Chapter S3 Electric Power

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Appendixes

Tables and Figures

S3-A1 List of Thermal Power Plants in Argentina (1) (#234)

(Rated Capacity more than 10MW)

	Power Station	Rated Capacity (MW)	Plant Number	Fuel Type	Plant Type	Remarks
Capital Federal	Central Buenos Aires	321	2(1)	G, GO	CC	1CG, 1CV
	Nuevo Puerto	420	3	G, FO	TV	
	Puerto Nuevo	589	3	G, FO	TV	
	Nuevo Puerto	786	3(1)	G, GO	CC	2CG, 1CV
	Central Costanera	1,311	6	G, FO	TV	
	Central Costanera	851	3(1)	G, GO	CC	2CG, 1CV
Gran Buenos Aires	Dock Sud	75	2	G, GO	TG	
	Dique Blanca	68	4	G, GO	TG	
	CMS Ensenada	128	1	G, GO	TG	
	Genelba	674	3(1)	G	CC	2CG, 1CV
Buenos Aires	CET.Luis Piedrabuena	620	2	G, FO	TV	
	San Nicolas	650	5	C, G, FO	TV	
	San Nicolas	830	3(1)	G	CC	2CG, 1CV
	Mar de Ajo	34	2	GO	TG	
	Mar del Plata	98	5	G, GO	TG	
	Mar del Plata	60	2	G, FO	TV	
	Necochea	206	4	G, FO	TV	
	Villa Gesell	32	2	GO	TG	
	Argener	169	1	G	TG	
Catamarca	E.T.Catamarca	16	1	GO	TG	
Cordoba	Modesto Maranzana	70	4(2)	G, GO	CC	2CG, 2CV
	Dean Funes	34	2	G, GO	TG	
	Dean Funes	33	1		TV	
	Rio Cuarto	34	2	G, GO	TG	
	San Francisco	40	2	G, GO	TG	
	Sudoeste	140	4	G, GO	TG	
	General Levalla	46	2	G, GO	TG	
	Pilar	216	4	G, FO	TG	
	Villa Maria	48	3	G, GO	TG	
Corrientes	Goya	11	8	GO	D	
	Ituzaingo	10	11	GO	D	
	Corrientes	17	1	GO	TG	
	Goya	17	1	GO	TG	
	Santa Catalina	34	2	GO	TG	
Chaco	Barranqueras	76	5	GO	TG	
	Barranqueras	35	3		TV	
Chubut	Comodoro Rivadavia	13	6	G	TG	
	Puerto Madryn	46	2	G	TG	
	Patagonia	78	2	G	TG	
Entre Rios	Caseros	22	4	FO	TV	
	Parana	17	1	GO	TG	
Formosa	Formosa	17	1	GO	TG	
Jujuy	Palpala	35	2	G	TG	
	San Pedro	32	2	G	TG	
La Pampa	General Pico	17	1	G, GO	TG	
La Rioja	La Rioja	9	2	GO	D	
	La Rioja	31	2	G	GT	
Mendoza	Lujan de Cuyo	120	2	G, FO	TV	
	Lujan de Cuyo 2 (TG25)	290	2(1)	G, GO	CC	1CG, 1CV
	Lujan de Cuyo 1 (TG21,22)	70	3(1)	G	CC	2CG, 1CV
	Lujan de Cuyo (TG23,24)	44	2	G	TG	Co-Gene

G: Natural Gas, FO: Fuel Oil, GO: Gas Oil, C: Coal

TV: Steam Turbine, TG: Gas Turbine, CC: Combined Cycle, D: Diesel

S3-A1 List of Thermal Power Plants in Argentina (2)

(Rated Capacity more than 10MW)

	Power Station	Rated Capacity (MW)	Plant Number	Fuel Type	Plant Type	Remarks
Misiones	La Tablada	22	2	GO	TG	
	Obera	35	2	GO	GT	
	Posadas	11	4	GO	GT	
Neuquen	Filo Morado	68	3	G	TG	
	Loma de la Lata	375	3	G	TG	
	Agua del Cajon	671	7(1)	G	CC	6CG, 1CV
	Alto Valle	80	4(2)	G	CC	2CG, 2CV
	Alto Valle	18	1	G	TG	
Rio Negro	General Roca	125	1	G	TG	
Salta	General Guemes	245	3	G	TV	
	Oran	10	6	GO	D	Emergencia
	Oran	4	1	G, GO	TG	Emergencia
	Salta	11	1		TG	
	Tartagal	13	2	G	TG	
	Termo Andes	414	2	G	TG	Co-Gene
San Juan	Presidente Sarmiento	32	3	G, GO	TG	
Santa Cruz	Pico Truncado Ⅰ	59	5	G	TG	
	Pico Truncado Ⅱ	22	2	G	TG	
	Rio Gallegos Ⅱ	13	4	GO	D	
	Rio Gallegos Ⅱ	32	6	G, GO	TG	
	Rio Gallegos Ⅰ	12	1	G	TG	
Santa Fe	Venado Tuerto	19	10	GO	D	
	Venado Tuerto	8	8	G	TG	
	Calchines	30	1		TV	
	Santa Fe Oeste	42	2	G, GO	TG	
	Sorrento	226	3	G, FO	TV	
Santiago Del Estero	Frias	32	2	G	TG	
	La Banda	16	1	G	TG	
Tierra Del Fuego	Rio Grande	3	3		D	
	Rio Grande	59	3	G	TG	
	Termo Electrica Turbo	24	6	G, GO	TG	
Tucuman	Independencia	30	2	G	TG	
	Sarmiento	11	1	G	TG	
	CT Tucuman	438	3(1)	G	CC	2CG, 1CV
	CT San Miguel de Tucuman	123	1	G	TG	
	CT Ave Fenix	40	1	G	TG	

G: Natural Gas, FO: Fuel Oil, GO: Gas Oil, C: Coal

TV: Steam Turbine, TG: Gas Turbine, CC: Combined Cycle, D: Diesel

S3-A2 Various Air Pollutant Control Measures at Thermal Power Plants

Main Reference
1) Flue Gas Clean-up Technologies in the World by Junpei Andou (J)
2) Stationary Source Control Manual at Developing Countries by JEA (J)
3) Experiences and in-house data of the JICA Team

1. Measures against Sulfur Oxides

(1) Implementation of Fuel Measures

This measure is to reduce an emission rate of sulfur oxides from a thermal power plant by converting its fuel to one of lower sulfur contents, such as, diesel oil, naphtha, NGL, natural gas.

(2) Implementation of Facility Measures

This is a measure that sulfur oxides are removed directly from flue gas by means of flue gas desulfurization plants. **Table 1** shows major desulfurizing methods.

Table 1 Kind of Flue Gas Desulfurization Processes

Processes		Chemical Agents	Byproducts
WET	Limestone-Gypsum	limestone or lime slurry for absorption, and air for oxidation	calcium sulfate particles for recovery or throwaway
	Limestone-Sludge	limestone or lime slurry for absorption	calcium sulfite sludge for throwaway
	Wellman Lord	sodium carbonate solution	concentrated sulfur dioxide
	Magnesium Throwaway	magnesium carbonate solution	magnesium sulfite solution throwaway
DRY	Lime Slurry Spray	slurry sprayed to dryer vessel or duct	calcium sulfite collected with soot
	Limestone Injection	limestone slurry injected to furnace	ditto
	Active Carbon Adsorption	active carbon moving bed	concentrated sulfur dioxide
	Limestone Fluidizing	with coal combustion in fluidized bed	calcium sulfite collected with ash

The plant by-producing concentrated sulfur dioxide needs a sulfur or sulfuric acid plant nearby.
There are many other processes than listed above, commercialized or under development, in the world.
Their varieties are in contact methods of flue gas with chemical agents, and types of chemical agents.

(3) Wet Limestone Desulfurization Processes

The most commonly used in the power industry are wet limestone processes. The basic flow scheme of this process (**Figure 1**) is as follows: 1) sulfur oxides (SO_x) in flue gas is absorbed in a slurry containing limestone in a contacting device, such as a spray tower, 2) calcium sulfite produced in the slurry is completely oxidized with air in order to get gypsum (calcium sulfate), and 3) after free water is separated from the gypsum, it will be taken out as a by-product.

A key variation of the above process is an elimination of air oxidation and accordingly of gypsum production. The process is called a limestone sludge throwaway process. By this variation, there was a problem of hard scale deposits in the absorption tower in the past. However, the problem has overcome by an addition of chemicals (oxygen scavenger) in the absorption slurry.

One another variation of the limestone process is the CT-121 process (**Figure 2**) which uses the JBR (jet bubbling reactor) contacting device instead of the absorption tower. All chemical processes, absorption, oxidation, and neutralization, are carried out in one JBR. This process is simple and revolutionary, because of less number of facilities, smaller area where such plant is installed, easier operation, and competitive construction and operation costs.

(4) Basis for Adoption of Wet Limestone Desulfurization Process

Generally a desulfurization process for a large power plant should be selected based on following considerations, besides ordinary economical and technical feasibility studies: a) process history - one year continuous operation by more than 100MW capacity, b) no secondary pollution by plant operation including throwing away of by-products, c) easiness of operation by power plant operators, d) availability of chemical agents and spare parts locally, e) easiness of maintenance, and f) market of by-product, if salable.

The limestone desulfurization process has the following characteristics, and is widely employed in power plants because it is the most reliable and the economical one from the general point of view.

1) Its process is relatively simple and high SO_2 removal efficiency can be obtained.
2) Its plant operation is stable and easy for power plant operators. Long continuous operation is possible. Its plant can withstand severe load changes.
3) The plant equipment is easy to maintain.
4) Limestone is found in abundance, costs low, and is safe for handling.

Further, if gypsum is by-produced,

5) It can be sold as raw material of cement, gypsum boards etc., or can be stored relatively easily without further pollution.
6) Any secondary pollution is not generated.

(5) Construction and Operation Costs

The installation cost of the wet type limestone gypsum flue gas desulfurization plant of 90% SO_2 removal efficiency is in the range of ¥ 7,000 - 15,000/kW in Japan, or around 10% of the corresponding thermal power plant installation cost itself. For the plant to be built in a power plant of 500MW rated capacity, the construction cost ranges from ¥3,500 to 7,500 million. The difference is from costs of engineering, equipment and labor, and know-how fee.

Operating cost is different from local prices of electricity, limestone, water, wage of operators, and maintenance, and also policy of depreciation. Requirements for rough estimation of the operating cost of the limestone gypsum process of 90% SO_2 removal are as follows:

Electricity	0.7 - 1.0 % of the rated capacity of the corresponding power plant: 5MWh if 500MW.
Limestone	1.64 tons of $CaCO_3$ (as 100%) per 1 ton of SO_2 to be removed.
Water	0.5 - 0.8 tons/day for 1 MW rated capacity: if 500 MW, it is 250 - 400 tons/day; practically it should be calculated from an evaporation rate of water contacting with flue gas (temperature and water vapor contents at the outlet of a gas-gas heat exchanger) to cool it to its water saturation temperature. The requirement is the sum of the above evaporation rate and the water discharge rates with byproducts and else.
Operators	2 operators/a shift.
Maintenance	In case of the limestone gypsum plant, it can be annually 2% of the plant construction cost as a practical and marginal estimation.

(6) Cost-down of Limestone Flue Gas Desulfurization Plant

The limestone process is the most advantageous selection in the power industry, if circumstances allow so. However, the cost of its plant construction and operation is not the cheapest among others in general. Therefore, various research and development studies are being carried out to reduce expenses sharply by simplifying processes and plants as much as possible. Generally, reduction of the cost is achieved with the items shown in **Table 2** by plant suppliers. Users' consideration for less costs of the installation are also included in **Table 2**.

Table 2 Measures to Cut Down Construction Cost of Flue Gas Desulfurization Plants

Item	Description	User Side's Consideration
Decrease of engineering time	New planning and designing should not be conducted each time.	Selecting the plant with standardized arrangement, capacity, and specifications
Simplification of equipment/ machines comprised the plant	Cutting down of design surplus, Development of new design.	Lowering request of desulfurization efficiency within the acceptable ranges in view of environmental preservation.
Re-evaluation of construction materials of equipment and machines	Conversion from high-grade materials to low-priced ones.	Supporting with a regular check and maintenance plan. Change of specifications.
Simplification of processes	Development of a process which constituent equipment / machines can be omitted or integrated.	Lowering demanded levels of peripheral matters such as qualities of the by-product.
Omission of some of constituent equipment and machines by simplifying the control method		Adopting a minimum automatic control process required.

(7) Operation and Maintenance

In many cases, flue gas desulfurization plants in thermal electric power plants are operated automatically with instrumentation control systems. However, since full automation from starting to stopping operation is difficult from the viewpoint of safety and economy, there are some left to operators' judgements. Therefore, it is important to educate operators so that they can cope with exactly whatever kinds of events occur. The limestone processes are the easiest processes of operation that educational requirement is the minimum for power plant operators.

Flue gas desulfurization plants, especially in thermal electric power plants, have to be operated continuously for 1 - 2 years without stopping. This is the most important requirement of the flue gas desulfurization plant. The plant should not cause operational stoppages of thermal power plants. Reliability of long continuous operation should be emphasized at the beginning of the process selection. Also, the point to stress is the importance of the regular plant inspection and maintenance after commencement of operation. The maintenance system should be established including prediction of repair, replace, or reinforcements of the plant equipment, purchase of spare and consumable parts. Also a cooperation system with venders concerned should be established, following to the inspection and trouble-shoot manual.

(8) Tendency of Future Technologies

The limestone gypsum flue gas desulfurization process has a history of about 35 years, and is completed as the one to be used practically with satisfaction in full. However, there is a possibility of further improvement on the process and plant and introduction of technology to eliminate or minimize water discharge rate.

There are under going of another kinds of flue gas desulfurization process development. **Table 3** shows noteworthy flue gas desulfurization techniques. The seawater desulfurization method is not used in Japan because of low desulfurization efficiency and uncertainty of secondary pollution in seas. However, there are applications in England, Norway, India, etc. The electron beam method has materialized at a Japanese electric power company with a capacity of 225MW. Its uniqueness is to by-produce fertilizer (mixture of ammonium sulfate and nitrate).

Table 3 Toward the Future of Flue Gas Desulfurization

Name etc.	Description	Problems and Check Points
Seawater desulfurization method	Method to desulfurize by Ca/Mg contained in seawater. Used seawater is treated and discharged. As a large quantity of seawater is required, it is necessary that a power plant is adjacent to the seashore.	Assessment regarding sea pollution.
Electron beam method	Method to convert NO_x and SO_2 to mixture of ammonium nitrate and sulfate by irradiating flue gas with electron beam under the existence of ammonia. Because temperature of gas does not fall much, there are advantages such as no cost of re-heating and no waste water discharge. It is said that construction and operation costs of this method can comprehensively compete with those of the limestone gypsum method.	Though by-products can be used as fertilizer, they are subject to a market size and distribution. Power consumption is about 2.5% of the rated power plant capacity. Availability and maintenance of beam generators

There are also developments of dry lime or limestone processes and dry simultaneous SO_x and NO_x removal processes in the world.

2. Measures against Nitrogen Oxides

For emission reduction of nitrogen oxides (NO_x), there are three methods: fuel measures, combustion improvement and installation of flue gas denitrification facilities. NO_x is generated from nitrogen in air and in fuel. The former NO_x is called as thermal NO_x and the latter as fuel NO_x.

(1) Fuel Measures

This measure is to restrain the fuel NO_x by burning lighter fuels, such as naphtha, natural gas, etc. having less amount of nitrogen.

(2) Combustion Improvement

As to thermal NO_x, the higher combustion temperature inside a furnace, the higher O_2 concentration, and the longer retention time in high temperature generate the more thermal NO_x. Therefore, the quantity of NO_x generation can be restrained by reducing O_2 concentration in combustion zone by restraining excess air. This is possible by the low excess-air combustion method, the two-stage combustion method, the exhausted-gas mixture method, and the process employing a low NO_x burner.

1) Two-Stage Combustion

Two-stage combustion is a method based on the following procedures: 1) air supply to the lower part of a furnace is restrained to produce reduced atmosphere for combustion, and 2) subsequently the sufficient amount of air is added to the upper part of the furnace to complete the combustion, and as a result generation of NO_x is restrained. Although this is effective, observation and care are required because the combustion is likely to be unstable and there are tendencies of increased unburned combustibles in exhausts and of more soot generation, particularly for coal combustion.

There is another measure that takes one more step forward. Fuel is blown into the upper part of combusting flames in furnace, in order to be burned in reduction atmosphere and reduce NO_x generation, and then further additional air is blown into furnace to make complete combustion. With this variation, NO_x can be reduced by around 50%. This method called as Furnace Denitrification, Three-Stage Combustion or Re-burning process requires a little higher height of a furnace, and is difficult to be applied for existing furnaces.

2) Flue Gas Recirculation

The flue gas recirculation is a method to reduce NO_x by returning a part of flue gas of around 350 to 400℃ to the vicinity of a burner and mixing it with combustion air so as to lower combustion temperature and O_2 concentration during burning.

Although much volume of recirculated flue gas is effective for reduction of NO_x, the more volume of recirculated flue gas exists, the poorer combustion occurs. Therefore, the volume of recirculated flue gas is limited to be 20 - 30 % of that of combustion air.

3) Low-NO_x Burner

The Low-NO_x burner has the structure to promote burning under the optimum conditions by forming two combusting areas with concentrated fuel and with lean fuel in the burner so as to make premixed combustion and diffusion controlled combustion in each burner. With this structure, generation of NO_x is reduced by lowering combustion temperature and oxygen concentration in the burner and shortening the retention time of combustion gas.

4) Measures for Reduction of NO_x by Combination of Combustion Improvements

It is possible to further reduce emission of NO_x with synergetic effect of combustion improvement measures. In many cases in small-sized plants, NO_x is decreased by 20 - 40 % by changing fuel from residual oil to gas oil or by using low NO_x burners. In the large-sized plants, NO_x is decreased by up to around 60 - 70% by combining low NO_x burners, two-stage combustion, flue gas recirculation, etc.

NO_x at an exit of a burner is decreased to 150 - 300 ppm in the case of a coal burner, and to 80 - 200ppm, 60 - 100ppm and 40 - 80ppm in the cases of residual oil, kerosene and natural gas respectively. NO_x emission standards can be generally cleared with these combustion improvements.

However, in some countries where emission is regulated severely with regulations and agreements, various kinds of deeper denitrification is necessary. Measures of NO_x reduction by means of combustion improvement are as shown in **Figure 3** and **Table 4**.

Table 4 Reduction of NO_x by Combustion Improvement

(Unit: NO_x ppm)

Fuel		Coal	Residual oil	Kerosene	Gas
Nitrogen compounds in Fuel (%wt as N)		0.7〜3	0.1〜0.5	0〜0.3	0
O_2 in Flue Gas (%Vol)		6	4	4	5
①	Standard combustion	550〜800	400〜500	350〜450	300〜400
②	Excess air	600〜900	500〜600	400〜500	350〜450
③	Low oxygen combustion	450〜650	300〜400	250〜350	200〜300
④	③+ Two stage combustion	300〜500	200〜300	150〜250	150〜200
⑤	③+ Flue gas recirculation	350〜550	200〜300	150〜250	150〜200
⑥	④+ Flue gas recirculation	200〜400	200〜300	100〜150	80〜120
⑦	⑥+ Low NOx burner	150〜300	80〜200	60〜100	40〜80

(3) Flue Gas Measures

Kinds of direct flue gas denitrification processes are given in **Table 5**. Among the given processes, the dry process is exclusively applied, because higher removal efficiency in comparison with wet absorption processes. In the dry process, a method to reduce NO_x to N_2 is employed. Ammonia is generally used as a reducing agent that reacts selectively with NO_x.

Table 5　Kinds of Flue Gas Direct Denitrification

Dry method	Wet method
• Selective catalytic reduction process • Non-selective catalytic reduction process • Non-catalytic reduction process • Catalytic cracking process • Adsorption process • Electron beam irradiation process	• Gas-phase oxidation absorption process • Liquid-phase oxidation absorption process • Complex-salt-generating absorption process

1) Process

Another classification of denitrification processes is given below, according to installation places of denitrification reactor. Either method should be determined upon a practical plant plan, with comprehensive study.

① High-soot Denitrification Process

This is a process where flue gas from boiler is introduced directly to denitrification facilities and soot is later removed by an electrostatic precipitator. This is generally applied to boilers burning low ash contained fuel, such as natural gas, or residual oil.

② Low-soot Denitrification Process

This is a process to denitrify after soot removal. An electrostatic precipitator is installed in the upper stream of denitrification facilities. It is sometimes used for denitrification of gas containing a large amount of soot such as flue of coal.

2) Denitrification Catalyzer

① Required characteristics of denitrification catalyzers are:

a. High denitrifying capacity in the temperature range where it is used,

b. Few side reaction such as conversion from SO_2 to $SO_{3,}$

c. Sufficiently long life,

d. Sufficient mechanical strength and heat resistance, and

e. Abrasion resistance, in the case of flue gas containing soot likely to cause abrasion.

Catalyzers that satisfy the above, are put to practical uses currently. For main ones, porous ceramic such as titanium or aluminum is used as a carrier, to which several kinds of metal oxide compounds, and others are given as active components.

② Selection of Denitrifying Catalyzers

Catalyzers have to be capable for varieties of flue gas properties.

In case of clean flue gases, such as by burning natural gas, catalyzers should be selected only from heat resistance because the flue gas does not contain soot nor SO_x which causes deterioration. For dirty flue gases such as burning residual oil, or coal, it is necessary to consider soot and SO_x contained in the gases.

Table 6 shows variety of boiler fuel and points to be duly considered for selection of catalyzers. **Figure 4** shows the vertical view of the boiler unit having denitrification of catalytic reduction with ammonia.

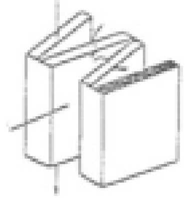
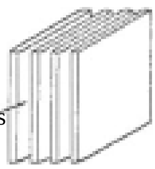
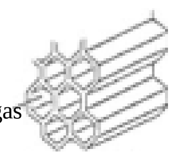
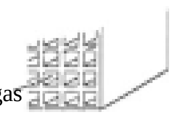
Table 6 Boiler Fuels and Points for Selection of NO_x Removal Catalyzers

Kinds of Fuel		Points to be Considered
Gas		High activity, heat-resistance
Residual Oil		High activity, heat-resistance, resistance to suffering from soot poison, SO_x resistance, Low SO_3 conversion rate
Coal	Low-soot Denitrification	Ditto
	High-soot Denitrification	Ditto, abrasion resistance

③Shapes of catalyzers

There are shapes of particle, lattice, honeycomb, and plate in use practically. Any type can be applied for clean gases. For dirty gases, however, lattice, honeycomb or plate types are commonly applied to avoid deposit of fly ash. **Table 7** shows shapes of catalyzers.

Table 7 Shapes of NO_x Removal Catalyzers

Type of catalyzer	Catalyst (pellets)  Flue gas Catalyst	Flue gas 	Flue gas 	Flue gas 
	Through flow type catalytic plate filled with catalytic pellets (fixed bed or moving bed reactors) gas flows through passing pore space (using particulate catalysts with fewer than 10 mm of grain diameter)	Parallel flow type catalytic plate (gas flows between the plates)	Parallel flow type catalyzer having honeycomb structure (gas flows along honeycomb shaped channels)	Parallel flow type catalyzer of lattice structure (gas flows along square channels)
Main targeted gas type	The fixed bed reactor is applied to such clean gas containing very minute dust and SO_x as the flue gas from natural gas combustion, while the intermittent moving bed reactor is used for a semi-dirty gas containing some dust and SO_x, which is emitted by the low and medium sulfur heavy oil combustions.	These types of catalyzer are used for dirty gas abound with dust and SOx, such as the flue gas from coal and high sulfur heavy oil combustions.		

3) Construction Cost of Denitrification Facilities

Construction cost of denitirification facilities largely differs by types of fuel and required performances. For example, cost of denitrification facilities with the 0.8 - 1.0 of ammonia injection mol ratio and the 80 % of denitrification efficiency is roughly estimated as follows:

Boiler burning residual oil: ¥4,000 - 5,000/kW

Boiler burning coal: ¥6,000 - 7,000/kW

The cost of a storage tank occupies largely of the whole cost of an ammonia injector facility necessary for denitrification. It is roughly ¥ 4,000 - 5000/tank capacity (m^3). All of above-mentioned facilities costs exclude costs of foundation work.

For reference, an example of cost of denitrification facilities for thermal power plants (in 1981) is shown in **Table 8**.

Table 8 Example of Cost of Denitrification Facilities

Condition / Method	Invest-ment cost	Operation cost	Re-moval	Operation Difficulty	Applicat-ion Range	Use	Mainten-ance Difficulty
	¥1000 / m^3 / H	Unit ¥1000 / m^3 / hr ① NO_x ppm in inlet gas ② Assumed utilization ③ Cost of ammonia	%		gas volume Nm^3/hr	applicable facilities	Difficult/ Average/ Easy
Ammonia catalytic reduction process	0.6 - 7.0	0.3 - 2.8 ①60-400ppm ② 70% utilization ③ ¥60,000/t NH_3	<90	Average	70,000 ～3 million	・Boiler ・Gas turbine ・Diesel engine ・Garbage incinerator ・Heating furnace	Average
Ammonia non-catalytic reduction process	0.7 - 1.0	≧0.8 ① 100-150ppm ② 70% utilization ③ ¥60,000/t NH_3	<40	Easy	570,000 ～1 million	・Garbage incinerator ・Heating furnace ・Boiler	Easy

US1$ = ¥130

According to “PROSPECTIVA 2000” (#255), combined cycles of natural gas burnt are predominated in the list of potential power plant installation in the future until 2010. This will presumably continue after 2010 in Argentina.

New combined cycles have to have low NO_x combustion systems by the regulation in Argentina. Flue gases from these newly installed plants will have less than 100mg/m^3N (or 50ppm) of NO_x. Future technical development will reduce further NO_x emissions.

In case a new combined cycle plant is planned, dry low NO_x combustion system should be considered at first as currently done in Argentina. If the dry system becomes not enough to satisfy the requirement of NO_x emission in future, it is recommendable to employ a denitrification facility.

For reference, **Table 9** shows installation and operational costs of a denitrification facility for 800 MW combined cycle plant with 2 gas turbines and 1 steam turbine. The system is popular in Japan and will be so in Argentina in the future.

Table 9 Costs of Denitrificaton Units for Combined Cycles

Conditions / Method	Facilities cost	Operation cost	Efficiency	Remarks
	Unit ¥1,000,000 Output: 800MW equivalent (2 gas turbines and a steam turbine) (Amount of exhaust gas : $1,800 \times 10^3 m^3N/hr$ equivalent × 2 units)	Unit ¥1,000,000 / year ①Inlet NOx Concentration ②Utilization ③Cost of chemicals (Catalyst, NH_3, water) ④Electricity	%	US$1 = ¥130
Ammonia catalytic reduction process	1,000～1,200 Denitrification unit is integrated in the Heat Recovery Steam Generator (HRSG)	①lower than $100mg/m^3N$ ② 85% ③ 55～60 ④ negligible	90	

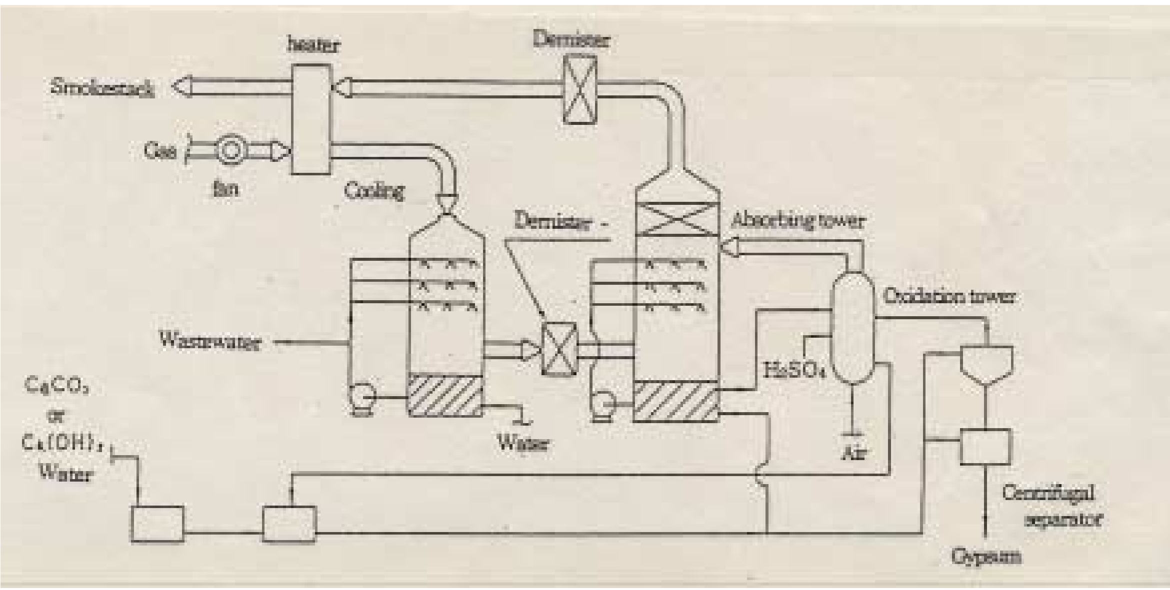


Figure 1 Flow Diagram of Limestone Desulfurization Process

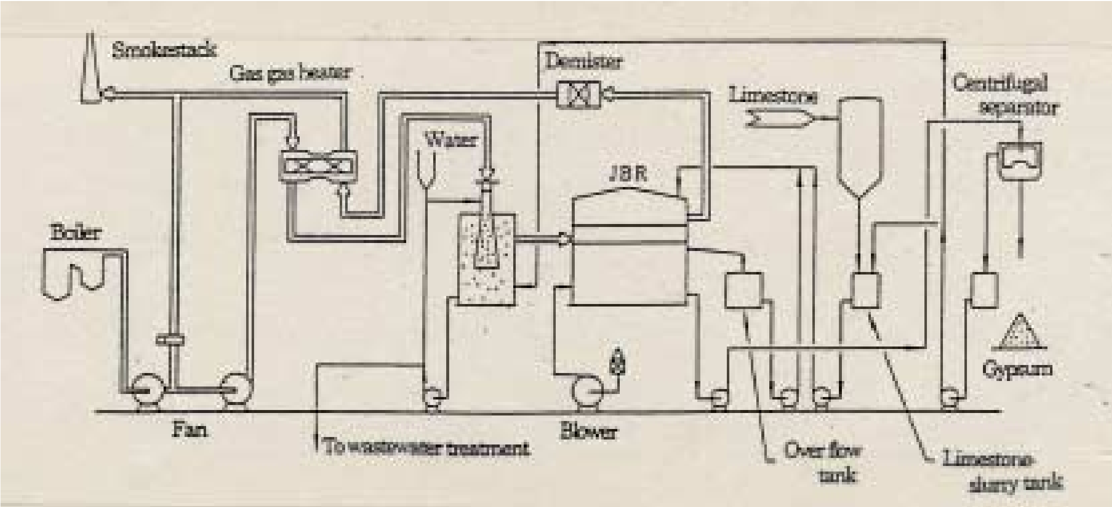


Figure 2　Flow Diagram of CT-121 Process (One of Limestone Desulfurization Processes)

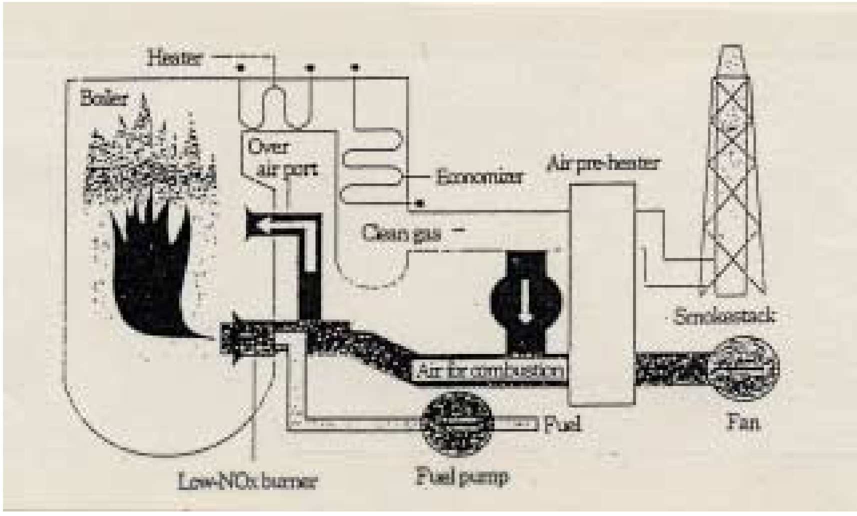


Figure 3　Measures for Reduction of NO_x by Combustion Improvement

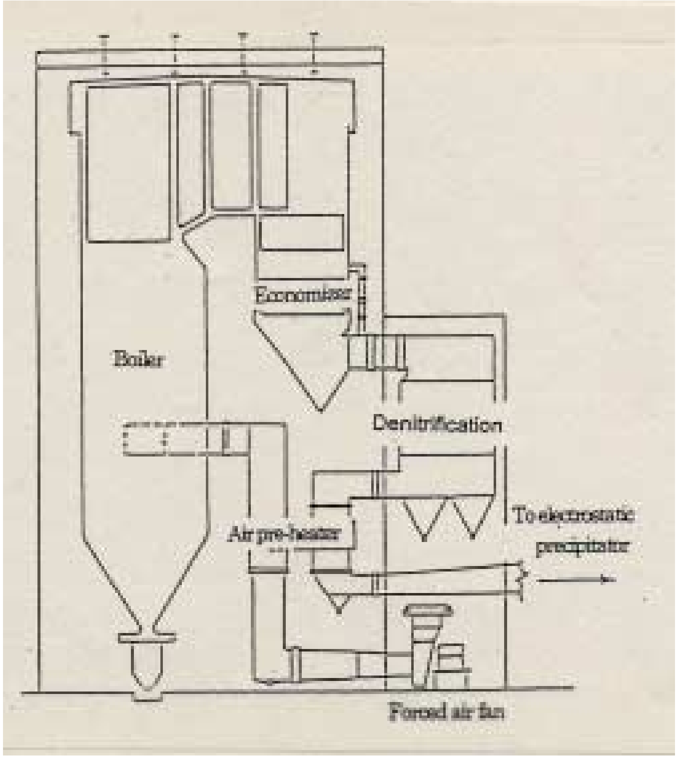


Figure 4 Vertical View of Boiler with Catalytic Denitrification with Ammonia