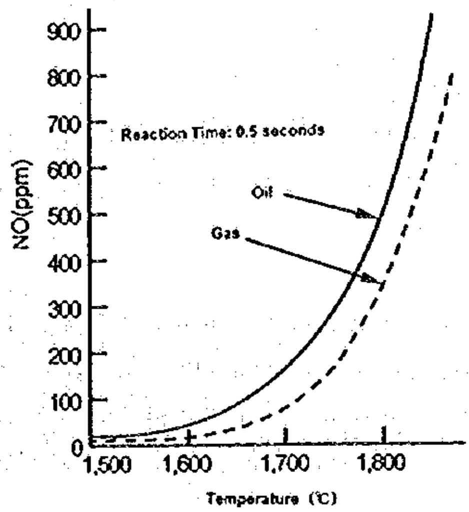


Fig. 5.2.2 Theoretical NO Generation vs. Combustion Temperature (#058)

Table 5.2.2. Percentages of Calculated Values to Measured Data

%

	Jorge Lacerda		Charqueadas		Candiota	
	Range	Average	Range	Average	Range	Average
Stack Gas	69.1～97.7	84.5	96～134	125	66.5～89	76.9
SO_2	59.6～102	77.6	80.4～136	107	70.4～133	103

Appendix 5-8 shows comparisons between the monitoring results (dust and SO_2) and the current emission standard in Brazil (#02) on the assumption that similar plants would have constructed now. Dust emissions of dust from the bigger units seem to exceed the national standards. SO_2 emissions from all units except some units at Charquedas largely surpassed the standards.

Table 5.2.3 lists the ratios of the measured values to the ones in the agreements with the State of Rio Grande do Sul (**Table 3.2.4**). The ratio over than 1.0 means that the current emission does not satisfy the agreement. Emissions of dust and SO_2 at all units in the list do not conform to the agreement when the expanded units are in operations. Also NOx emissions from Candiota A1 and 2 units are slightly higher than the agreement rate.

(2) Dust

1) Jorge Lacerda Plant

The concentration of dust was in the range of 0.083~1.261g/m^{3}N. Although there were a small number of data, the comparison in pseudo-condition with the national standard indicated that measured values at all Units except Unit 5 conformed to the standard.

Analysis of dust distribution was carried out for Units 1, 2, 3, 4 and 6. Gas velocity at Units 1 and 2 was faster in the upper part and slower in the lower part, and the velocity at Units 3, 4 and 6 was shown to be almost uniform. Sampling should be made around the center part in order to obtain typical values at all units in the Jorge Lacerda plant.

Table 5.2.3 Ratios of Measured Values to FEPAM Agreement

Power Plant	Units	Dust	SO_2	NOx
Charqueadas	1	-	13.6	0.9
		5.0	9.1	0.9
		7.0	9.3	0.7
	2	-	12.7	0.6
		1.0	10.5	0.5
		1.4	11.1	0.6
		13.5	10.1	0.6
	3	6.5	12.1	0.9
		4.8	8.1	0.8
		5.7	8.2	0.8
	4	6.6	8.9	0.8
		7.9	9.9	0.8
Candiota	A1	19.1	-	1.0
		12.5	18.6	0.9
	A2	11.6	15.1	1.2
		11.3	15.3	1.3
	B1	-	2.9	1.0
	B2	-	3.0	0.7
		-	3.2	0.7
		-	3.3	0.9

2) Charqueadas Plant

The concentration of dust was in the range of 0.081~1.081g/m^{3}N. In pseudo-condition comparison with the national standard, it was indicated that the emissions from all units conformed to the standard. In comparison with the FEPAM agreement of 80 mg/m^{3}N, the measured values were 1.0~13.5 times higher. It will be necessary to improve facilities in order to achieve the agreement values by 2005.

Analysis of dust distribution was carried out twice for Unit 1. At the central point of Unit 1, the data were close to the average with ±10% or lower of deviation. Therefore, the center point is regarded as the representative point. Distribution analysis of gas velocity showed that the velocity was almost uniform.

3) Candiota Plant

The concentration of dust was in the range of 0.929~2.052g/m^{3}N. In the pseudo-condition comparison with the national standard, the measured values were higher at larger units (B1 and 2). In comparison with the FEPAM agreement value of 80mg/m^{3}N, the measured values were about 10~20 times higher. It will be necessary to improve facilities in order to achieve the agreement values by 2002 or 2004.

Analysis of dust distribution was conducted for Unit A1 only. The largest deviation was around±50 % and the distribution was narrow. Therefore, for dust sampling, one sample each at two central positions of sampling nozzles is enough (C-2 and D-2 nozzles: **Appendix 5-4**), and then those values should be averaged to obtain representative data. Distribution analysis of gas velocity indicates that the velocity is faster on the side of Sampling Nozzle Line (A) than that of (F).

(3) SO_2

1) Jorge Lacerda Plant

SO_2 concentration was in the range of 5,829~8,371mg/m^{3}N by conversion to 6% O_2. In pseuod-comparison with the national standard, the standard was not met at any units. In the comparison between calculated exhaust gas volume/theoretical volume of SO_2 emitted from the power plant, and measured values (**Table 5.2.2**), the percentages of the calculated values to the measured values were 84.5% and 77.6% respectively on the average, and relatively good coincidence was indicated. If the amount of coal use is measured with a conveyor scale, etc., nearly 100% of the agreement will be obtained. This will enable understanding of the volume of SO_2 emissions by means of calculation.

According to agreement with FATMA, the maximum acceptable value of total SO_2 emission generated from the power plant, including that from Unit IV, is 20.4t/h. As the maximum total within measurement of existing boilers is 12.2t/h, Unit IV has room for 8.2t/h. This is equivalent to 2.2%S at 100% load, while what has been agreed with FATMA is 2.2%S.

2) Charqueadas Plant

SO_2 concentration was in the range of 3,257~5,429mg/m^{3}N by conversion to 6% O_2. In pseudo-comparison with the national standard, except Unit 4, all others did not meet the standard although the differences are small. In comparison, any unit could not satisfy with the FEPAM agreement rate (**Table 3.2.4**).

In comparison between calculated stack gas or SO_2 volumes and measured ones emitted from the power plant (**Table 5.2.2**), the percentages of calculated values to measured ones were 125% and 107% respectively on the average, and great coincidence was shown.

3) Candiota Plant

SO_2 concentration was in the range of 6,057~7,457mg/m^{3}N by conversion to 6% O_2. In pseudo-comparison with the national standard, the standard is not conformed at any units. The FEPAM agreement value is neither satisfied at any units.

(4) NO_x

1) Jorge Lacerda Plant

NO_x concentration was in the range of 264~750 mg/m^{3}N (6% O_2 conversion values).

2) Charqueadas Plant

NO_x concentration was in the range of 196~368 mg/m^{3}N (6% O_2 conversion values). The FEPAM agreement value is met at all units.

3) Candiota Plant

NO_x concentration was in the range of 370~663 mg/m^{3}N (6% O_2 conversion values). In comparison with the FEPAM agreement, those of Units A1, B1 and B2 conform to the agreement, while those of Unit A2 are slightly over it. As Units A1 and A2 have the same structure, appropriate measures against NO_x will be required for both units the future.

(5) O_2

O_2 concentration in exhaust gas was generally high. It was supposed that there were leaks from air heaters etc. in addition to an excess of combustion air. Residual O_2 was 8.12~10.7 % at Jorge Lacerda, 6.7~9.8 % at Charqueadas, and 9.6~16.2 % at Candiota.

With excess O_2 in the stack gas, a boiler thermal efficiency decreases. As shown in **Appendix 5-6**, the difference in the thermal efficiency between the operations with 6% residual O_2 and the operation with 10% O_2, is almost 3%. In consideration of power generation thermal efficiency of around 30%, this loss is large. While, low-oxygen combustion is also used for restraint of NO_x generation as well as for improvement of the thermal efficiency. However, as excessively low oxygen combustion causes incomplete combustion which then results in promotion of generation of the unburnt combustibles such as carbon-dust, CO, and hydrocarbon, it is necessary to take sufficient care.