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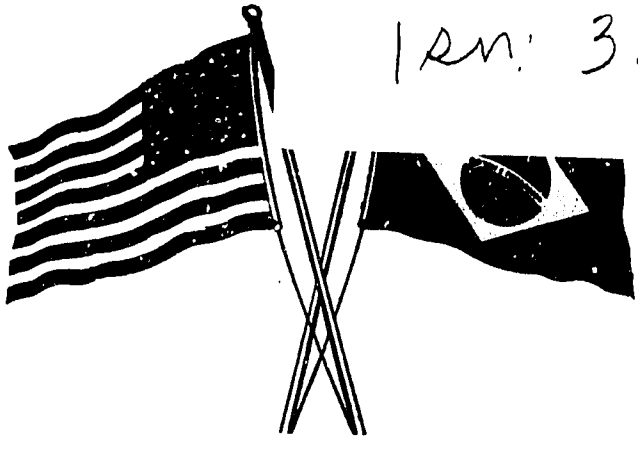

BRAZIL
SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM
FEASIBILITY STUDY

VOLUME II

UNITED STATES
TRADE AND DEVELOPMENT PROGRAM
AND
AGENCY FOR INTERNATIONAL DEVELOPMENT

CONTRACT PDC-0000-C-00-1106-00

FLUOR ENGINEERS, INC.

CONTRACT 836504

AUGUST 1982

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BRAZIL SOUTHERN CONE ENERGY NETWORK

COAL GASIFICATION FOR SNG PRODUCTION
AND PIPELINE SYSTEM
FEASIBILITY STUDY

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BRAZIL SOUTHERN CONE ENERGY NETWORK

COAL GASIFICATION FOR SNG PRODUCTION
AND PIPELINE SYSTEM
FEASIBILITY STUDY

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BRAZIL SOUTHERN CONE ENERGY NETWORK

COAL GASIFICATION FOR SNG PRODUCTION

AND PIPELINE SYSTEM

FEASIBILITY STUDY

PART I

COAL GASIFICATION FOR SNG PRODUCTION

UNITED STATES

TRADE AND DEVELOPMENT PROGRAM

AND

AGENCY FOR INTERNATIONAL DEVELOPMENT

CONTRACT PDC-0000-C-00-1106-00

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1.0 INTRODUCTION

This report is divided into two volumes, each of which is separately bound. Volume I includes only the Executive Summary of the report. Volume II (this volume) includes the full text of the report, and consists of two major parts: Part I covers the Coal Gasification for SNG Production; Part II, the second half of this volume, covers the Gas Pipeline and Distribution System.

This technical and economic feasibility study of coal gasification for a substitute natural gas (SNG) production and pipeline system has been performed by Fluor Engineers and Constructors Inc., in association with Jaakko Poyry Engenharia for the United States Trade and Development Program and Agency for International Development, and for the Brazilian Government.

As part of the Brazil Southern Cone Energy Network, the study will assist Brazilian Government authorities in defining technical and economically viable crude oil substitution programs, to meet Brazil's energy demands by the use of domestic resources.

The gasification plant will be at a minemouth location in the area of Minas do Leao, south of the Jacui River, approximately 100 kilometers from Porto Alegre. The plant will produce 3.61 million normal cubic meters per day (Nm^3/D) of SNG, which would be transported north by pipeline. The pipeline serves the states of Rio Grande do Sul, Santa Catarina, Parana, and Sao Paulo. The system has been sized to transport 10 million normal cubic meters per day of natural gas in addition to the SNG produced by coal gasification.

Figures 1-1 and 1-2 illustrate the proposed SNG plant location and pipeline route.

Part I of this volume reports on the coal gasification plant study performed by the Advanced Technology Division of Fluor Engineers and Constructors, Inc., together with information on coal resources and markets, gas demand, and by-product markets provided by Jaakko Poyry. Jaakko Poyry also supported the study with site, cost, economic, and other required local Brazilian data.

Part II of this volume presents the results of Fluor's study of an SNG gas transport and distribution system. Also included are the results of an alternate study into barging coal north to a gasification plant located in the Santos area.

The initial steps in this feasibility study were to investigate coal resources, to establish reserve capability to support a 30 year plant life, and to obtain coal characterization data. The next step in the gasification plant study was the identification of technologies considered capable of producing SNG from Brazilian coal. A combination of Lurgi and Westinghouse technologies was selected as the basis for conceptual process design. The plant will require 14 283 metric tons per day of 35 percent ash (dry basis) coal feed.

A discussion of the technology selection background and a rationale for the Lurgi/Westinghouse combination is presented. Process descriptions, block flow diagrams, plant energy and material balances, and a plot plan are provided.

The gasification plant has been designed for low capital cost, with minimum sparing consistent with acceptable reliability.

Fluor prepared capacity factored capital and operating cost estimates stated in January 1982 U.S. dollars. These were used together with coal feed costs, naphtha, ammonia, and sulfur product revenues, to perform a discounted cash flow analysis of the gasification plant. Economic criteria for the analysis was provided by Jaakko Poyry and the Brazilian Government. Results of this analysis show the plant gate price of the SNG produced.

Other cases were analysed to illustrate the sensitivity of the plant viability to changes or uncertainties in selected key variables such as coal costs, interest and inflation rates, debt/equity ratios, etc. Gasification plant economic results are detailed in Section 5. They are combined with the pipeline transportation economic results shown in Part II of this volume, and summarized for the overall project in the Executive Summary volume.

The gasification plant schedule and implementation plan, which addresses the various steps of engineering, procurement, and construction is presented in Section 3 of Part I.

FLUOR

FIGURE 1-1

MAP OF SOUTH AMERICA

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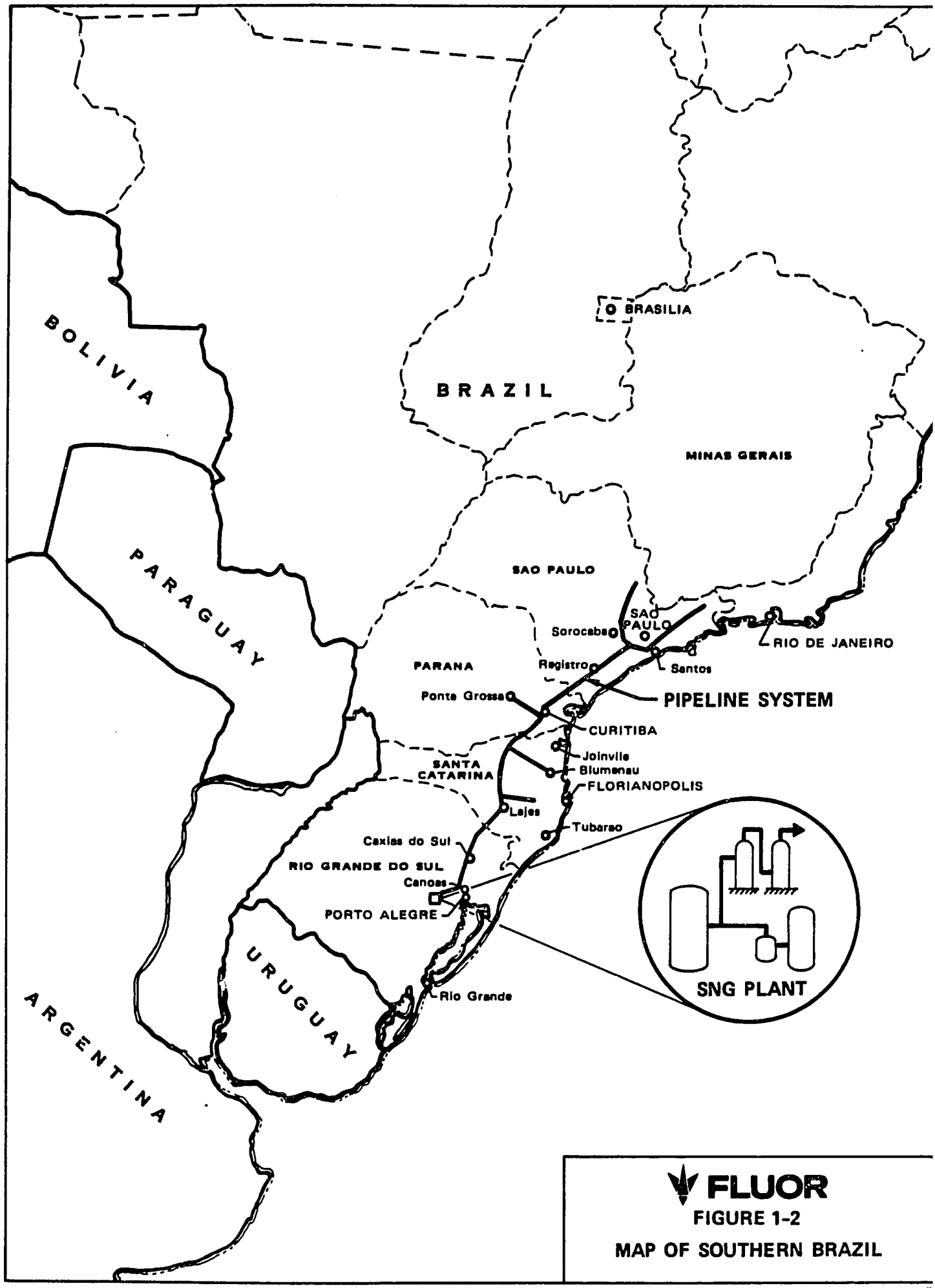

FLUOR

FIGURE 1-2

MAP OF SOUTHERN BRAZIL

2.0 GASIFICATION PLANT

2.1 TECHNOLOGY SCREENING

As a part of this study, Fluor evaluated the applicability of various gasification processes and selected the ones most suitable for this specific application, a substitute natural gas (SNG) plant. This evaluation was based on a qualitative analysis that was guided largely by engineering judgement and experience. The criteria that were used as guidelines in the selection process are shown in Table 2-1.

The gasification technologies investigated are listed in Table 2-2 and include both commercial and near-commercial processes. Small scale moving bed gasification technologies were excluded from the study, as they generally prove to be uneconomical on feed coals containing large quantities of fines. The majority of coals currently mined in Brazil are subbituminous. In addition, they are generally noted as being very friable. This characteristic indicates the likelihood of a large quantity of coal fines being generated in the mining and handling operations required to support the plant. It is anticipated that the coal received at the Brazil plant site may contain 50 weight percent fines (6.35 mm or less).

The technologies listed in Table 2-2 may be further classified as entrained bed, fluid bed, or moving bed types. Entrained bed processes examined include Combustion Engineering (C.E.), Koppers-Babcock & Wilcox (K-BW), Koppers-Totzek (K-T), and Texaco. The C.E. system is not currently undergoing test runs in the Windsor pilot plant and has not been demonstrated in oxygen-blown operations. For these reasons it was dropped from consideration. The K-BW technology has not been demonstrated to date and commercial demonstration is not expected in the near future, and for these reasons was dropped from consideration. The K-T process was rejected because Krupp, the licensor of K-T technology, declined to provide the necessary technical and cost data. Finally, the Texaco process was rejected after Texaco Development Corporation, licensor of the process, concluded that their process would not be economical when utilizing the "reference" Brazil coal selected for this study effort.

The fluidized bed processes examined in this screening effort include Winkler, High Temperature Winkler, and Westinghouse. The Winkler process has the advantage that it utilizes pulverized coal feed and can accept fines. The major disadvantage with the atmospheric pressure process is that carbon conversion efficiency will be low due to the high ash content of the "reference" Brazil coal. Due to the typically high carbon content in the ash particles removed from the gasifier, it is estimated that only 34 percent carbon conversion efficiency would be obtainable on the reference coal. Consequently, the economic viability of this process will depend on the ability to utilize the reject carbon material from the gasifier. This material could be utilized to generate electric power; however, abundant hydroelectric power is available in Northern Brazil, and Southern Brazil does not appear to have sufficient demand. For these reasons, generation of electric power would probably not be competitive, and the Winkler process would probably exhibit poor economics. The Winkler process was therefore rejected as not meeting the feedstock suitability criteria.

TABLE 2-1

SELECTION CRITERIA

Element	Criteria for Brazil Project
Data Availability	Eliminate technologies (processes) for which adequate data are not available in the public domain and for which the process licensor is unable or unwilling to provide information.
Feedstock Suitability	The technologies selected should be able to accept the selected "reference" Brazilian coal.
Process Status	The processes must have been commercially demonstrated or have the likelihood of being commercially demonstrated in the near future.
Plant Complexity	For relatively new technologies, simplicity of the gasification scheme is preferred.
Environmental Acceptability	The selected processes should be able to meet the local and federal environmental regulations in Brazil. (The standards applicable to the United States were used for study purposes.)
By-Product Disposition	Principal by-products of the gasification plant must be consumed within the plant or be marketable.

TABLE 2-2

GASIFICATION TECHNOLOGIES CONSIDERED

Process	Reactor Type	Status	Comments
Combustion Engineering	Entrained Bed	No current activity	NA
Koppers-B & W	Entrained Bed	Offered Commercially	NA - process status
Koppers - Totzek	Entrained Bed	Commercial	NA - data availability
Texaco	Entrained Bed	Commercial plants in the design phase	NA - feedstock suitability
Atmospheric Winkler	Fluid Bed	Commercial	NA - feedstock suitability
High Temperature Winkler	Fluid Bed	Commercial size start-up in 1983 for lignite	NA - process status
Westinghouse	Fluid Bed	Commercial size start-up in 1984	Suitable
Lurgi	Moving Bed	Commercial	Suitable
BGC/Lurgi	Moving Bed	Offered commercially	NA - feedstock suitability and process status

NA = Either not applicable or not available

The High Temperature Winkler process, as the name implies, operates at higher temperatures and pressures than its predecessor. This would increase the carbon conversion efficiency as well as the gasifier thruput. The disadvantage of this process is that it does not appear that it will reach commercialization on subbituminous coal feed in the time frame being considered for the Brazilian SNG project. It was therefore eliminated from consideration.

The third fluidized bed process, Westinghouse, utilizes a technique for ash agglomeration that results in essentially total carbon conversion and relatively high efficiency. In addition, the Westinghouse process can handle a wide range of feed coals as well as fines. Westinghouse has announced plans to build a full scale demonstration unit for their technology at a location in South Africa, with start-up expected in 1984. The Westinghouse process is therefore a suitable contender for this project.

The moving bed processes considered in this screening effort include Lurgi and BGC/Lurgi. The Lurgi process cannot handle coal fines in the gasifier feed; however, the fines produced can be consumed in alternative gasification processes such as Westinghouse, or in coal fired boilers. The BGC/Lurgi process has the ability to consume fines, but this results in a decrease in gasifier capacity. In general, the BGC/Lurgi gasifier is more suitable for higher rank feed coals, while the Lurgi gasifier is preferable for lower rank coals such as lignites and subbituminous coals. The typical Brazilian subbituminous coals are characterized by relatively high ash fusion temperatures (1500°C to 1600°C). In order to handle these coals, the BGC/Lurgi gasifier would have to operate at a somewhat higher temperature than is typical of this process, with a corresponding increase in oxygen consumption and decrease in thermal efficiency. Another potential problem brought about by the higher operating temperature is the increased rate of slag attack of refractory material. As a result of the foregoing, the BGC/Lurgi technology was rejected from this study effort, and the Lurgi technology selected for additional investigation. The Lurgi process considered in this study will utilize Westinghouse coal gasification technology to consume the excess fines generated.

In summary, the gasification processes selected for evaluation in the Final Technology Selection Phase are the Westinghouse process and a Lurgi/Westinghouse process combination.

2.2 FINAL TECHNOLOGY SELECTION

The two candidate technologies from the Technology Screening Phase (Westinghouse and Lurgi/Westinghouse hybrid) were evaluated in greater detail in this phase of the study effort. Conceptual plant designs were developed in this effort in order to permit a quantitative comparison of feed requirements, product and by-product rates and overall thermal efficiencies between the two candidate plants. The plant descriptions are presented in Sections 2.4 and 2.5 of this report. Based on the conceptual plant designs, it is apparent that the cases are essentially equivalent in regard to feed requirements, product and by-products rates and overall

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thermal efficiency. The selection of a final technology must, therefore, be made on the basis of some other criteria, such as level of commercial demonstration. Since the Lurgi technology is mature, and has been proven in operation on coals similar to the Brazilian "reference" coal, and since Westinghouse technology lags behind Lurgi in degree of commercial development, the Lurgi/Westinghouse hybrid case was selected as the final case for the Process Design Phase of the study effort.

Plant Comparisons

The following paragraphs highlight the significant criteria on plant feed rates, product and by-product rates and overall thermal efficiency of the two candidate cases.

The criteria for determining the capacity of each of the candidate plants was based on utilizing the largest capacity trains compatible with shop fabrication of major equipment, while targeting SNG production at approximately 3.5 million Nm^3/D. This initial estimate of projected plant SNG production capacity was suggested by the Brazilian government. The required plant capacity for the Lurgi/Westinghouse hybrid case was obtained by providing two trains of maximum capacity Oxidant Feed and Rectisol units, while for the Westinghouse case, the SNG output requires the use of three trains of the Oxidant Feed System.

Feed and Product/By-products. Both of the SNG plants utilize the same "reference" coal. Table 2-3 presents the coal consumption rates, product rates, and by-product production rates for the two cases. The feed coal required to produce equivalent amounts of SNG is approximately 6.4 percent less for the Westinghouse case than for the Lurgi/Westinghouse hybrid case. However, the Westinghouse case imports about 70 MW of electric power, whereas the Lurgi/Westinghouse case produces all its electric power requirements within the plant. Table 2-4 presents the product SNG characteristics which could be anticipated from the two plants. The Lurgi/Westinghouse hybrid case and the Westinghouse case produce SNG at a rate equivalent to 33 000 million kilocalories per stream day, and 33 500 kilocalories per stream day respectively. The SNG analysis, as shown in Table 2-4, is very similar to natural gas, with the exception of hydrogen content. Typically, natural gas contains about 96 percent methane (or methane and ethane) with the remainder of the gas consisting of nitrogen and carbon dioxide. The hydrogen content of the SNG in the two cases, at around 1.5 volume percent, is not expected to cause any particular problems in either transportation or usage, and the SNG should be compatible with natural gas.

The by-product sulfur produced by the hybrid case is around 5 percent lower than the Westinghouse case since the sulfur consumed in the boiler is not recovered. The hybrid case produces a substantially larger quantity of ammonia than the Westinghouse case and, in addition, produces a naphtha by-product stream.

Overall Thermal Efficiency. The overall thermal efficiencies of the two cases are presented in Table 2-5. The energy inputs and outputs are expressed as percentages of coal feed higher heating value both with and without inclusion of by-products. The efficiencies for the two cases are essentially equivalent.

TABLE 2-3

FEED AND PRODUCT/BY-PRODUCT DATA

Feed/Product Data (Stream Day Basis)	Lurgi/Westinghouse Hybrid Case	Westinghouse Case
Washed Coal Feed, mT/D	14 283	13 739
SNG Product, 10^6 Nm^3/D	3.61	3.71
SNG HHV, $kcal/Nm^3$	9 139	9 040
Sulfur By-product, mT/D	226.2	242.9
Ammonia By-product, mT/D	45.2	27.7
Naphtha, liters/D	109 600	-

TABLE 2-4

SNG CHARACTERIZATION

Component	Lurgi/Westinghouse Hybrid Case, Mole %	Westinghouse Case, Mole %
CH_4	95.67	94.62
H_2	1.47	1.51
CO	0.06	0.06
CO_2	0.51	0.49
N_2 + Ar	2.29	3.32
TOTAL	100.00	100.00
HHV, $kcal/Nm^3$	9 139	9 040
Rate, 10^6 Nm^3/D	3.61	3.71

TABLE 2-5

OVERALL THERMAL EFFICIENCIES

Energy As Percentage Of Coal(1)	Lurgi/Westinghouse Hybrid Case, Mole %	Westinghouse Case, Mole %
Input:		
Coal	100.00	100.00
Electrical Power (2)	0.00	7.45
TOTAL	100.00	107.45
Output:		
SNG	57.46	60.73
Sulfur	0.87	0.97
Ammonia	0.42	0.27
Naphtha	1.52	0.00
TOTAL	60.27	61.97
Efficiency With By-products	60.27	57.67
Efficiency Without By-products	57.46	56.52

(1) On an HHV Basis

(2) Energy content of electricity equivalent to coal required to produce power at an overall station efficiency of 35 percent.

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2.3 PROCESS ALTERNATIVES

Fluor performed a qualitative evaluation to determine whether high-BTU gas (SNG) or medium-BTU gas (MBG) should be produced in the Brazilian minemouth gasification plant. MBG production would allow the Shift and Methanation Units to be eliminated and the Acid Gas Removal systems to be smaller. MBG would also require larger volumes of gas to be handled to achieve the same rate of energy output as SNG production. This entails larger equipment in the gas processing units downstream of the gasification plant, such as compressors and the pipeline system itself. Additionally, the compression power requirements would increase.

Where gas must be transported over long distances, experience has shown that the cost savings realized in the gasification plant by producing MBG are more than offset by the increased investment costs required for downstream gas handling equipment.

2.4 PLANT DESCRIPTION - WESTINGHOUSE CASE

The plant processes 13 739 metric tons per day (mT/D) of 35 weight percent ash coal to produce 33 500 million kilocalories equivalent of SNG. Coal is gasified using Westinghouse technology. The overall process configuration is shown in the Overall Block Flow Diagram, Drawing No. 836504-00-4-0003, and the associated material balance is presented in Table 2-6. Brief descriptions of the various units in the plant follow.

Unit 01 - Coal Receiving, Storage, Preparation, and Distribution

The previously prepared and washed (to 35 weight percent ash and -38.1 mm size) coal is transported by receiving conveyor from the coal preparation plant at minemouth to the covered 4-day live storage pile. The coal receiving equipment includes a magnetic separator to remove tramp iron and a continuous sampling station to monitor the incoming coal. Coal is reclaimed from live storage and conveyed to the crusher feed hopper. The coal is crushed as required for gasification, and conveyed to the gasifier collection hopper. From the collection hopper the coal is diverted onto conveyors which deliver the prepared coal to each gasifier coal feed surge bin.

Air emissions from this section of the plant are limited to particulate emissions in the form of coal dust. These emissions are controlled by enclosing conveyor systems and screening operations, and by water sprays at conveyor transfer points.

Unit 03 - Ash Handling

Ash, along with small quantities of rejected fines, is conveyed from the gasification unit to the ash pile.

Unit 10 - Gasification, High Temperature Gas Cooling, and Gas Quench

Gasification Unit: Prepared coal (-6.35 mm) is gasified in Westinghouse gasifiers. The Westinghouse gasification unit is an integrated system of gasification, ash removal, coal fines recycle, high temperature heat recovery, and particulate scrubbing. Thirteen gasification trains are provided, each capable of processing 1 249 metric tons per day of 35 percent ash coal. Under normal operation all thirteen gasifiers will be operating at a reduced load (85% of full load). During periods when a gasifier is shutdown for repairs or maintenance, the feed to the remaining operating gasifiers will be increased.

Coal from the gasifier feed surge bin flows into the pressurized coal lockhopper system, which consists of two lockhoppers: a pressurization lockhopper, and coal feed lockhopper. Coal is drawn from the feed lockhopper and is pneumatically transported by recycle gas into the bottom of the gasifier. Oxygen is introduced at the bottom of the gasifier and initiates combustion of the coal. The action of the recycle gas and oxygen flowing upward through the reactor causes fluidization of the small coal particles. Steam is injected into the lower portion of the reactor.

TABLE 2-6

WESTINGHOUSE CASE - STREAM DATA

STREAM NO. AND NAME	1 FEED COAL	2 OXIDANT	3 ASH*	4 SCRUBBED GAS	5 SHIFTED GAS	6 GAS TO SELEXOL	7 GAS TO ZnO BED AND METHANATION	8 GAS TO CO_2 ABSORBER	9 GAS TO COMPRESSION	10 SNG PRODUCT
COMPONENT/kgMol/hr (kg/hr)										
CH_4				1 984	1 984	1 984	1 939	6 655	6 531	6 531
H_2	7 509		46	6 509	14 992	14 992	14 858	104	104	104
CO				12 646	4 162	4 162	4 117	4	4	4
CO_2				4 091	12 586	12 592	1 804	1 200	34	34
H_2S				316	326	331				
COS				16	5	1	2ppm			
O_2	1 419	7 087	1							
N_2+Ar	156**	114	4	231	231	231	229	229	229	229
NH_3										
H_2O	4 671			5 176	5 566	91		11		
SO_2										
C	20 034		1 347							
S	350		18							
ASH	(170 911)		(170 911)							
TOTAL kgMol/hr		7 201		30 969	39 852	34 384	22 947	8 203	6 902	6 902
kg/hr	572 463		187 904	693 389	853 453	755 010	264 919	167 636	115 737	115 737
				25 792						
PRESSURE kg/cm² ABS	1.03	35.2		30.2	27.8	25.7	22.0	47.8	45.1	68.6
TEMPERATURE °C		232		149	259	38	27	38	29	50

* DRY BASIS
** NITROGEN ONLY

Heat from the combustion of a portion of the incoming coal is used to devolatilize the remainder of the incoming coal to form a char. The char in turn reacts with steam to form carbon monoxide and hydrogen. As the coal and char circulate, they are gradually consumed by combustion and gasification, leaving small particles of ash. The hot ash begins to agglomerate, forming denser particles which defluidize from the bed and collect in the ash annulus. The agglomerated ash particles are cooled as they pass through the bottom of the annulus, and are removed from the gasifier via a rotary feeder into the ash lockhopper system. The ash is depressurized through two lockhoppers and delivered to the ash handling system.

Raw product gas exits from the top of the gasifier and passes through a two stage cyclone system. Fine, entrained solids are removed from the raw gas by cyclones and pneumatically transported for recycle to the gasifier.

The raw gas next passes through the raw gas heat recovery area. The gas is first cooled by heat exchange with preheated boiler feed water to produce 44 kg/cm^2, 410°C superheated steam. Each gasification train has its own steam generator, superheater, steam drum, boiler feed water pump, and boiler feed water chemical addition system.

Further cooling of and particulate removal from the gas occurs by direct quench with water in a venturi scrubber. The effluent from the venturi scrubber flows into a particulate scrubber from where the quenched gas is withdrawn overhead and a fines slurry as the bottoms product. The quenched gas is split into two streams: quench gas product and recycle gas. The recycle gas is cooled and compressed before being recycled back to the coal feed lockhoppers and cyclone discharge feeders for transporting the coal to the gasifier and recycling of the raw gas fines respectively. The quenched gas product is routed to the shift unit.

The fines slurry produced from the particulate scrubber is concentrated and combined with the coarse slag. A small amount of water is lost from the system with the fines. Some water is rejected from the quench water to control the buildup of dissolved solids in the quench water.

The quench blowdown from the gasification unit is treated in the Process Condensate Treating Unit. The treated water from Process Condensate Treating is used for cooling water makeup, while the gasification water makeup requirements are applied by treated raw water.

Unit 11 - Crude Gas Shift

The Crude Gas Shift Conversion Unit catalytically reduces the carbon monoxide concentration in the crude gas product of the Gasification Unit and produces additional hydrogen by the exothermic reaction:

$$CO + H_2O \qquad CO_2 + H_2$$

Reaction steam is provided by the addition of 44 kg/cm^2 steam and the normal steam content of the crude gas, and the elevated reaction temperature range of the two stage conversion is attained by a feed-effluent heat exchange scheme in this unit. In addition to converting carbon monoxide, the cobalt molybdenum catalyst hydrogenates HCN and organic sulfur contained in the crude gas.

Crude gas by-pass is provided as a means for controlling the H_2-to-CO ratio required in the synthesis gas. The H_2-to-CO ratio required in the synthesis gas for methanation is about 3.6 to avoid carbon deposition in the methanation catalyst.

This unit consists of two parallel operating trains. The feed to the shift unit is preheated in the feed/effluent exchangers to 313°C prior to being combined with the steam and fed to the catalyst beds. Gas exiting the first set of beds is cooled by the generation of 48 kg/cm^2 steam. The converted gas exiting the second set of beds at a temperature of 371°C is cooled to 259°C in the feed/effluent exchangers and sent to the Gas Cooling Unit.

Unit 12 - COS Hydrolysis and Gas Cooling

The converted gas from the Shift Unit at 259°C and 28 kg/cm^2 (abs.) is cooled to 173°C in shell and tube exchanger to recover heat by generating 48 kg/cm^2 steam. This gas is combined with the by-passed gas and sent through the COS hydrolysis reactor.

COS Hydrolysis. The following overall reaction occurs in the presence of Haldor Topsoe, Inc. catalyst, Type CKA:

$$COS + H_2O \qquad CO_2 + H_2S$$

Shifting the reaction equilibria to the right is favored by low temperature and high steam-to-dry gas ratio. The operating temperature is maintained 50°F above the dew point of the gas to avoid pore condensation. The COS concentration is reduced to 30 ppmv in gas leaving the catalyst bed.

Further heat recovery is accomplished by cooling the gas in shell and tube exchangers to preheat boiler feed water.

Next, air coolers are utilized for additional heat removal. Gas liquor is condensed as the heat is removed, then separated in the air cooler knock out (K.O.) drums prior to routing to the process condensate treating unit for processing. Finally, heat is removed by cooling water exchange which condenses more gas liquor, which is also routed to the process condensate treating unit.

This unit consists of two 50 percent parallel operating trains.

Unit 13 - Acid Gas Removal

Allied Chemical Corporation's Selexol process is used for acid gas removal. The sulfur compounds are reduced to a concentration of 2 ppm.

Also, the CO_2 content of the gas is reduced to a concentration such that the stoichiometric number (SN) in the pure gas (defined below) is greater than 0.65 to avoid damaging the methanation catalyst.

$$SN = \frac{H_2 - 2C_2H_4 - C_2H_6}{3CO + 4CO_2}$$

The gas is combined with recycle flash gas and cooled by exchange with treated gas and fed to the acid gas absorber. The gas contacts the Selexol solvent, countercurrently, over a packed bed. Removal of the H_2S, COS, and some CO_2 occurs by absorption of these gases into the cooled lean Selexol solvent. Treated gas from the first absorber, essentially free of sulfur, flows into a second absorber after combining with recycle flash gas where the CO_2 is removed to satisfy the requirements defined by the stoichiometric number. Gas from this second absorber flows to a knockout drum for recovery of entrained solvent and after heat exchange, a portion is used as fuel gas in the steam superheater and the remainder sent to the ZnO treatment in the Methanation Unit.

Rich solvent leaving the first absorber flows through a valve to reduce the pressure prior to discharging into a flash drum. Vapor flashed from the rich solvent is recycled to the absorber to increase the selectivity of H_2S and COS absorption and minimize CH_4 losses.

The rich solvent from the flash drum is heated by exchange against lean solvent and fed to the top of the stripper. Acid gas components are stripped from the solvent by the application of heat, which is supplied by a steam reboiler. The regenerated lean solvent leaving the stripper bottoms is cooled and charged to the absorber.

The overhead from the stripper is condensed by an air cooled condenser. The condensate collected in the accumulator is refluxed to the stripper. The temperature in the accumulator is adjusted to maintain a unit water balance. The acid gas produced from the accumulator, which contains hydrogen sulfide, is sent to the Sulfur Recovery Unit.

Rich solvent from the CO_2 absorber is regenerated by flashing in three stages; the flash gas from the first stage being recycled to the absorber to reduce CH_4 losses. Gas from the second flash provides part of the fuel gas for the steam superheater. Gas from the third flash is primarily CO_2 and may be vented. The solvent thus recovered from the absorbed gases is cooled and charged to the absorber.

Final CO_2 Removal - CO_2 Selexol Section

Rich gas from Methanation at 38°C which has been compressed to 48 kg/cm^2 (abs.) is combined with recycled flash gas and cooled in a feed/effluent exchanger prior to being introduced into an absorber where the CO_2 is removed.

Rich solvent from the absorber is regenerated by staged flashing, the flash gas from the first stage being recycled to the absorber to reduce CH_4 losses. Gas from the second flash provides a portion of the fuel gas required for the steam superheater. The solvent thus regenerated is cooled and charged to the absorber.

SNG leaves as overhead off the absorber with CO_2 removed to 0.5 volume percent. After the feed/effluent heat exchange, it is sent to the SNG compression unit at 29°C.

A total of two 50 percent trains are provided for this unit. A freon refrigeration system is provided for the Selexol Unit.

Unit 16 and 52 - Ammonia Recovery and Process Condensate Treating

The Process Condensate Treating Unit treats the quench blowdown from the gas quench system and process condensate from the gas cooling system. A proprietary waste water treatment system is used as the basis for removal of heavy metals, sulfides, cyanide, and formates from the water. The Ammonia Recovery Unit used is U.S. Steel Company's proprietary Phosam-W process. The following steps are involved:

- Chemical addition with precipitation
- Settling
- Filtration
- Ammonia removal/recovery
- Biotreatment

In the Ammonia Recovery Unit, sour water is fed to a stripper, where ammonia, acid gases, and dissolved gases are separated as an overhead product by countercurrent steam stripping. The stripper bottoms product is cooled and sent to the Wastewater Treating Unit.

The absorber overheads are fed to an ammonia absorber where the ammonia is selectively removed by countercurrent absorption in phosphoric acid. Absorber outlet gas is cooled ar' sent to the steam superheater for incineration. The absorber bottoms are pumped to an ammonia stripper where the ammonia is recovered as an overhead product by countercurrent steam stripping. Phosphoric acid bottoms are cooled and recycled to the absorber. The stripper overheads are condensed and collected and pumped to an ammonia fractionator in final product distillation. Caustic solution is added to the fractionator to neutralize impurities in the ammonia feed and give a 99.9 percent pure liquid anhydrous ammonia product. The aqueous fractionator bottoms are recycled for reprocessing.

Sludge from the filter presses and biotreatment pond is discarded by way of ash disposal system.

The treated effluent stream is returned as makeup to the Process Cooling Towers. A small portion of the treated stream is drawn off just downstream of the biological treatment, and supplies plant utility water requirements.

Unit 17 - Sulfur Recovery

The sulfur plant is a two-stage acid gas bypass-type Claus unit.

About one-third of the acid gas stream from the acid gas removal unit is burned in a sulfur furnace, thereby converting hydrogen sulfide to water vapor and sulfur dioxide. The air required for combustion in the furnace is supplied by a blower. Heat is recovered from the furnace combustion products by generating steam in a waste heat boiler. Hot exhaust gas from the waste heat boiler is mixed with the bypassed feed gas and the mixture is fed to the first sulfur converter. The amount of gas bypassing the furnace is controlled to maintain a ratio of hydrogen sulfide to sulfur dioxide in the mixture gas slightly greater than 2:1. Hydrogen sulfide and sulfur dioxide react in the converter to produce elemental sulfur and water according to the reaction:

$$H_2S + 0.5\ SO_2 \qquad 1.5\ S + H_2O$$

This exothermic reaction is catalyzed by an alumina catalyst contained within the converter. Complete conversion of the hydrogen sulfide and sulfur dioxide to elemental sulfur is not achieved because of thermo- dynamic equilibrium.

The gaseous sulfur produced in the first converter is condensed and recovered by cooling the converter effluent in a sulfur condenser. The sulfur condenses in the tubes and flows by gravity to concrete sumps. The sumps are provided with steam coils to keep the sulfur in a molten state.

The effluent gases from the first condenser react further in the second converter. Sulfur in the exhaust gas is condensed and cooled in the second condenser by heating boiler feed water. The condensed sulfur then flows to one of the previously mentioned sumps.

Tail gas from the second converter, containing small amounts of sulfur compounds, is sent to the steam superheater for incineration. A total of two 50 percent trains are provided.

Unit 20 - ZnO Treating and Methanation

The Methanation Unit converts CO and CO_2 into CH_4 by reaction with H_2.

$$CO + 3H_2 \qquad CH_4 + H_2O$$

$$CO_2 + 4H_2 \qquad CH_4 + 2H_2O$$

Both these reactions are promoted by a nickel containing catalyst and are strongly exothermic. Minor quantities of ethylene and ethane, also present in the gas, will be hydrogenated as follows:

$$C_2H_4 + 2H_2 \qquad 2CH_4$$

$$C_2H_6 + H_2 \qquad 2CH_4$$

Studies of catalytic methanation, the conversion of carbon oxides to methane, date back to 1902. This reaction has become commercially important in recent years in the production of synthetic ammonia. The synthesis gas, after several stages of shift and removal of carbon dioxide, normally contains up to one percent of carbon oxides which will cause deactivation of the ammonia synthesis catalyst. They are, therefore, catalytically converted to methane which is inert towards the catalyst.

Although the methanation reaction is very exothermic, the low concentration of carbon oxides associated with ammonia synthesis gas limits the temperature rise to less than 75°C and a simple adiabetic packed bed reactor is used. These converters are normally designed to operate with an exit temperature below 450°C. Concentration of carbon oxides is generally reduced to below 5 ppm. Also, the hydrogen is present in large excess (>75 percent).

A number of large commercial substitute natural gas (SNG) plants have been operated in the United States with naphtha as the feed stock. The processes appear to be technically efficient.

Methanation in coal gasification processes presents a considerably different challenge in that the carbon monoxide concentration is much higher.

The difficulty with the high carbon monoxide concentration is that in an adiabatic reactor, the heat of reaction causes the temperature to rise by 60°C for each one percent of CO converted to methane; so, with a feed concentration of 15 to 20 percent CO, the temperature rise would be high enough to cause catalyst sintering and decomposition of the product methane to carbon. Novel reactor configurations are used to circumvent this problem.

The Lurgi Methanation Process is closest to being demonstrated on a large commercial scale. This process utilizes adiabatic fixed beds and hot-gas recycle to absorb the heat of reaction and to keep the bed temperatures within limits. The rapid rates at which the reactions occur and the use of gas recycle to control temperature make the design of this system simple, being amenable to thermodynamic treatment rather than complicated transfer processes. The U.S. Department of Energy has concluded that this process poses no technical risk.

Lurgi has operated two semicommercial pilot plants to demonstrate this methanation system. In Schwechat, Austria, synthesis gas from naphtha was methanated. The other demonstration was on a sidestream from the SASOL Fischer-Tropsch plant in Sasolburg, South Africa. This plant produces a

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synthesis gas from coal in Lurgi gasifiers. In both cases a BASF catalyst was used in a fixed bed recycle methanator followed by a clean-up methanator. Based on the pilot plant experience, a catalyst life of 16 000 hours is expected.

This principle was demonstrated at a scale of 67 000 Nm^3/D by Continental Oil Company along with 16 other American companies in a $6 million demonstration project at the Westfield Coal Gasification plant in Scotland. Raw gas was produced by Lurgi dry bottom gasification. A fixed-bed, gas recycle, adiabatic methanation reactor was used. The product was fed into the local gas grid. The plant was operated for two months and produced a substitute natural gas with a higher heating value of 9 218 $kcal/Nm^3$. Based on the results from this demonstration, a catalyst life of 1 to 1-1/2 years was projected. (A pilot plant test conducted by the Department of Energy at Pennsylvania predicts a catalyst life of 5 years for commercial operation.)

The Lurgi Methanation Process will be commercially demonstrated by the Great Plains Coal Gasification Project. The first phase of this project is scheduled for start-up in late 1984 and will produce 3.7×10^6 Nm^3 per stream day of 9 124 $kcal/Nm^3$ of substitute natural gas.

The Lurgi Methanation process includes a multistage reaction system and recycle of product gas. Adiabatic reactors connected with waste heat boilers are used to remove the heat in the form of high pressure steam and to prevent sulfur poisoning of the methanation catalyst, the feed gas is treated with ZnO to reduce the sulfur content of the gas to less than 0.1 ppm.

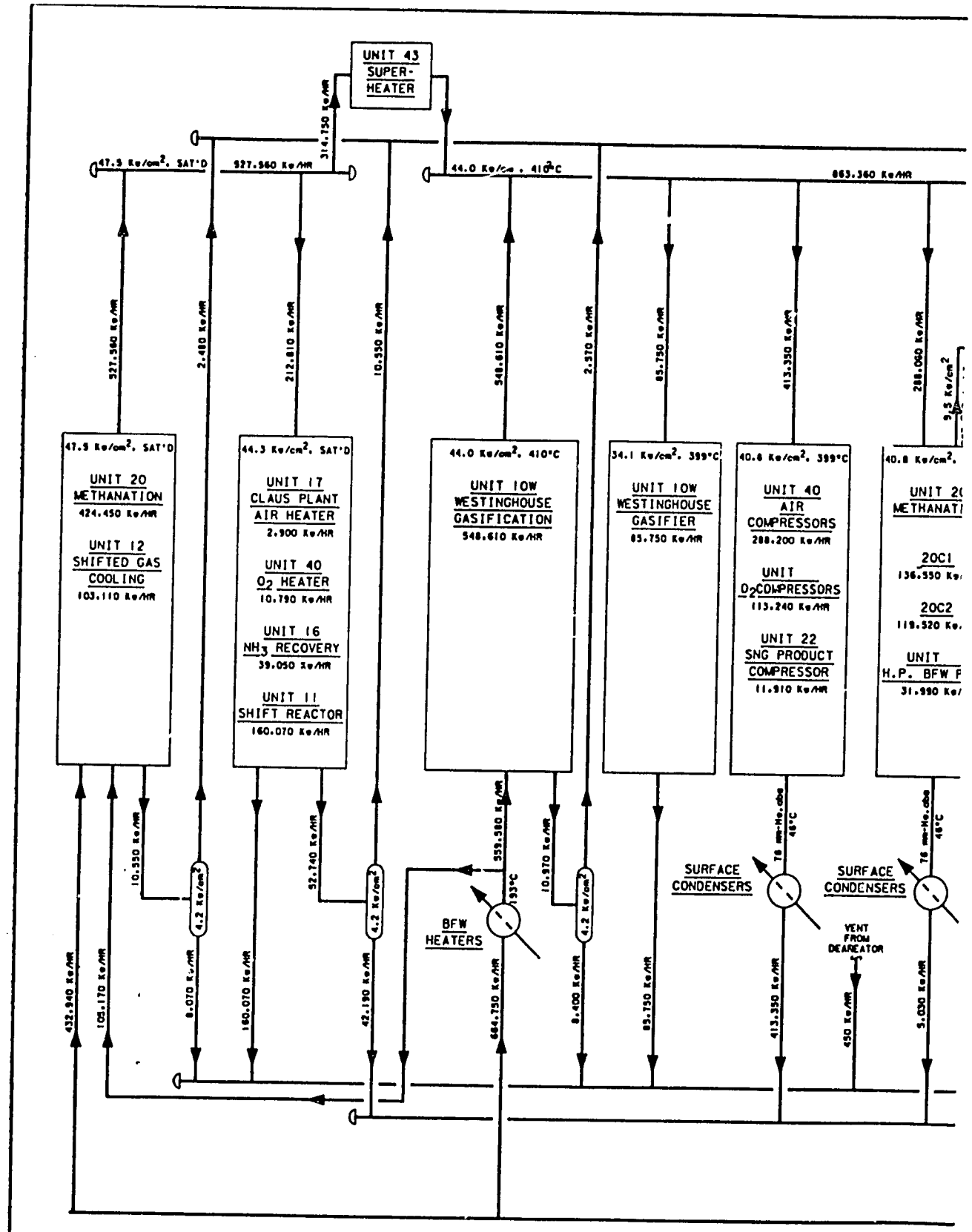
<u>ZnO Treating</u>: This involves passing preheated gas at 192°C through beds of ZnO (Type HTZ-3 by Haldor Topsoe, Inc.). Both COS and H_2S are removed by formation of ZnS.

Next, the gas is mixed with total recycle from the methanation reactors and fed to the first methanation bed. The effluent from the first bed is partially cooled so that when it is combined with another portion of the makeup, the mixture is at or above the initiating reaction temperature, then fed to the second bed. This procedure is continued to the third and subsequent bed. The inlet temperature to the reactors is kept between 260°C and 300°C and the outlet temperature between 450°C and 500°C. A final clean-up (damp) methanator is used after most of the water formed is removed to achieve the final high conversion. The gas leaving the damp methanator is cooled, the condensed water separated, compressed, cooled again, the condensed water separated, and sent to CO_2 removal in the Acid Gas Removal Unit to form the product gas.

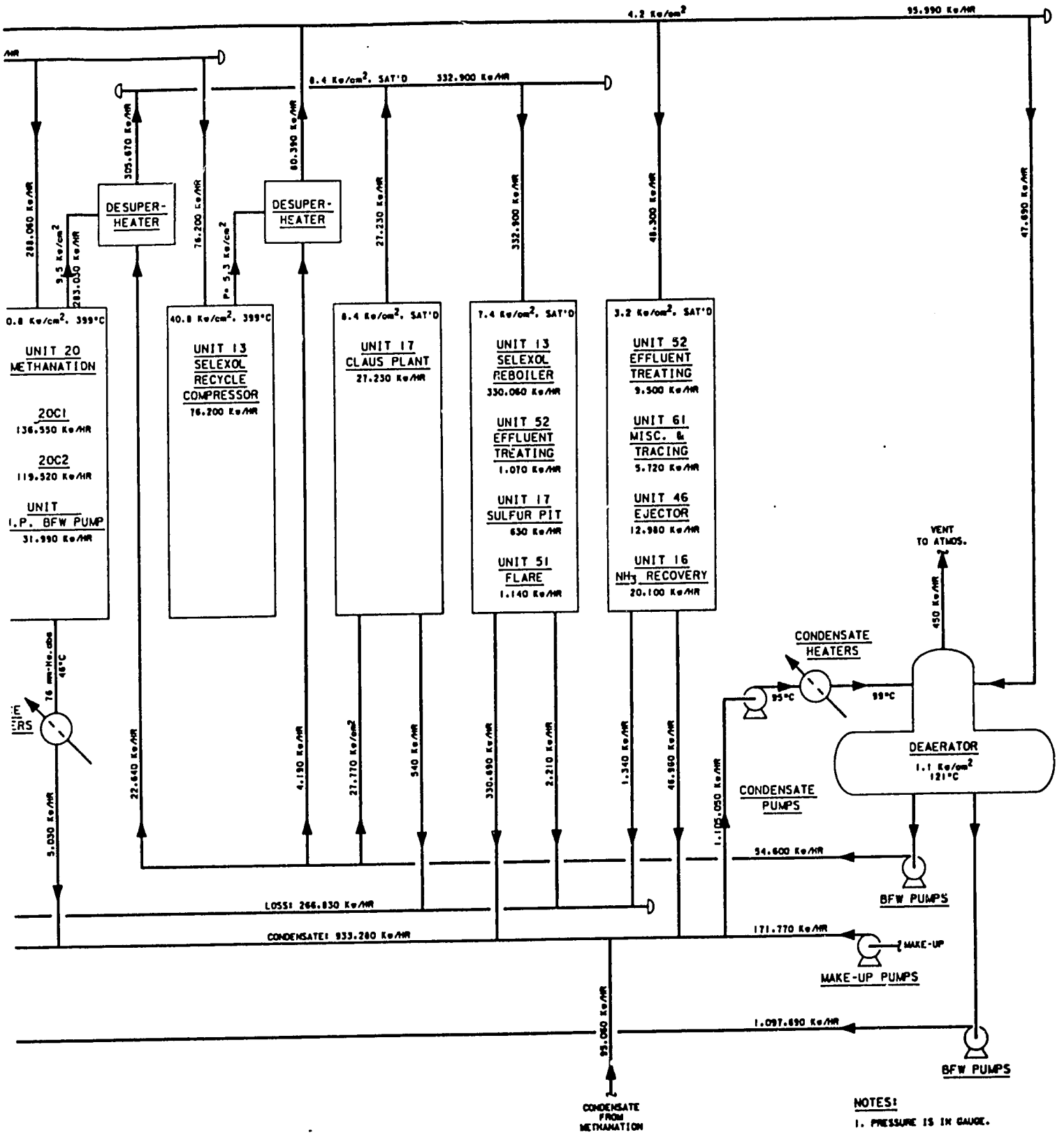
Two 50 percent trains are provided.

<u>Unit 22 - SNG Compression</u>

The SNG product from the Acid Gas Removal Unit at 29°C and 45.1 kg/cm^2 (abs.) is compressed to pipeline pressure of 68.6 kg/cm^2 (abs.)


UNIT 43
SUPER-
HEATER
314.750 Kg/HR
47.5 Kg/cm², SAT'D
927.560 Kg/HR
44.0 Kg/cm², 410°C
863.360 Kg/HR
927.560 Kg/HR
2.480 Kg/HR
212.810 Kg/HR
10.550 Kg/HR
548.610 Kg/HR
2.570 Kg/HR
85.750 Kg/HR
413.350 Kg/HR
288.060 Kg/HR
9.5 Kg/cm²
47.5 Kg/cm², SAT'D
UNIT 20
METHANATION
424.450 Kg/HR
UNIT 12
SHIFTED GAS
COOLING
103.110 Kg/HR
44.3 Kg/cm², SAT'D
UNIT 17
CLAUS PLANT
AIR HEATER
2.900 Kg/HR
UNIT 40
O2 HEATER
10.790 Kg/HR
UNIT 16
NH3 RECOVERY
39.050 Kg/HR
UNIT 11
SHIFT REACTOR
160.070 Kg/HR
44.0 Kg/cm², 410°C
UNIT 10W
WESTINGHOUSE
GASIFICATION
548.610 Kg/HR
34.1 Kg/cm², 399°C
UNIT 10W
WESTINGHOUSE
GASIFIER
85.750 Kg/HR
40.8 Kg/cm², 399°C
UNIT 40
AIR
COMPRESSORS
288.200 Kg/HR
UNIT
O2 COMPRESSORS
113.240 Kg/HR
UNIT 22
SNG PRODUCT
COMPRESSOR
11.910 Kg/HR
40.8 Kg/cm²,
UNIT 20
METHANATI
20C1
136.550 Kg/
20C2
119.520 Kg/
UNIT
H.P. BFW P
31.990 Kg/
10.550 Kg/HR
4.2 Kg/cm²
52.740 Kg/HR
559.580 Kg/HR
193°C
10.870 Kg/HR
BFW
HEATERS
SURFACE
CONDENSERS
78 mm-Hg.abs
46°C
VENT
FROM
DEAEATOR
450 Kg/HR
432.940 Kg/HR
105.170 Kg/HR
8.070 Kg/HR
160.070 Kg/HR
42.190 Kg/HR
664.750 Kg/HR
8.400 Kg/HR
85.750 Kg/HR
413.350 Kg/HR
5.030 Kg/HR

12



FLUOR	D.P.HALVERSON C.C.ABATAY G.O.ROMO A.RAO	BLOCK FLOW DIAGRAM WESTINGHOUSE CASE STEAM & CONDENSATE SYSTEM U.S. A.I.D./BRAZIL	
		NONE	836504-00-4-0004 0

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Flow metering of the gas and BTU analysis are carried out for inplant information. Upon entering the unit, the gas passes through a Selexol solvent knockout drum. (During normal operation of the Selexol unit, there will be no entrainment of the solvent.) The gas then enters a single stage, centrifugal compressor where its pressure is increased to enter the pipeline. The compressor is driven by a steam turbine. After compression, the gas is air cooled to 50°C. Before entering the pipeline, the flow is measured and BTU analysis is made.

A single 100 percent train is provided.

Unit 40 - Oxidant Plant

Atmospheric air is compressed in two-stage steam turbine-driven centrifugal machines. Interstage cooling and afterstage cooling of the air is accomplished with cooling water in shell and tube heat exchangers. The water condensed from the feed air is collected and used as makeup to the plant cooling water system.

The compressed air is processed cryogenically to produce 98 mole percent purity oxygen. The 98 mole percent oxygen from the air separation units is compressed by multistage steam turbine driven centrifugal compressors prior to being fed to the gasifiers. The interstage cooling for these compressors is provided by water cooled exchangers. The compressed oxygen is heated by condensing steam and fed to Westinghouse gasifiers.

Three 33-1/3 percent parallel trains are provided for this unit.

Unit 43 - BFW Treatment and Steam Generation

The overall plant steam, boiler feed water, and condensate system is shown in Drawing No. 836504-00-4-0004.

Treated BFW from demineralizers is preheated upstream of the deaerators, with heat transferred from the gas cooling unit. Condensate returned from the plant is also preheated with recovered heat from gas cooling unit prior to entering the deaerators.

The Westinghouse Gasification Unit produces 44 kg/cm^2, 410°C superheated steam in its waste heat boilers. Superheaters are included to superheat the saturated steam generated in the Shift Unit and in the Methanation Unit.

A start-up boiler would be included.

OFFSITES, UTILITIES, AND OTHER SUPPORT FACILITIES

The plant electrical power requirements would be imported into the plant. The plant would receive fresh water makeup from the Jacui River. The plant would otherwise be self-sufficient in all respects.

Included in the plant would also be the following offsite, utility systems and necessary infrastructure:

- Raw Water and Boiler Feed Water Treating
- Process and Utility Cooling Water
- Plant and Instrument Air
- Interconnecting Pipeway
- Flare System
- Communications
- Storm and Oily Water
- Power Distribution System
- Underground Piping
- Fire Water System
- Sanitary Sewage
- Buildings
- Roads, Fencing, and Lighting
- Tank Farm and Dispatch

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2.5 PLANT DESCRIPTION-LURGI/WESTINGHOUSE HYBRID CASE

The Lurgi plant processes 14 283 metric tons per stream day of 35 weight percent ash coal to produce 33 000 million kilocalories equivalent of SNG per day. Coal is gasified using Lurgi gasification technology for the coarse coal and Westinghouse gasification technology for the fines. The overall process configuration is shown in the Overall Block Flow Diagram, Drawing No. 836504-00-4-0001 and the associated material balance is presented in Table 2- . Brief descriptions of the various units in the plant follow.

Unit 01 - Coal Receiving, Storage, Preparation, and Distribution

The previously prepared and washed (to 35 weight percent ash and -38.1 mm size) coal is transported by receiving conveyor from the coal preparation plant located at the minemouth to a 4-day live covered storage. The coal receiving equipment includes a magnetic separator to remove tramp iron and a continuous sampling station to monitor the incoming coal. Coal is reclaimed from the live storage and conveyed to the screening section where the coal is separated into fines and the range of sizes suitable for feed to the Lurgi gasifiers (38.1 mm x 6.35 mm). Part of the fines are used in Westinghouse gasifiers and remainder in a boiler. Conveyors transfer the acceptably sized coal to the gasification coal feed bins from which the coal is fed into the coal gasifiers.

The fine coal conveyed to the steam generating facilities is pulverized and fed to the coal-fired boiler.

A 30-day dead storage for the coal is provided. Air emissions from this section of the plant are limited to particulate emissions in the form of coal dust. These emissions are controlled by the use of enclosed conveyor systems and screening operations, and by water sprays at conveyor transfer points.

Unit 03 - Ash Handling

Ash from the Lurgi gasifiers is discharged from the ash locks directly into a sluiceway and is transported into the dewatering plant. The coarse Lurgi ash is removed by a vibrating screen and discharged on a conveyor belt along with the coarse ash from the Westinghouse gasifiers. The remaining ash/water slurry flows into a rake classifier where coarse ash is raked out. The fine ash/water slurry is fed to a thickener along with the fine ash/water slurry from the Westinghouse particulate scrubber.

The water overflowing from the thickener is recycled for sluicing water. Thickened ash slurry from the bottom of the thickener is combined with the rake classifier ash. The coarse ash removed by the rake classifier retains the fine ash from the thickener so that the total ash can be transported by the conveyor belt.

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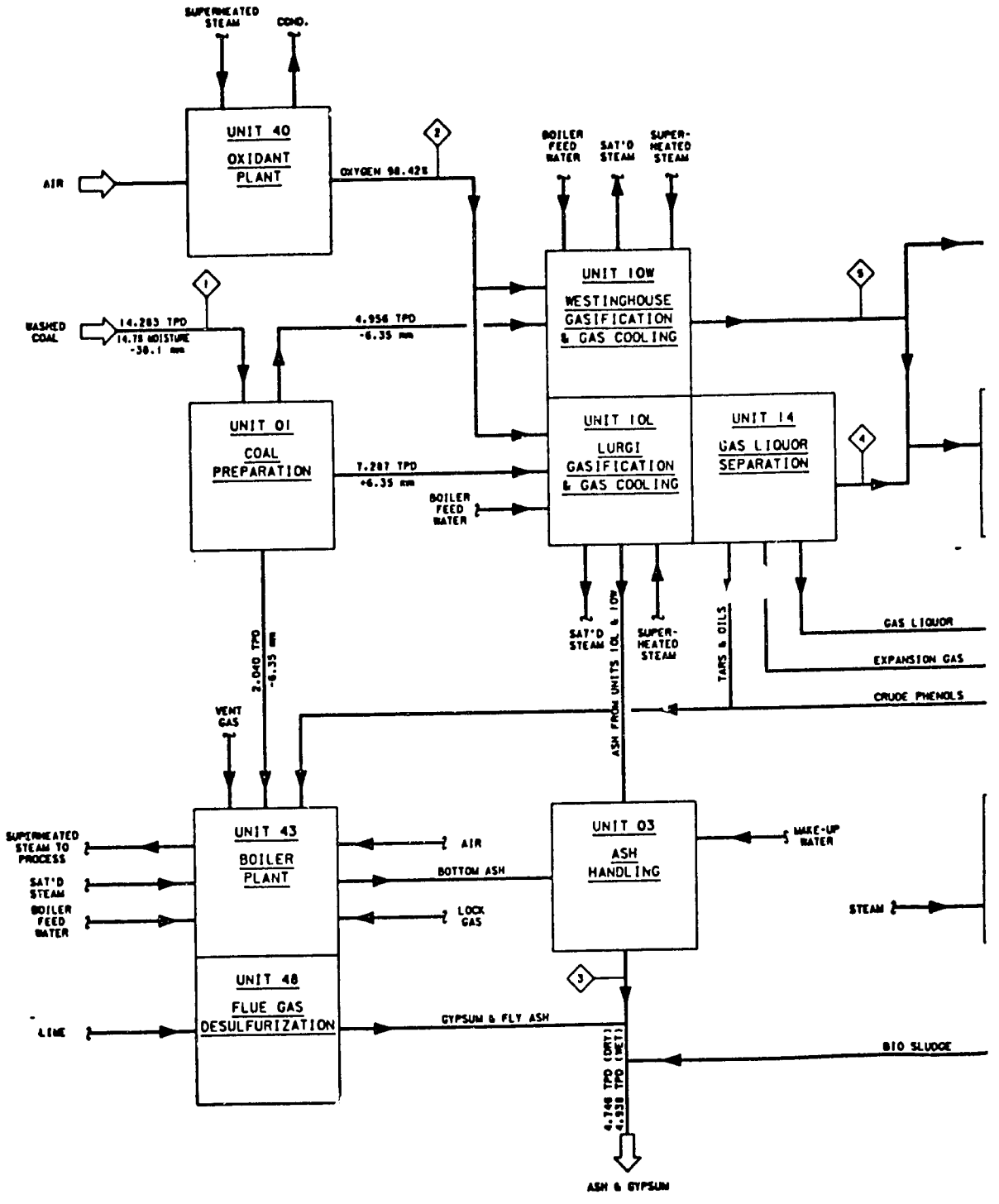
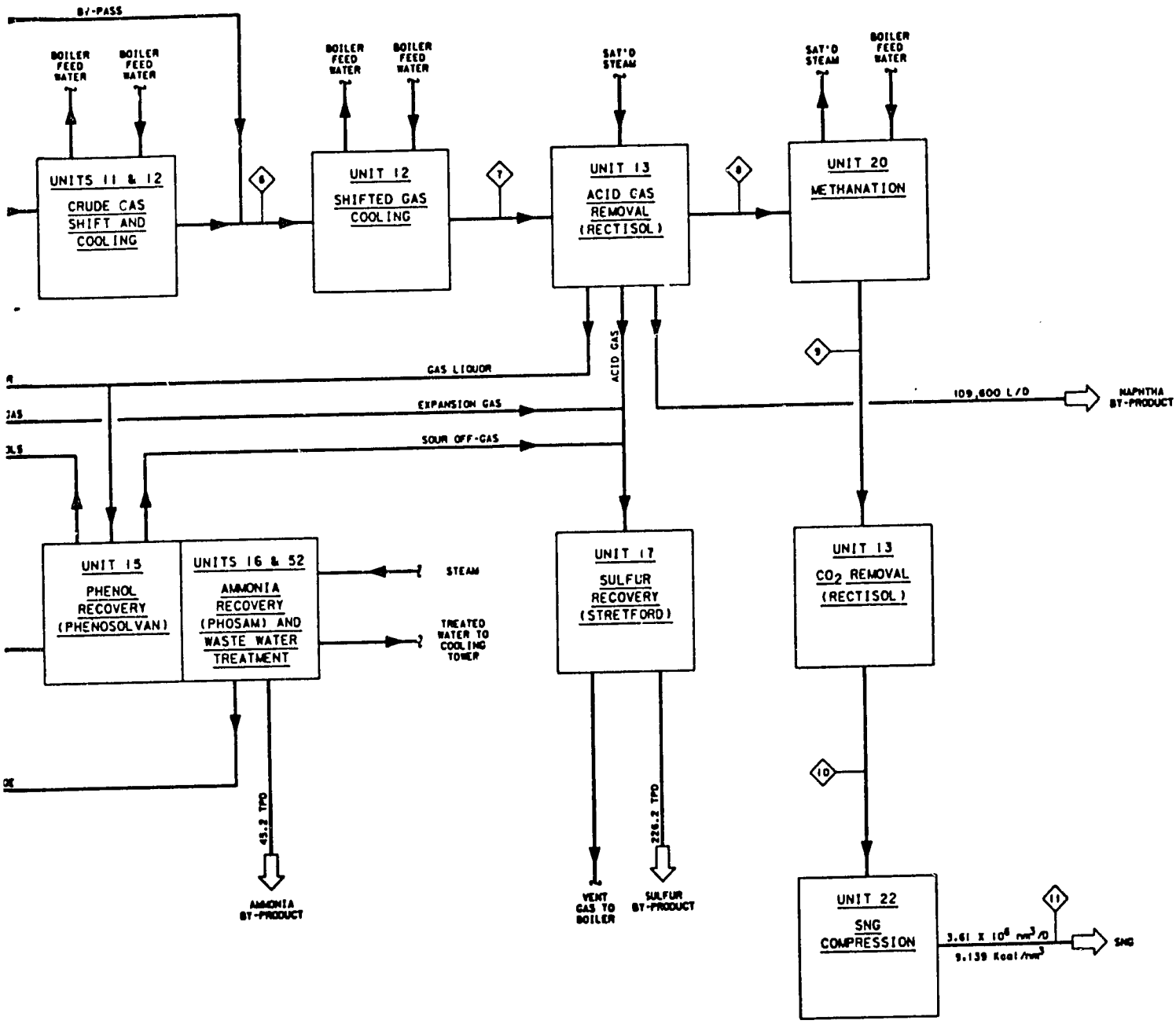

SUPERHEATED STEAM
COND.
UNIT 40
OXIDANT PLANT
AIR
OXYGEN 98.42%
BOILER FEED WATER
SAT'D STEAM
SUPER-HEATED STEAM
UNIT 10W
WESTINGHOUSE GASIFICATION & GAS COOLING
WASHED COAL
14,283 TPD
14.7% MOISTURE
-38.1 mm
4,956 TPD
-6.35 mm
UNIT 01
COAL PREPARATION
7,287 TPD
+6.35 mm
BOILER FEED WATER
UNIT 10L
LURGI GASIFICATION & GAS COOLING
UNIT 14
GAS LIQUOR SEPARATION
SAT'D STEAM
SUPER-HEATED STEAM
TARS & OILS
GAS LIQUOR
EXPANSION GAS
CRUDE PHENOLS
2,040 TPD
-6.35 mm
ASH FROM UNITS 10L & 10W
VENT GAS
SUPERHEATED STEAM TO PROCESS
SAT'D STEAM
BOILER FEED WATER
UNIT 43
BOILER PLANT
AIR
BOTTOM ASH
LOCK GAS
UNIT 03
ASH HANDLING
MAKE-UP WATER
STEAM
UNIT 48
FLUE GAS DESULFURIZATION
LIME
GYPSUM & FLY ASH
BIO SLUDGE
4,746 TPD (DRY)
4,938 TPD (WET)
ASH & GYPSUM



NOTES:

1. FLOWRATES ARE PER STREAM DAY.

FLUOR

D.P. HALVERSON
C.C. ABATAY
G.O. ROMO
A. RAD

OVERALL BLOCK FLOW DIAGRAM
LURGI/WESTINGHOUSE HYBRID CASE
SNG FROM COAL
U.S. A.I.D./BRAZIL

NONE | 836504-00-4-0001 | 0

001 36500001

TABLE 2-7

LURGI/WESTINGHOUSE HYBRID CASE - STREAM DATA

STREAM NO. AND NAME	1 FEED COAL	2 OXIDANT	3 ASH*	4 SCRUBBED GAS FROM LURGI	5 SCRUBBED GAS FROM WESTINGHOUSE	6 SHIFTED GAS	7 GAS TO RECTISOL	8 GAS TO METHANATION	9 GAS TO CO_2 ABSORBER	10 SNG TO COMPRESSION	11 SNG PRODUCT
COMPONENT/kgMol/hr (kg/hr)											
CH_4				1 730	716	2 555	2 555	3 073	7 001	6 426	6 426
H_2	7 806		17	6 435	2 348	12 231	12 231	12 227	99	99	99
CO				2 392	4 562	3 398	3 398	3 396	4	4	4
CO_2				5 199	1 476	10 233	10 233	1 414	932	34	34
H_2S				182	114	297	297				
COS					6	5	5				
O_2	1 475	4 725									
N_2+Ar	162**	76	1	71	83	154	154	154	154	154	154
NH_3											
H_2O	4 856			8 056	1 867	6 365	114	TRACE	11		
SO_2											
C	20 879		744								
S	364		6								
ASH	(177 678)		(157 376)								
C_2^+				109		54	54	28			
(T+O+N+P+A)***				(10 676)		(11 234)	(3 522)				
TOTAL kgMol/hr		4 801		24 174#	11 172	35 292#	29 041#	20 292	8 201	6 717	6 717
kg/hr	595 130	154 236	166 567	504 655	250 157	755 250	634 946	238 291	159 989	111 046	111 046
PRESSURE kg/cm² ABS	1.03	35.2		30.2	30.2	29.0	27.8	24.4	47.8	45.1	68.6
TEMPERATURE °C		149 FOR LURGI 232 FOR WESTINGHOUSE		177	149	149 292	38	27	38	20	50

* DRY BASIS
** NITROGEN ONLY
*** TARS OILS NAPHTHA PHENOLS AND FATTY ACIDS.
\# WITHOUT T+O+N+P+A

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Water is lost to the ash system through water vapor generation during ash quenching and moisture retention during the ash dewatering operations. Quenching water, high in mineral content, is utilized as makeup water since this is a convenient way to dispose of these effluent streams.

Bottom ash from the power plant boilers is quenched in a manner similar to the method used for the gasification ash. Fly ash from the boilers is discharged dry, mixed with the filter cake from the Flue Gas Desulfurization Unit and discharged along with the other ash via a conveyor to the ash pile.

Unit 10 - Gasification, High Temperature Gas Cooling, and Gas Quench

This system is a hybrid of Lurgi gasification and Westinghouse gasification systems enabling the system to process both coarse and fine coal.

Lurgi Unit: Coarse coal (+6.35 mm) is gasified in Lurgi gasifiers. The Lurgi gasification unit consist of integrated gasification, ash removal, particulate scrubbing, and heat recovery systems. The Lurgi gasification system consists of nine gasifiers operating in parallel (seven operating with two spares) each capable of processing 1041 metric tons per day of 35 percent ash coal. The operation of the Lurgi gasifier is a batch-continuous operation. Coal feed and ash removal are conducted in the batch mode, whereas oxygen and steam are added continuously.

Depressurizing of the coal lock at the top of the gasifier is followed by opening the coal feed valve at the top of the coal lock. During the depressurizing operation, the gas in the coal lock is fed to a gas holder until the pressure is too low for the transfer of the gas. Following this operation, the remainder of the gas is vented to the atmosphere.

Following the charge of coal into the coal lock, the top valve is closed and the coal lock is pressurized with reactor gas to a pressure equivalent to that in the gasifier. Upon equalization of the pressure between the gasifier and the coal lock, the bottom valve on the coal lock is opened and the coal is introduced into the gasifier reaction chamber. The ash lock operates in a similar manner except that high pressure, superheated steam is used as the pressurizing medium. The coal lock gas in the gas holder is used as a fuel gas in the steam plant.

The coal passes slowly through the gasifier, continuously changing chemical composition as it passes through four distinct zones. From top to bottom, these zones are: coal preheat and devolatilization, gasification, combustion, and ash zones. The top zone preheats and dries the coal by contact with the hot crude gas leaving the gasifier. As the coal is heated, devolatilization and gasification commence in zones which overlap and encompass temperatures ranging from 600°C to 850°C. Devolatilization of the coal is accompanied by gasification of resulting char to produce carbon monoxide and hydrogen.

Oxygen and steam enter as a mixture near the bottom of the gasifier, and the mixture is heated by the ash as it passes upward to the combustion zone. The steam-to-oxygen ratio, dictated by the coal composition,

determines the temperature in the combustion zone. The temperature must be maintained below the ash melting point, yet sufficiently high to ensure the gasification of the coal.

The raw gas from the gasifier leaves the reactor in the temperature range of 350°C to 500°C and in the pressure range of 28 kg/cm^2 to 32 kg/cm^2.

The crude gas product stream is cooled rapidly and the particulates removed by quenching with a gas liquor spray in the scrubber. This quenched gas is further cooled by heat exchange with boiler feedwater, recovering waste heat as low pressure steam in the Waste Heat Boiler, and is subsequently routed to the Shift Unit. Condensed hydrocarbons and water, and recovered particulates from the Waste Heat Boiler are routed to the Gas Liquor Separation Unit for further processing.

The ash leaving the ash lock is quenched and generates saturated steam at atmospheric pressure. This steam is routed through a wet cyclone separator for particulate removal and then the clean steam is discharged to the atmosphere. The coarse ash is separated from the fine ash by the use of screens and delivered to the ash handling system.

Water used in this section consists of the recycled sluice water for ash quenching and conveying.

Westinghouse Unit: Fine coal (-6.35 mm) is gasified in Westinghouse gasifiers. The Westinghouse gasification unit is an integrated system of gasification, ash removal, coal fines recycle, high temperature heat recovery, and particulate scrubbing. Five gasification trains are provided, each capable of processing 1 239 metric tons per day of 35 percent ash coal. Under normal operation all five gasifiers will be operating at a reduced load (80% of full load). During periods when a gasifier is shut down for repairs or maintenance, the feed to the other four gasifiers will be increased to operate each at full load.

Coal from the gasifier feed surge bin flows into the pressurized coal lockhopper system which consists of two lockhoppers: a pressurization lockhopper and coal feed lockhopper. Coal is drawn from the feed lockhopper and is pneumatically transported by recycle gas into the bottom of the gasifier. Oxygen is introduced at the bottom of the gasifier and initiates combustion of the coal. The action of the recycle gas and oxygen flowing upward through the reactor causes fluidization of the coal particles. Steam is injected into the lower portion of the reactor. Heat from the combustion of a portion of the incoming coal is used to devolatilize the remainder of the incoming coal to form a char. The char in turn reacts with steam to form carbon monoxide and hydrogen. As the coal and char circulate, they are gradually consumed by combustion and gasification, leaving small particles of ash. The hot ash begins to agglomerate, forming denser particles which defluidize from the bed and collect in the ash annulus. The agglomerated ash particles are cooled as they pass through the bottom of the annulus, and are removed from the gasifier via a rotary feeder into the ash lockhopper system. The ash is depressurized through two lockhoppers and delivered to the ash handling system.

Raw product gas exits from the top of the gasifier and passes through a two stage cyclone system. Fine, entrained solids are removed from the raw gas by cyclones and pneumatically transported for recycle to the gasifier.

The raw gas next passes through the raw gas heat recovery area. The gas is first cooled by heat exchange with preheated boiler feed water to produce 105 kg/cm^2 saturated steam. Each gasification train has its own steam generator, steam drum, boiler feed water pump, and boiler feed water chemical addition system.

Further cooling and particulate removal from the gas occurs by direct quench with water in a venturi scrubber. The effluent from the venturi scrubber flows into a particulate scrubber from where the quenched gas is withdrawn overhead and a fines slurry as the bottoms product. The quenched gas is split into two streams: quench gas product and recycle gas. The recycle gas is cooled and compressed before being recycled back to the coal feed lockhoppers and cyclone discharge feeders for transporting the coal to the gasifier and recycling of the raw gas fines respectively. The quench gas product is routed to the shift unit.

The fines slurry produced from the particulate scrubber is concentrated and combined with the Lurgi fine ash in the ash clarifiers. A small amount of water is lost from the system with the fines. Some water is rejected from the quench water to control the buildup of dissolved solids in the quench water.

The quench blowdown from the Westinghouse gasification unit is combined with the Lurgi condensate and treated in the process condensate treating unit. The treated water from Process Condensate Treating is used for cooling water makeup, while the gasification water makeup requirements are supplied by treated raw water.

Unit 11 - Crude Gas Shift

The Crude Gas Shift Conversion Unit catalytically reduces the carbon monoxide concentration in the crude gas product of the Gasification Unit while producing additional hydrogen by the exothermic reaction:

$$CO + H_2O \qquad CO_2 + H_2$$

Reaction steam is provided by the normal steam content of the crude gas, and the elevated reaction temperature for the single stage conversion is attained by a feed-effluent heat exchange scheme in this unit. In addition to converting carbon monoxide, the cobalt molybdenum catalyst hydrogenates unsaturated hydrocarbons and most of the higher phenols, HCN, and organic sulfur contained in the crude gas. The catalyst is also expected to hydrocrack all of the tars and a portion of the remaining hydrocarbons to lighter species.

Crude gas by-pass is provided as a means for controlling the H_2-to-CO ratio required in the synthesis gas. The H_2-to-CO ratio required in the synthesis gas for methanation is about 3.6 to avoid carbon deposition in the methanation catalyst.

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This unit consists of two parallel operating trains. The feed, to each of the shift unit trains, is preheated in its feed/effluent exchanger to 291°C prior to being fed to catalyst beds. The converted gas exiting the beds at a temperature of 405°C is cooled to 292°C in the feed/effluent exchanger and sent to the Gas Cooling Unit.

Unit 12 - Gas Cooling

The converted gas from the Shift Unit at 292°C and 29 kg/cm^2 (abs.) is processed through shell and tube exchangers for removal of waste heat to a tempered water system that transfers heat from the raw gas to the steam generating facilities. A tempered water circuit is used for BFW preheat to prevent contamination of BFW.

Next, air coolers are utilized for additional heat removal. Tarry gas liquor is condensed as the heat is removed, separated in the air cooler knock out drums and is routed to the Gas Liquor Separation Unit for processing. Finally, heat is removed by cooling water exchange which condenses oily gas liquor. This is routed to the Gas Liquor Separation Unit for further treatment.

This unit consists of two 50 percent parallel operating trains.

Unit 13 - Acid Gas Removal

The Lurgi Rectisol Unit is used for acid gas removal. The sulfur compounds are reduced to a concentration of less than 0.1 ppm to prevent sulfur poisoning of the methanation catalyst. Also the CO_2 content of the gas is reduced to a concentration such that the stoichiometric number (SN) of the pure gas (defined below) is greater than 0.65 to avoid damaging the methanation catalyst.

$$SN = \frac{H_2 - 2C_2H_4 - C_2H_6}{3CO + 4CO_2}$$

The Rectisol Unit utilizes cold methanol to remove all sulfur compounds from the gas leaving the Gas Cooling Unit. The gas fed to the Rectisol Unit is washed with medium-cold methanol to remove gas naphtha components; i.e., pentanes, hexanes, benzene, toluene, and heavier aromatics. The prewash methanol stream is flashed in a flash tower to release dissolved gases and naphtha. Methanol is recovered from the naphtha by extraction with water in a proprietary system, and the gases are routed to the Sulfur Recovery Unit for removal of the H_2S. The naphtha after stabilization is sent to storage.

The prewashed gas is then fed to the main wash in a methanol wash tower where the bulk of the H_2S and CO_2 is removed by washing with very cold methanol. The gas is finally washed in the fine wash system by methanol which comes from the CO_2 Rectisol section (for CO_2 removal from methanated gas) via a chiller.

Loaded methanol from the main and fine wash systems is regenerated by flashing in several stages in the main wash flash tower. Part of the flashed methanol is stripped in the hot regenerator for use in the CO_2 Rectisol section. Gas from the first stage flash in the main wash flash tower is combined with the fresh feed from the Gas Cooling Unit. All other flash gases and hot regenerator offgas, containing H_2S and CO_2 are fed to the Sulfur Recovery Unit for H_2S removal.

Gas condensate from the fresh feed to Rectisol Unit is removed from the gas stream and fed to the Gas Liquor Separation Unit.

Final CO_2 Removal - CO_2 Rectisol Section

Rich gas from Methanation at 38°C which has been compressed to 48 kg/cm^2 (abs.) enters a series of heat exchangers and is cooled against SNG product gas and propylene refrigerant. Water condenses out of the gas in the first two exchangers and is collected and combined with condensate from Methanation. Methanol is injected into the gas after condensate is removed to prevent icing. Condensed methanol and water from the last two exchangers are collected in a K.O. vessel and sent to methanol recovery. The K.O. vessel contains a packed section which can be used for methanol washing if water break through to the wash tower becomes a problem.

The cooled gas enters a wash tower for washing with regenerated methanol. The regenerated methanol is pumped through a propylene chiller and into the wash tower where it passes countercurrently to the rich gas and absorbs CO_2 plus some CH_4. Leaving the tower, the methanol is cooled and goes on to a wash on the top trays of the main methanol wash tower. This completes the methanol loop.

SNG leaves as overhead off the wash tower with CO_2 removed to 0.5 volume percent. It is warmed in exchangers against the incoming methanated gas to 20°C and then goes to the SNG Compression Unit.

A total of two 50 percent trains are provided for this unit. A propylene refrigeration system is provided for the Rectisol Unit.

Unit 14 - Gas Liquor Separation

This unit uses gravity separation of the gas liquor to produce tar, oil, and water phases.

The gas liquor is cooled and depressurized to essentially atmospheric pressure. The dissolved gases released (mainly CO_2) are routed to the Sulfur Recovery Unit for H_2S removal.

Gas liquor then flows into a primary separator whose function is to separate the tar phase from the water phase. Tar settles to the bottom of the separator from where it is pumped to a liquid fuels storage tank.

Gas liquor and oil flows from the top of the primary separator into the secondary separator. Oil is drawn from the top, water from the middle, and a small quantity of light tar is drawn periodically from the bottom.

The oil is combined with the tar in the liquid fuels storage tank.

The gas liquor is cooled to the lowest temperature possible with cooling water and flows into the tertiary separator for the separation of light oil and tars still present. The gas liquor then flows into the Phenol Recovery Unit. Part of the gas liquor is recycled to gasification for use in the scrubber.

A single train is provided.

Unit 15 - Phenol Recovery

The Lurgi Phenosolvan Process is used for the phenol recovery.

The liquor from the Gas Liquor Separation Unit is solvent extracted in a liquid/liquid contactor to recover the phenols. The solvent, rich in phenols, is routed to an extract tank.

The crude phenol stream from the extract tank is processed through a solvent distillation column for removal of pure solvent from the crude phenol. The recovered solvent is recycled to the phenol extractor.

The bottom product of the solvent distillation column is stripped in a solvent recovery stripper to provide a solvent-free crude phenol product. The overheat product, which contains some phenols, is recycled to the phenol extractor for additional recovery of phenols. The phenol stream is pumped to the liquid fuels tank. Water effluents from maintenance and operating drains are collected in a closed sewer system and recycled to the feed surge tank. Water effluent is routed to the Ammonia Recovery Unit.

A single train is provided.

Unit 16 - Ammonia Recovery

The Ammonia Recovery Unit is U.S. Steel Company's proprietary Phosam-W process. In this unit, sour water from the Phenol Recovery Unit is fed to a sour water stripper, where ammonia, acid gases, and dissolved gases are separated as an overhead product by countercurrent steam stripping. The stripper bottoms product is cooled and sent to the Wastewater Treating Unit.

The absorber overheads are fed to an ammonia absorber where the ammonia is selectively removed by countercurrent absorption in phosphoric acid. Absorber outlet gas is cooled and sent to the Sulfur Recovery Unit, for further processing. The absorber bottoms are pumped to an ammonia stripper where the ammonia is recovered as an overhead product by countercurrent steam stripping. Phosphoric acid bottoms are cooled and recycled to the absorber. The stripper overheads are condensed and collected and pumped to an ammonia fractionator in final product distillation. Caustic solution is added to the fractionator to neutralize impurities in the ammonia feed and give a 99.9 percent pure liquid anhydrous ammonia product. The aqueous fractionator bottoms are recycled for reprocessing.

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A single train is provided.

Unit 17 - Sulfur Recovery

Acid gases from Rectisol Unit, Gas Liquor Separation Unit, and Phenosolvan Unit are routed to the Sulfur Recovery Unit for conversion of the H_2S into product sulfur. The Sulfur Recovery Unit uses the Stretford Process to convert H_2S to elemental sulfur.

The gas containing H_2S is countercurrently washed with regenerated Stretford solution in a Contactor. The H_2S is selectively absorbed into the alkaline solution. The hydrosulfide formed reacts with the pentavalent state vanadium and is oxidized to elemental sulfur. The liquor is regenerated by air blowing in an Oxidizer Tank, the reduced vanadium being restored to the pentavalent state through a mechanism transferring oxygen via anthraquinone disulfonic acid.

The sulfur is removed from the solution by air flotation, which produces a froth containing the sulfur. The froth overflows the oxidizing tank into a skim tank. Next, it is heated to produce molten sulfur. Vent gas from the Stretford Unit, containing volatile organic carbon (VOC), H_2S, and COS is routed to the boiler plant for combustion. VOC is converted to CO_2, and the H_2S and COS are converted to SO_2.

Two 50 percent trains are provided.

Unit 20 - Methanation

The Methanation Unit converts CO and CO_2 into CH_4 by reaction with H_2.

$$CO + 3H_2 \qquad CH_4 + H_2O$$

$$CO_2 + 4H_2 \qquad CH_4 + 2H_2O$$

Both these reactions are promoted by a nickel containing catalyst and are strongly exothermic. Minor quantities of ethylene and ethane, also present in the gas, will be hydrogenated as follows:

$$C_2H_4 + 2H_2 \qquad 2CH_4$$

$$C_2H_6 + H_2 \qquad 2CH_4$$

The synthesis gas, after several stages of shift and removal of carbon dioxide, normally still contains up to one percent of carbon oxides, which would cause deactivation of the ammonia synthesis catalyst. The carbon oxides are, therefore, catalytically converted to methane, which is inert towards the catalyst.

Although the methanation reaction is highly exothermic, the low concentration of carbon oxides associated with ammonia synthesis gas limits the temperature rise to less than 75°C, and a simple adiabatic packed bed reactor is used. These converters are normally designed to operate with an exit

temperature below 450°C. Concentration of carbon oxides is generally reduced to below 5 ppm. Also, the hydrogen is present in large excess (>75 percent).

Methanation in coal gasification processes presents a challenge in that the carbon monoxide concentration is much higher than in other methanation processes. The difficulty with the high carbon monoxide concentration is that in an adiabatic reactor, the heat of reaction causes the temperature to rise by 60°C for each one percent of CO converted to methane; so, with a feed concentration of 15 to 20 percent CO, the temperature rise would be high enough to cause catalyst sintering and decomposition of the product methane to carbon. Novel reactor configurations are used to circumvent this problem.

The Lurgi Methanation Process is closest to being demonstrated on a large commercial scale. This process utilizes adiabatic fixed beds and hot-gas recycle to absorb the heat of reaction and to keep the bed temperatures within the limit. The rapid rates at which the reactions occur and the use of gas recycle to control temperature make the design of this system simple, being amenable to thermodynamic treatment rather than complicated transfer processes. The U.S. Department of Energy has concluded that the use of this process poses no technical risk.

Lurgi has operated two semicommercial pilot plants to demonstrate this methanation system. In Schwechat, Austria, synthesis gas from naphtha was methanated. The other demonstration was on a sidestream from the SASOL Fischer-Tropsch plant in Sasolburg, South Africa. This plant produces a synthesis gas from coal in Lurgi gasifiers. In both cases a BASF catalyst was used in a fixed bed recycle methanator followed by a clean-up methanator. Based on the pilot plant experience, a catalyst life of 16 000 hours is expected.

This principle was demonstrated at a scale of 67 000 Nm^3/D by Continental Oil Company along with 16 other American companies in a $6 million demonstration project at the Westfield Coal Gasification plant in Scotland. Raw gas was produced by Lurgi dry bottom gasification. A fixed-bed, gas recycle, adiabatic methanation reactor was used. The product was fed into the local gas grid. The plant was operated for two months and produced a substitute natural gas with a higher heating value of 9 218 $kcal/Nm^3$. Based on the results from this demonstration, a catalyst life of 1 to 1-1/2 years was projected. (A pilot plant test conducted by the Department of Energy at Pennsylvania predicts a catalyst life of 5 years for commercial operation.)

The Lurgi Methanation Process will be commercially demonstrated by the Great Plains Coal Gasification Project. The first phase of this project is scheduled for start-up in late 1984 and will produce 3.7×10^6 Nm^3 per stream day of substitute natural gas with a heating value of 9 124 $kcal/Nm^3$.

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The Lurgi Methanation process includes a multistage reaction system and recycle of product gas. Adiabatic reactors connected with waste heat boilers remove the heat in the form of high pressure steam. Fresh makeup gas is mixed with total recycle and fed to the first bed. The effluent from the first bed is partially cooled so that when it is combined with another portion of the makeup, the mixture is at or above the initiating reaction temperature. This mixture is fed to the second bed. This procedure is continued to the third and subsequent beds. The inlet temperatures to the reactors are kept between 260°C and 300°C and the outlet temperatures between 450°C and 500°C. A final cleanup (damp) methanator is used after most of the water formed is removed to achieve the final high conversion. The gas leaving the damp methanator is cooled, separated from the condensed water, compressed, again cooled again separated from the condensed water, and sent to CO_2 removal in the Acid Gas Removal Unit to form the product gas.

Two 50-percent capacity trains are provided.

Unit 22 - SNG Compression

The SNG product from the Acid Gas Removal Unit at 20°C and 45.1 kg/cm^2 (abs.) is compressed to pipeline pressure of 63.6 kg/cm^2 (abs.)

Upon entering the compression unit, the gas passes through a methanol knockout drum. (During normal operation of the Rectisol Unit, there will be no entrainment of liquid methanol). The gas then enters a single stage, centrifugal compressor where its pressure is increased to enter the pipeline. The compressor is driven by a steam turbine. After compression, the gas is air cooled to 50°C. Before entering the pipeline, the flow is measured and BTU analysis is made.

A single 100 percent train is provided.

Unit 40 - Oxidant Plant

Atmospheric air feed is compressed in two-stage steam turbine-driven centrifugal machines. Interstage cooling and aftercooling of the air is accomplished by cooling water in shell and tube heat exchangers. The water condensed from the feed air is collected and used as makeup to the plant cooling water system. The compressed air is processed cryogenically to produce 98 mole percent purity oxygen. This oxygen from the air separation units is then compressed by multistage steam turbine-driven centrifugal compressors and fed to the gasifiers. The interstage cooling for these compressors is provided by water cooled exchangers. The compressed oxygen fed to Westinghouse gasifiers is heated by condensing steam.

Two 50-percent parallel trains are provided for this unit.

OFFSITES AND UTILITIES

All the offsites and utilities required to support the gasification plant are included in the plant battery limits. The plant receives fresh water makeup from the Jacui River. The plant will otherwise be self-sufficient.

Brief descriptions of the various offsite and utility systems that are included in the plant are presented in this section.

Unit 43 - BFW Treatment and Steam Generation

The overall plant steam, boiler feed water, and condensate system is shown in Drawing No. 836504-00-4-0002.

BFW Treatment

The BFW Treatment Facilities are comprised of filtration, activated carbon, and demineralization units. Water which has been clarified upstream in the Raw Water Treatment unit is fed to the BFW Treatment facilities. The treated BFW from the demineralizers is preheated upstream of the deaerators, with heat transferred from the tempered water system. (Tempered water is circulated between the Gas Cooling Unit and BFW Treatment Unit. The tempered water method of heat transfer avoids the possibility of contaminating the BFW with the higher pressure raw gas.) Condensate returned from the plant is also preheated with tempered water prior to entering the deaerators.

Steam Generation

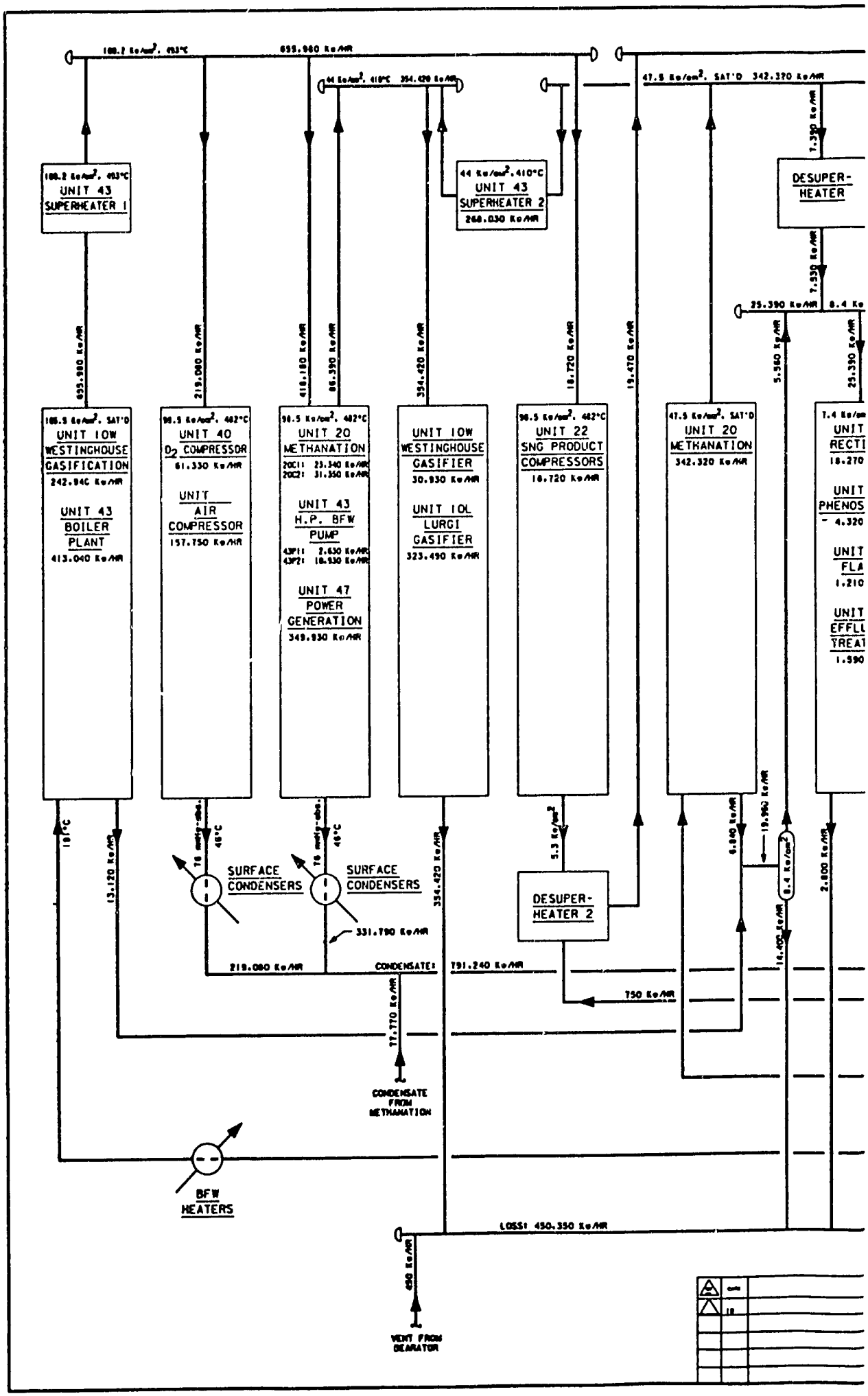
The Process Steam Generation Unit produces high pressure superheated steam for inplant power requirements. Bulk of the high pressure steam is generated in coal-fired boilers designed to produce 100 kg/cm^2, 493°C steam. This system is furnished with associated equipment including precipitator, coal bunker, coal conveyor, deaerator, boiler feed water pumps, ash handling collection and transport system, flue gas ducting, exhaust stack, blowdown systems, and controls. The Westinghouse Gasification Unit produces the remainder of the high pressure steam in its waste heat boilers. Superheaters are included to superheat the saturated steam generated in the Westinghouse Gasification Unit and in the Methanation Unit.

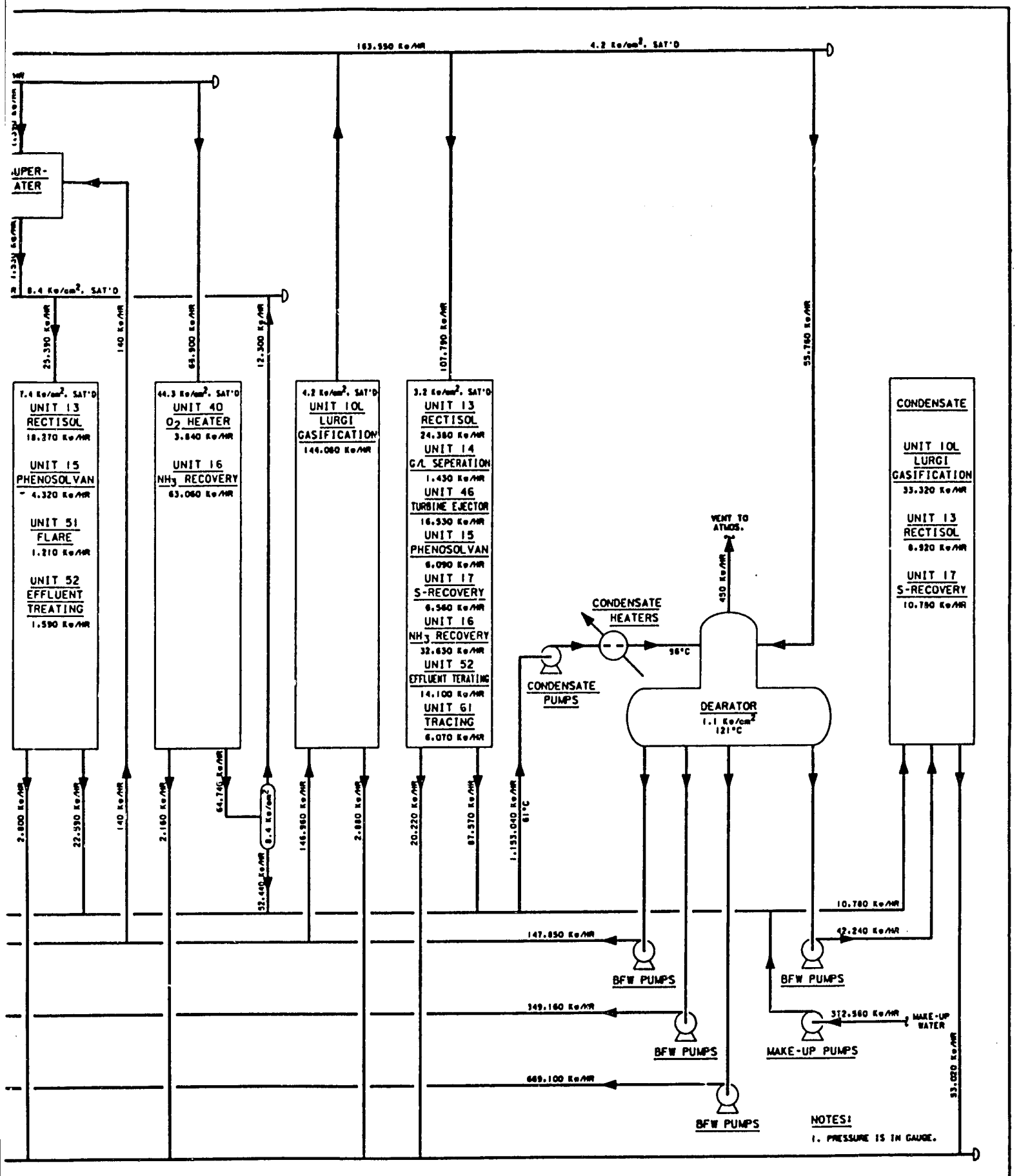
Two 60-percent trains are provided.

Unit 44 - Raw Water and Boiler Feed Water Treating

The water requirements of the plant are met by treating local river water. Various levels of treatment are necessary for various uses.

Water is pumped from the Jacui River to the plant battery limits and stored in the raw water storage tank. The bottom half of this tank serves as storage for the plant fire water system. Raw water is required for cooling water makeup, quench water makeup, potable water, and boiler feed water


UNIT 43
SUPERHEATER 1
UNIT 43
SUPERHEATER 2
DESUPER-
HEATER
UNIT 10W
WESTINGHOUSE
GASIFICATION
UNIT 43
BOILER
PLANT
UNIT 40
O2 COMPRESSOR
UNIT
AIR
COMPRESSOR
UNIT 20
METHANATION
UNIT 43
H.P. BFW
PUMP
UNIT 47
POWER
GENERATION
UNIT 10W
WESTINGHOUSE
GASIFIER
UNIT 10L
LURGI
GASIFIER
UNIT 22
SNG PRODUCT
COMPRESSORS
UNIT 20
METHANATION
UNIT
RECTI
UNIT
PHENOS
UNIT
FLA
UNIT
EFFLU
TREAT
SURFACE
CONDENSERS
SURFACE
CONDENSERS
DESUPER-
HEATER 2
CONDENSATE FROM METHANATION
BFW
HEATERS
VENT FROM DEARATOR



FLUOR

D.P. HALVERSON
C.C. ABATAY
G.O. ROMO
A. RAO

BLOCK FLOW DIAGRAM
LURGI/WESTINGHOUSE HYBRID CASE-
STEAM AND CONDENSATE SYSTEM
U.S. A.I.D./BRAZIL

NONE | 836504-00-4-0002 | 0 | 001 | 36500002

makeup. All of the plant raw water is initially treated by clarification and filtration. The water required for cooling water makeup and quench water makeup does not need further treating. Water for drinking is further treated by activated carbon filtration and chlorination.

Boiler feed water (BFW) treatment, after clarification and filtration, is comprised of activated carbon filtration and demineralization by cation and anion exchangers. Rinse water from both the boiler feed water and raw water treatment systems is discharged to a solar evaporation pond.

Units 45 and 46 - Process Utility Cooling Water

These units provide cooling water for process heat rejection, condensation of exhaust steam from the steam turbines, and cooling of mechanical equipment. The utility cooling water system, consisting of mechanical draft towers and low head pumps, serves only the surface condensers. The process cooling water system involves higher head pumps. This separation of systems allows the use of the low head surface condenser water supply pumps by keeping the runs of cooling water lines to a minimum. A further significant advantage is the confinement of contaminants to one cooling tower in the event of a process fluid leak to cooling water.

Unit 47 - Power Generation

The power generation facility consists of turbogenerators driven by a condensing steam turbine using 100 kg/cm^2 (abs.), 493°C steam. Included in this unit are the associated surface condensers and vacuum pumps.

Three 50 percent trains are provided.

Unit 48 - Flue Gas Desulfurization (FGD)

The Double-Alkali FGD process is comprised of two distinct sections, the sulfur dioxide absorption section and the sodium regeneration section. Sodium is the alkali reagent in the absorption section; and calcium in the regeneration section.

In the sulfur dioxide absorption section, a fan forces the flue gas through an FMC low energy Disc Contactor Absorber with an integral recirculation sump in the base. Internal to the absorber is a series of discs and donuts over which flows the process liquor. Gas flow is countercurrent to the process liquor flow and intimate mixing is obtained as the gas penetrates the cascading liquid. The process liquor is a clear, concentrated, highly reactive, and buffered solution of sodium sulfite, sodium bisulfite, and sodium sulfate which creates the following advantages over calcium slurry systems: a liquid-to-gas ratio of 15 gal/1000 ACF is generally sufficient to ensure high sulfur dioxide removal efficiency; scaling and plugging of equipment and piping are virtually eliminated; and the system is easier to operate, control, and maintain with fluctuating inlet conditions.

Soda ash (sodium carbonate) is used to provide the initial charge of sodium and to make up any sodium losses which may occur. At start-up sodium carbonate reacts with sulfur dioxide to yield sodium sulfite, which becomes the primary reactant in the operating system. Sodium sulfite, in turn, reacts with SO_2 to produce sodium bisulfite. A small portion of the sodium sulfite also reacts with oxygen from the flue gas to form sodium sulfate.

A bleed stream proportional to the amount of sulfur dioxide formed is taken from the recirculation stream and sent to the sodium regeneration sections. There, in the lime reactor, the bleed stream is mixed with calcium hydroxide which has been formed by slaking pebble lime (calcium oxide). The sodium bisulfite in the solution reacts with the calcium hydroxide to form calcium sulfite precipitate and sodium sulfite. The regenerated sodium sulfite, plus that recovered from the bleed stream, is returned to the SO_2 absorption section. The calcium sulfite is thickened and filtered to a cake consisting of 55 percent to 70 percent solids. The filter cake has a dry, clay-like consistency, and is normally suitable for trucking or conveying to landfill disposal without further treatment. However, fly ash from the boiler electrostatic precipitator will be blended with the calcium sulfite solids to further improve the storage properties of the solids.

Unit 52 - Wastewater Treatment

The Effluent Treatment Unit is designed to upgrade contaminated water streams to a quality suitable for cooling tower makeup; and to evaporate concentrated blowdown to such a degree that it can be suitably disposed.

Stripped gas liquor from Ammonia Recovery, oily water, and cooling water blowdown are combined and treated to cooling water makeup quality. The treatment scheme consists of removing dissolved organics and mineral ions. Most of the organic pollutants are removed using biological oxidation and clarification. Filtration and adsorption, using an activated carbon media, are employed to remove trace organics and to protect the downstream ion exchange system (weak anion exchange). An activated carbon regeneration system is provided to minimize carbon makeup requirements. Sludge from the biological system is dewatered and incinerated.

A softening unit and a weak anion exchange unit are provided to remove ions and thereby reduce scaling tendencies of the water. The softening unit reduces the calcium hardness in the stream; the weak anion exchange unit reduces the chloride and sulfate ion concentrations. The anion exchange unit utilizes ammonia regeneration.

The treated effluent stream is returned as makeup to the Process Cooling Towers. A small portion of the treated stream is drawn off just downstream of the biological treatment, and supplies plant utility water requirements.

OTHER SUPPORTING FACILITIES

Included in the plant are also the following offsite, utility systems, and necessary infrastructure:

- Plant and Instrument Air

  This unit is comprised of plant and instrument air compressors, inter/after coolers, and instrument air drying facilities. It provides plant air and a continuous supply of instrument air.

- Interconnecting Pipeway

  Includes all above ground process and utility piping between the battery limits of the process, utility, and offsite units.

- Flare System

  The plant flare system consists of a collection header network, flare stack, and knockout drum. The system is provided to dispose of plant vents in a safe manner during a relief condition. The stack will be fitted with a smokeless burning tip, water seal, and a pilot ignition system.

- Communications

  Includes telephone system, fire alarm, gas alarm, radio communication, public address system, and master time system.

- Storm and Oily Water

  This system includes facilities to separately impound oily water and clean storm water which drains from the plant. Recovered clean water is used as cooling water makeup. Oil recovered is disposed of by combustion in the boiler plant.

- Power Distribution System

  All equipment necessary to distribute the internal power required in the facility, and also the electrical systems to handle the input power (for startup) are included in this system.

- Underground Piping

  This system consists of all the underground piping outside the battery limits of operating units.

- Fire Water System

  The fire water system is a network designed to supply fire water at the hydrants and incinerators in all areas of the plant. Two main fire water pumps and one spare pump supply water to the fire water distribution network.

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- Sanitary Sewage

  The waste from the sanitary sewage is processed by biological treatment, filtration, and chlorination. The treated water is used as makeup to the cooling water system.

- Buildings

  The scope of this unit covers those buildings necessary to support the operation of the plant according to U.S. practice. The major buildings included are:

  Administration and Engineering

  Workshop

  Warehouse

  Safety, First Aid, and Fire Department

  Laboratory

  Other minor office space is provided for security, change rooms, main computer control, etc.

- Roads, Fencing, and Lighting

  This includes general site preparation for a clear level site, rough grading or terracing in preparation for construction, rough grading, and finish surfacing for all roads and parking areas. Other facilities that are provided include:

  Road and railroad pipe tunnels and culverts, drainage culverts.

  All fencing outsite plant battery limits.

  Access to the plant site.

  Railroad spur to the plant site.

- Tank Farm and Dispatch

  One-week storage is provided for the Lurgi liquids (tars, oils, and phenols) which are consumed in the boiler plant. One-week storage is provided for the by-products naphtha and ammonia. Also storage is provided for the various chemicals used by the plant.

  Liquid sulfur pumped from the sumps in the Sulfur Recovery Unit is solidified into blocks. The sulfur, in solid block form, is then shipped out of the plant by rail. The naphtha and ammonia are shipped out of the plant in liquid form by truck to the nearest railway.

2.5.1 Utilities Requirements

The plant requires 1092 cubic meters per hour of raw river water (from the river Jacui). No importation of electric power is required under normal operation since the plant produces all its electrical power requirements.

2.5.2 Catalyst and Chemical Requirements

The catalyst and chemical requirements estimated for the plant are summarized in Table 2-8.

2.5.3 Operating Manpower Requirements

Table 2-9 lists the estimated operating manpower requirements for the plant. These estimates are based on a 40-hour work week.

2.5.4 Plot Plan

As discussed in Section 7, the plant will be located near the minemouth. The plot plan is presented in Drawing No. 836504-00-5-050. The arrangements shown are based on operating relationships of the various process units discussed in the previous section. The unit sizes and spatial arrangement of the plant are estimates based on Fluor's experience.

The plot size is approximately 1900 meters x 1280 meters. Areas have been provided for both process and offsite units including storage, dispatch, administration, maintenance buildings, plant infrastructure, and ash disposal pile.

TABLE 2-8

CATALYST AND CHEMICAL SUMMARY - LURGI/WESTINGHOUSE HYBRID CASE

UNIT	UNIT COST	INITIAL CHARGE	INITIAL COST $	ANNUAL CONSUMPTION*	ANNUAL COST* $
03 ASH HANDLING					
FLOCCULENT	$0.80/lb	545 lb	442	6484 lb	5 187
11 CO SHIFT					
SOUR SHIFT CATALYST	$340/ft^3	13 355 ft^3	4 540 700	13 355 ft^3	4 540 700
13 RECTISOL					
PROPYLENE	$0.20/lb	208 784 lb	41 757	294 547 lb	58 909
METHANOL	$0.90/gal	96 392 gal	86 753	1 243 463 lb	1 119 117
15 PHENOSOLVAN					
ISOPROPYLETHER SOLVENT	$0.19/lb	612 890 lb	116 452	212 636 lb	
GRAVEL	$0.023/lb	41 694 lb	960	5 212 lb	40 400
SAND	$0.018/lb	118 604 lb	2 134	14 825 lb	120
FILTRILUR	$0.375/lb	125 079 lb	46 903	15 635 lb	267
					5867
16 AMMONIA RECOVERY					
H_3PO_4 (100%)	$730.00/ton	139 ton	101 683	67 ton	
NaOH (50%)	$163.00/ton	1 083 ton	176 529	361 ton	48 693
					58 843
17 SULFUR RECOVERY					
STRETFORD CHEMICALS			730 801		1 532 852
20 METHANATION					
CATALYST	$400/ft^3	990 ft^3	435 727	350 ft^3	145 242
41 AIR AND NITROGEN					
ACTIVATED ALUMINA	$320/ton	5.3 ton	1 685	1.3 ton	423
43 BFW TREATMENT/STEAM GENERATION					
ACTIVATED CARBON	$0.75/ton	95 ton	71	31 ton	23
ANION RESIN	$177.00/ft^3	1126 ft^3	199 302	226 ft^3	40 002
CATION RESIN	$50.00/ft^3	1126 ft^3	56 300	226 ft^3	11 300
NaOH(50%)	$163.00/ton	654 ton	106 602	7415 ton	1 208 645
H_2SO_4(93%)	$6740/ton	195 ton	13 143	2210 ton	148 954
HYDRAZINE (35%)	$0.88/lb	554 lb	488	6204 lb	5 456
TRISODIUM PHOSPHATE	$0.43/lb	30 526 lb	13 125	346 233 lb	148 880
MORPHOLINE	$0.96/lb	3 822 lb	3669	43 487 lb	41 748

*At 100% capacity

TABLE 2-8 (Continued)

UNIT	UNIT COST	INITIAL CHARGE	INITIAL COST $	ANNUAL CONSUMPTION*	ANNUAL COST* $
44 RAW WATER TREATMENT					
ALUM	$121.00/ton	16 ton	1 900	176 ton	21 300
POLYMER	$1.00/lb	1126 lb	1 100	12 615 lb	12 600
CHLORINE	$145.00/ton	13 ton	1 800	141 ton	20 500
45&46 COOLING WATER TREATMENT					
CORROSION INHIBITOR	$0.80/lb	6 lb	5	52 lb	42
SCALE INHIBITOR	$0.85/lb	6 lb	5	52 lb	44
UTILITY TOWER CHLORINE	$145.00/ton	69 ton	10 005	790 ton	114 550
PROCESS TOWER BIOCIDE	$2.52/lb	2 600 lb	6 552	29 500 lb	74 340
PROCESS TOWER BIOCIDE DISPERSANT	$1.97/lb	250 lb	492	2 950 lb	5 812
48 FLUE GAS DESULFURIZATION					
LIME	$32.50/ton	2 281 ton	72 100	25 129 ton	816 700
SODA ASH	$62.00/ton	281 ton	17 400	3 181 ton	197 200
52 EFFLUENT TREATMENT					
H_3PO_4(100%)	$730.00/ton	22 ton	16 060	250 ton	182 500
SODA ASH	$62.00/ton	0.5 ton	31	5 ton	310
BENTONITE CLAY	$28.00/ton	0.5 ton	14	1 ton	28
POLYMER (SOLID)	$1.00/lb	105 lb	105	1 260 lb	1 260
CHLORINE	$145.00/ton	88 ton	12 760	998 ton	144 710
ACTIVATED CARBON	$0.75/ton	132 ton	99	44 ton	33
SOFTENER	$80.00/ft^3	306 ft^3	24 480	96 ft^3	7 680
SALT (NaCL)	$1.55/100 lb	48 500 lb	752	549 700 lb	8 520
WEAK BASE ANION RESIN	$177.00/ft^3	1 970 ft^3	348 690	390 ft^3	69 030
TOTAL			7 189 576		10 838 783

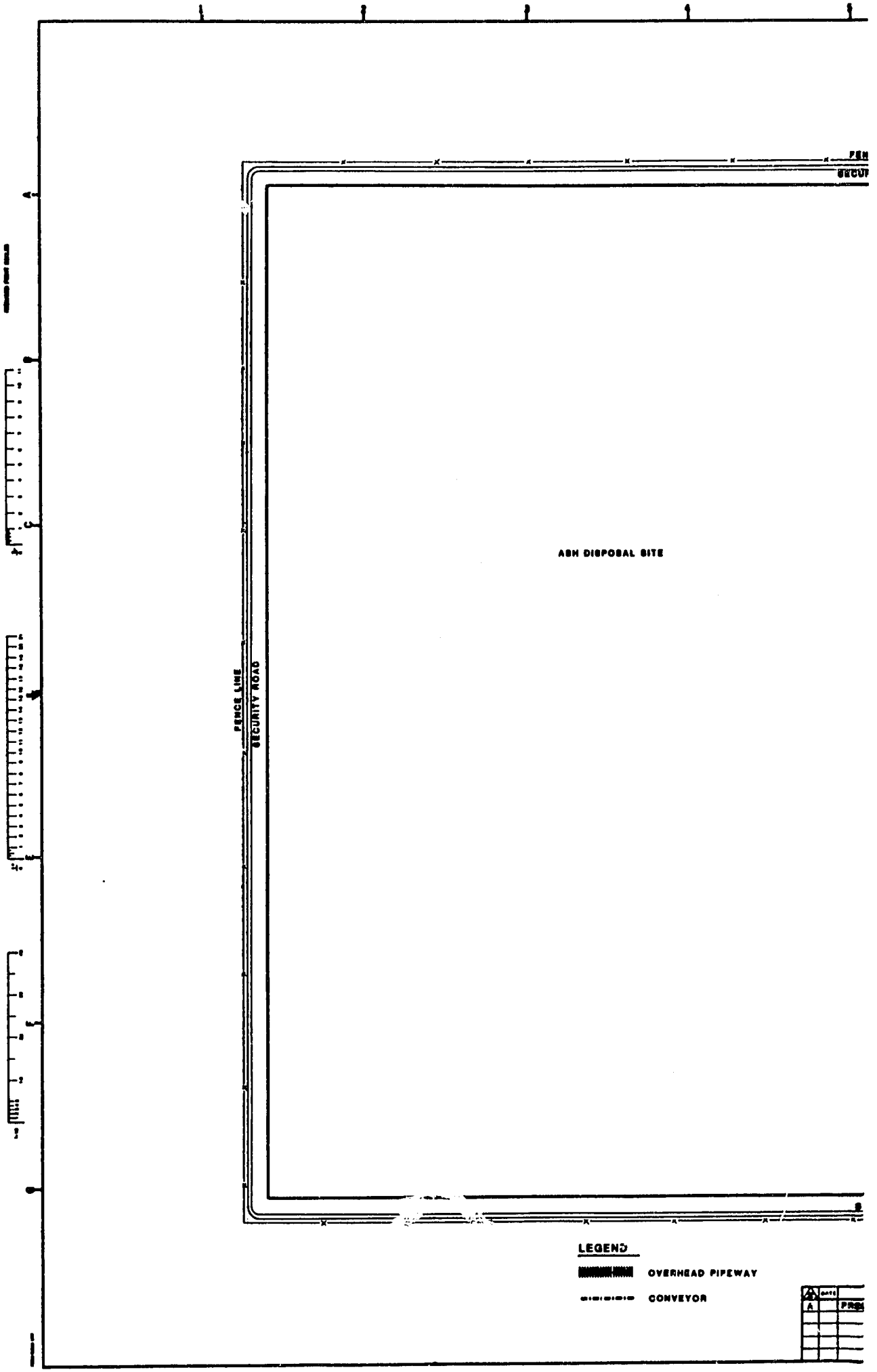
*At 100% capacity

TABLE 2-9

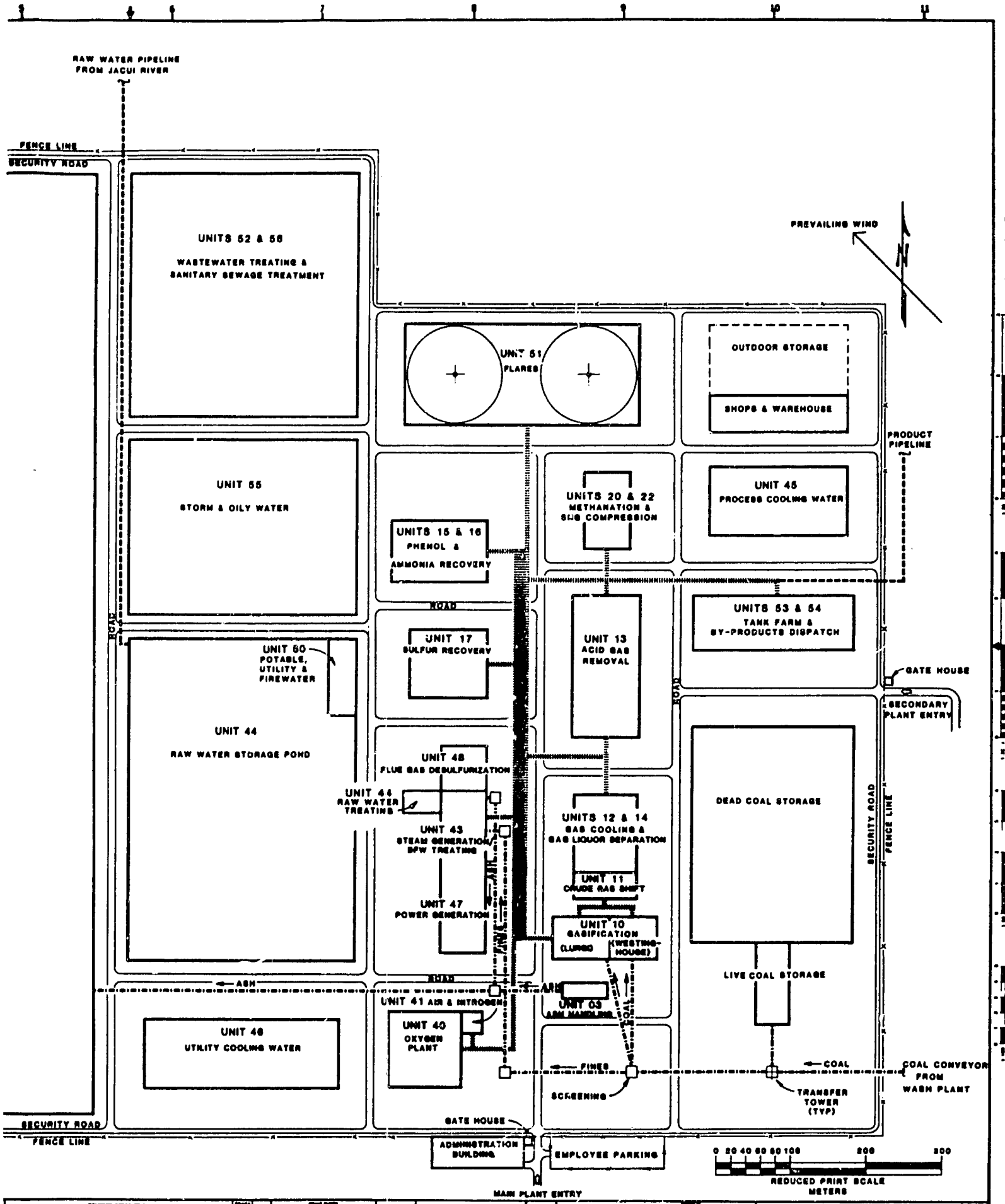
OPERATING MANPOWER REQUIREMENTS - LURGI/WESTINGHOUSE HYBRID CASE

Operating Manpower		
Control Room Operators	28	
Field Operators	164	
Foreman	16	
Lab and Instrument Technicians	28	
Unskilled Labor	132	
Subtotal		368
Plant Management and Other Services		
Management and Administration	20	
Clerical	13	
Security, Firemen	28	
Miscellaneous Services	33	
Subtotal		94
TOTAL		462

69


ASH DISPOSAL SITE
FENCE LINE
SECURITY ROAD
LEGEND
OVERHEAD PIPEWAY
CONVEYOR

70


RAW WATER PIPELINE FROM JACUI RIVER
FENCE LINE
SECURITY ROAD
UNITS 52 & 56
WASTEWATER TREATING & SANITARY SEWAGE TREATMENT
UNIT 55
STORM & OILY WATER
UNIT 50
POTABLE, UTILITY & FIREWATER
UNIT 44
RAW WATER STORAGE POND
UNIT 46
UTILITY COOLING WATER
UNIT 51
FLARES
OUTDOOR STORAGE
SHOPS & WAREHOUSE
PREVAILING WIND
N
PRODUCT PIPELINE
UNITS 20 & 22
METHANATION & SNG COMPRESSION
UNIT 45
PROCESS COOLING WATER
UNITS 15 & 16
PHENOL & AMMONIA RECOVERY
ROAD
UNIT 17
SULFUR RECOVERY
UNIT 13
ACID GAS REMOVAL
UNITS 53 & 54
TANK FARM & BY-PRODUCTS DISPATCH
GATE HOUSE
SECONDARY PLANT ENTRY
UNIT 48
FLUE GAS DESULFURIZATION
UNIT 44
RAW WATER TREATING
UNIT 43
STEAM GENERATION/ BFW TREATING
UNIT 47
POWER GENERATION
UNITS 12 & 14
GAS COOLING & GAS LIQUOR SEPARATION
UNIT 11
CRUDE GAS SHIFT
UNIT 10
GASIFICATION
(LURGI)
(WESTING-HOUSE)
DEAD COAL STORAGE
LIVE COAL STORAGE
SECURITY ROAD
FENCE LINE
ASH
UNIT 41 AIR & NITROGEN
UNIT 40
OXYGEN PLANT
UNIT 03
ASH HANDLING
FINES
SCREENING
COAL
TRANSFER TOWER (TYP)
COAL CONVEYOR FROM WASH PLANT
GATE HOUSE
ADMINISTRATION BUILDING
EMPLOYEE PARKING
MAIN PLANT ENTRY
0 20 40 60 80 100 200 300
REDUCED PRINT SCALE METERS
PRELIMINARY
FLUOR
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
OVERALL PLOT PLAN
BRAZIL FEASIBILITY STUDY
SNG PRODUCTION AND PIPELINE SYSTEM
1:2000
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3.0 SCHEDULE AND IMPLEMENTATION PLAN

3.1 SCHEDULE

The master schedule (Figure 3-1) displays the relationship between engineering, procurement, and construction for a coal gasification plant of the magnitude developed in this study. It represents activities and durations based on Fluor's experience in similar projects.

The schedule provides for a management review of the project during which preliminary design and a detailed estimate form the basis of the review and decision to proceed. Activities prior to this review are referenced on the schedule during the Step 1 period. The first activity is a large scale coal test to provide basic design data. At the conclusion of this test, the project is released for Step 1 design and procurement activities. During this period, the progress in engineering is directed to supporting the development of the detailed estimate. Inquiries are issued for equipment and the quotations received are incorporated in the estimate. Actual commitment of the orders is deferred until after the management review. Engineering continues during the review period, but at a reduced level.

The procurement section of the schedule displays those items of equipment that constrain construction progress because of their delivery requirements and the impact on associated construction activities. The span of time for sequential delivery is indicated and is representative for this equipment.

Construction commences after final project release with site preparation and the construction of temporary facilities and the construction camp to house the labor force. Effective construction is when manpower begins its buildup at a rate which can be sustained by engineering. This occurs when engineering is about 50 percent complete.

Mechanical completion is shown and defines that point when the plant has been turned over to the owner for precommissioning activities. Mechanical completion will have occurred incrementally as separate units are completed and turned over.

Start-up continues as units are completed and precommissioning and commissioning activities are accomplished by the owner. The end of the start-up activity indicates when the complete plant is operational and production reaches 100 percent.

The schedule reflects the following:

- All environmental permits and government regulations have been met.
- The inquiry and received quotation designations (I and Q) reflect the first inquiries and the first vendor quotations received.

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- Vendor quotes will be received on equipment items and a percentage of the bulk material, and these quotes will be used as the pricing base for the detailed estimate.

- Engineering/design work will continue during the management approval period, but at a reduced rate. Long lead time items will be identified and commitment details prepared and ready for prompt action following management approval.

- No commitments to vendors will be made until after the management approval period and some vendor quotes may have to be renegotiated.

3.2 PROJECT IMPLEMENTATION

3.2.1 Managing Contractor

Managing the interfaces between the different gasification licensors, engineering and construction contractors to provide a coordinated project complicates the overall management and execution of a project. Therefore, the efficient implementation of a project from the preliminary stage through detailed engineering, procurement of materials, and construction of facilities will be achieved most efficiently through the services of a Managing Contractor.

The Managing Contractor will incorporate the following basic managing contractor responsibilities:

a. Assist Brazilian authorities with project definition and scope, define interfaces and lines of communication with the Brazilian government authorities, the U.S. Agency for International Development, and other participants.

b. Provide the necessary technical support to optimize the process designs and project economics.

c. Assist the Client with finalization of agreements with gasification and subunit process licensors.

d. Prepare data for allocating parcels of work requiring contractor services for front end engineering and possibly construction.

e. Assist in the selection of, and the contracting with, Brazilian contractors and subcontractors.

f. Provide detailed project plans, milestone diagrams, project management phase/step control diagrams, schedules, and other documentation necessary for planning and monitoring the project.

g. Provide the systems and procedures necessary for project coordination and control, interface definition and coordination, project status, progress, materials, labor, and cost reporting.

h. Provide the necessary technical, administrative, and construction personnel to staff all functions necessary to plan, direct, coordinate, monitor, and control the engineering, procurement, and construction of the project.

i. Provide technical direction to all subcontractors in planning, directing, and coordinating their tasks and activities, monitoring their output, performance and progress, and implementing corrective action where necessary.

j. Procure material for the project; provide services for purchasing, expediting, inspection, routing, and receiving commodities.

k. Establish and operate a staging area and central warehouse convenient to the jobsite as a destination point for all normal shipments, and establish and implement a logistics plan for the control of traffic to and from the jobsite.

l. Procure all spare parts required for the operation of the project and establish and implement a spare parts inventory program to minimize the number and types of spare parts and the warehouse and inventory control facilities required for their storage.

3.2.2 Phased Engineering

The Management Plan for the project will be based on a "Phased Approach" to completing the project. The various phases or steps in completing the project encompass a sequence of activities organized to:

a. Minimize costs and provide an optimum project or schedule.

b. Provide major milestones to serve as decision points for assessing the future status of the project.

c. Accomplish the objectives of the project through realistic and thorough planning to minimize changes and delays after the project is released for construction.

The major gasification plant steps are:

- Step I - Project Scoping and Preliminary Engineering
- Step II - Full Scale Design Procurement and Construction

3.2.3 Step I - Project Scoping and Preliminary Engineering

The execution of this phase of the project is viewed as a team effort among Brazilian authorities, the Managing Contractor, and the process licensors.

An effective relationship will be established: for the development of the design basis for the project, for the preparation of procedures, and for the definition of responsibilities by all parties, covering the following functions:

- Interface Procedures
- Work Plan Definition
- Planning and Control (Estimating/Cost Control/Scheduling)
- Establish Technical Baseline, Resolve Process Options, Identify Long Lead Time Equipment Items

3.2.4 Step II - Full Scale Design Procurement and Construction

3.2.4.1 Procurement. When the project is fully released, Step II commences with completion of design engineering, commitment of purchase orders, and construction. Purchase orders and instructions to vendors to begin their procurement and fabrication activities will be issued per the project procurement schedule. Procurement activity will actually begin with the request for quotations in Step I. The Managing Contractor will be directly responsible for most procurement activity and will closely coordinate the procurement activity of subcontractors/contractors involved in the project.

Procurement will include:

- Preparation and issue of Requests for Quotations
- Bid evaluation and purchase order issue
- Expediting
- Inspection
- Traffic of delivered materials
- Subcontract Administration
- Vendor Information Control

3.2.4.2 Construction. A construction strategy will be developed during project scoping in Step I, and will be updated as project participants are selected and the work plan is better defined in Step II.

The Managing Contractor will have overall management and coordination responsibilities for the project. The Managing Contractor' organization should be fluid and have ample resources in order to meet various planning, management, design, and construction objectives.

The detailed Construction Management plan would include procedures, organization charts, schedules, and examples of key documents for such as:

- Quality assurance/control
- Vendor representative
- Damaged equipment and material replacement/repair
- Construction equipment management
- Nonconformance and corrective action
- Field procurement
- Material management
- Installation specifications
- Mechanical completion definition
- Plant turnover/acceptance procedure
- Precommissioning testing and documentation by Client

3.2.5 Brazilian Contractors

As reported by Jaakko Poyry, Brazilian contractors have the capability of undertaking projects exceeding 100 million dollars. Most of the contractors are Brazilian companies, but some are affiliates of multinational companies. Construction Management is usually performed either by the Client organization or by the Managing Contractor.

Contracting practices are similar to those in the United States; however, in Brazil, contractual prices (unit or lump sums) are always escalated in accordance with official government indices.

Typically, most of the construction work in a range of 100 million U.S. dollars is done by one general contractor or two separate general contractors: one civil, the other mechanical. The general civil contractor will generally execute the following:

- All concrete work for foundations and structures as well as architectural work
- Underground pipe systems, internal paving
- Auxiliary building (offices, canteen, etc.) including electricity and installation of minor equipment (kitchen, air conditioning)

The general mechanical contractor will execute the following:

- Installation of all minor equipment
- Installation of major equipment under supervision of manufacturer's representative
- Erection of structures
- Performance of all piping, electrical, and instrumentation work

Main substations are usually supplied by a manufacturer under a turnkey contract.

3.2.6 Permits

Typically, permits must be obtained from the following authorities for installations:

- Environmental Control (from appropriate state authority)
- Water Supply (from state authority)
- Fire Protection (from local state or county Fire Brigade)
- Design (architectural from state or county - assessment of property taxes)

In each case, a permit is required to start construction and another to start operation.

In addition, several other permits are needed, such as State authorities to allow water supply from rivers, Federal for generating electrical power, CNP for storage of fuel oil, Air Force in case of specially high structures, as well as certain permits from Health and Labor Ministries.

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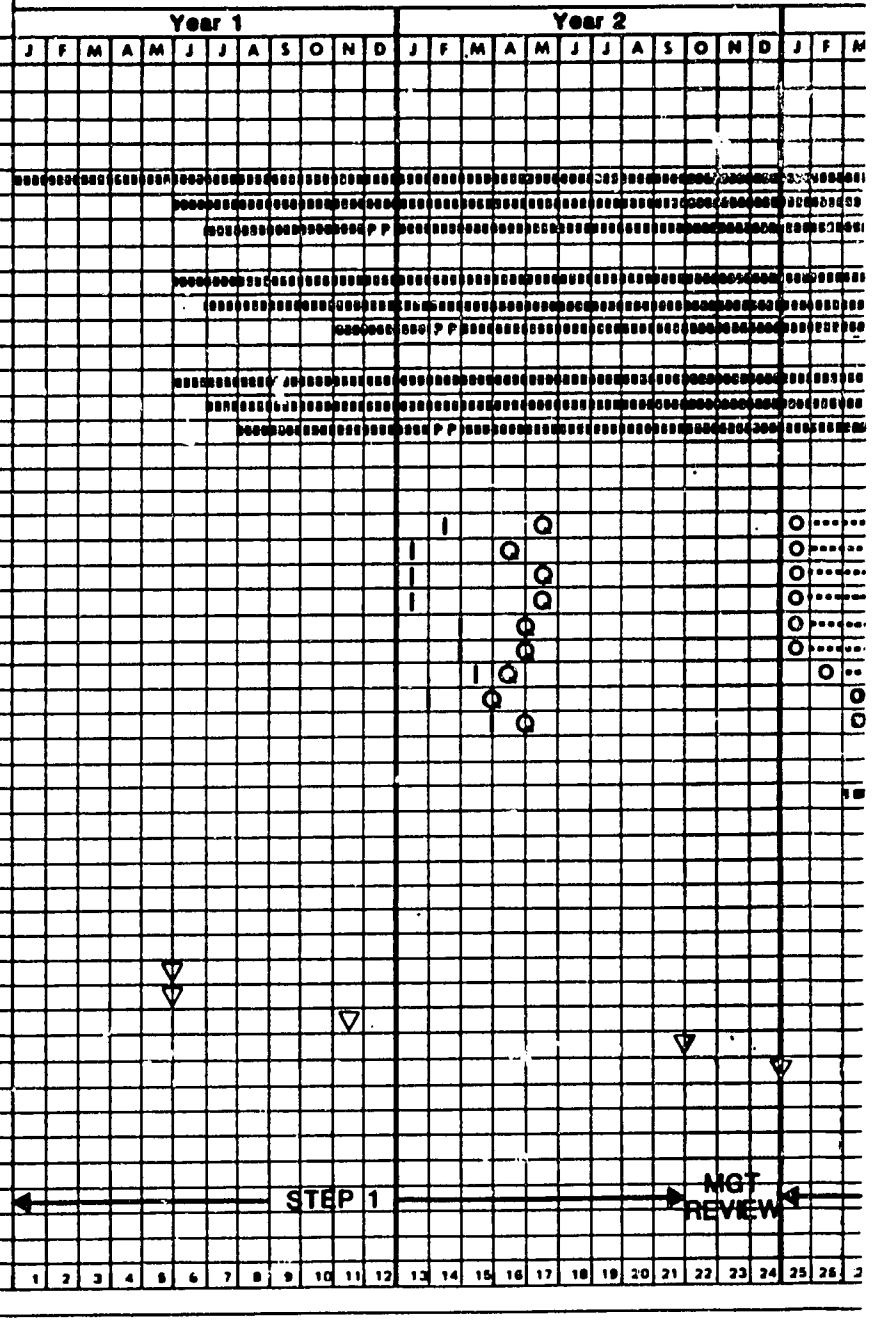
LEGEND

PLANNED CONSTRUCTION ACTIVITY			
PLANNED HOME OFFICE ACTIVITY			
TIME RANGE			
INQUIRY	I	PURCHASE ORDER	O
RECEIVE QUOTATION	Q	JOBSITE DELIVERY	△
MODEL REVIEW	MR	MILESTONE	▽
PLOT PLAN	PP		

	DESCRIPTION
1	SNG PLANT
2	
3	ENGINEERING
4	GAS PRODUCTION & BY-PRODUCTS
5	PROCESS FLOW DIAGRAMS
6	MECHANICAL FLOW DIAGRAMS
7	DESIGN
8	SNG PRODUCTION
9	PROCESS FLOW DIAGRAMS
10	MECHANICAL FLOW DIAGRAMS
11	DESIGN
12	OFFSITES/UTILITIES
13	PROCESS FLOW DIAGRAMS
14	MECHANICAL FLOW DIAGRAMS
15	DESIGN
16	
17	PROCUREMENT
18	LONG LEAD EQUIPMENT
19	GASIFIER SYSTEMS
20	BOILER
21	OXYGEN PLANT
22	VESSELS, COLUMNS & REACTORS
23	COMPRESSORS
24	FIRED HEATERS/BOILERS
25	ELECTRICAL
26	INSTRUMENTS
27	INSULATION & PAINTING
28	
29	CONSTRUCTION
30	SITE PREPARATION & MOBILIZATION
31	CIVIL
32	MECHANICAL
33	
34	PLANT START-UP
35	
36	MAJOR MILESTONES
37	PROJECT RELEASE
38	LARGE SCALE COAL TEST
39	OVERALL PROJECT PLOT PLAN
40	PLANT ESTIMATE
41	CLIENT MANAGEMENT APPROVAL
42	START EFFECTIVE CONSTRUCTION
43	MECHANICAL COMPLETION
44	
45	
46	
47	
48	
49	



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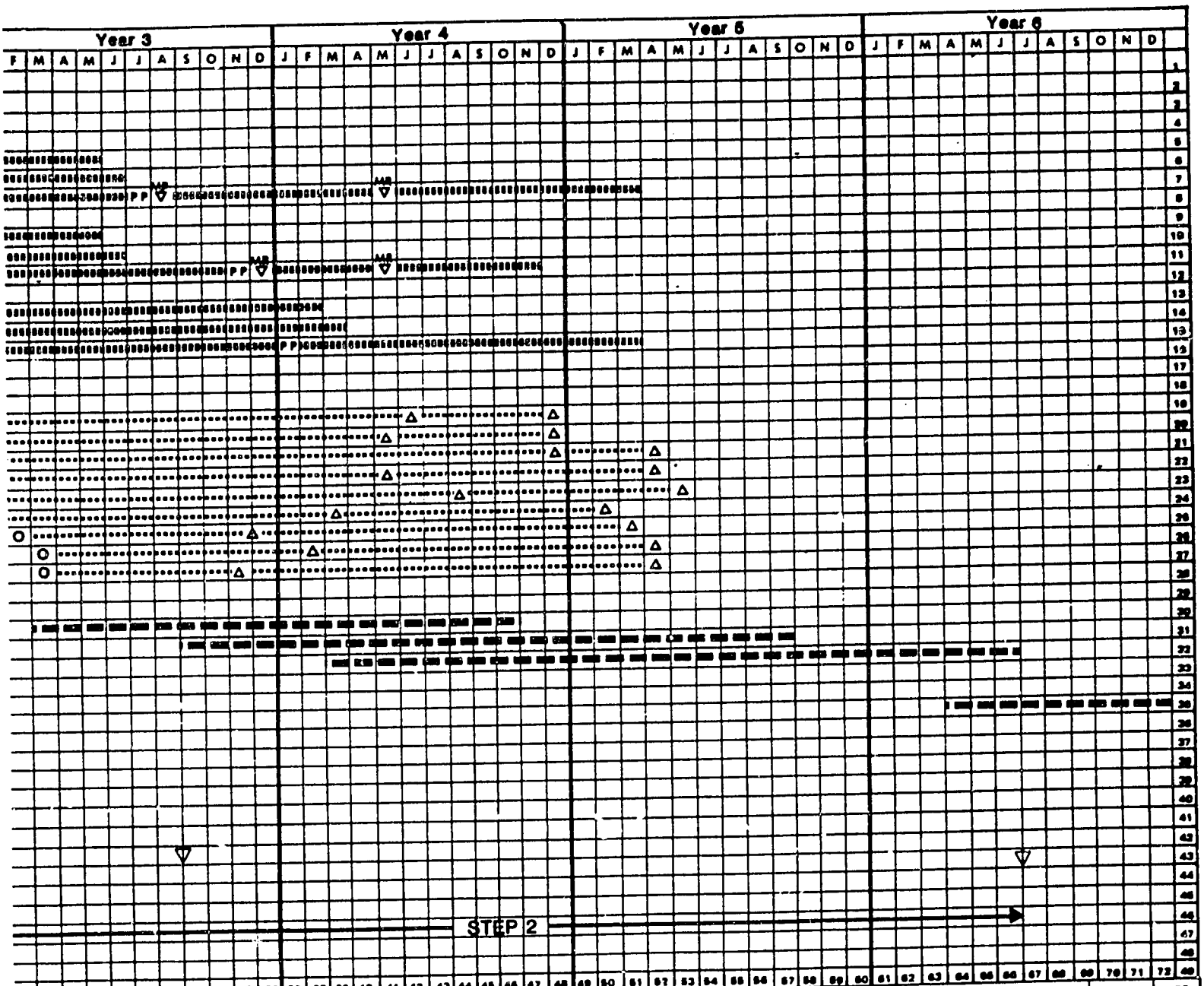
gency for International Development
Master Schedule
Gasification for SNG Production
Brazil Feasibility Study

FLUOR ENGINEERS AND CONSTRUCTORS INC.
CONTRACT 836504
Figure 3.1



REV.	DATE	REVISION DESCRIPTION	PREP.BY	APP.

FORM E-482 REV 12/74

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4.0 COST ESTIMATE

Costs developed for the gasification plant in this report are organized into the following categories:

- Capital costs of the plant which are typically within the scope of an engineering, procurement, and construction (EPC) contract.
- Operating and maintenance costs, which represent the recurring costs of operating the plant.
- Preoperational costs, which are typically the responsibility of the owner and are incurred prior to and during precommissioning and start-up.

4.1 CAPITAL COST

The Capital Cost Estimate is principally capacity-factored. This procedure includes the following sequence:

Process Engineering refers to a similar unit within Fluor's data base and, with Cost Engineering, establishes the comparability of the referenced unit and its corresponding unit in this study. After adjustments to make the units comparable, the direct field manhours and material are developed from the ratio of the unit capacity in this study to the referenced unit capacity raised by an appropriate exponent applied to the direct field manhours and material of the referenced unit. These elements are then adjusted to the specific site and the direct field cost is calculated.

The Capital Cost Estimate for the project which is presented in Table 4-1 is expressed in instantaneous January 1982, U.S. dollars and includes the following:

- Direct Field Cost

  Represents the cost of the equipment and material for the permanent facilities and the labor employed in their installation. Direct field cost includes all material and labor costs within the plant battery limits.

- Indirect Field Cost

  Field costs in support of the installation, such as temporary facilities, construction services and maintenance, field staff and expenses, labor social burdens and benefits, and construction equipment and construction camp.

- Office Cost

  Engineering office costs for the engineering, design, procurement, and project management of the project including labor, expenses for computer, reproduction, travel, communications, burdens, benefits and overheads, and licensor costs for basic process engineering.

- Contingency

  Every cost estimate is subject to some uncertainty. To minimize risk in making business commitments, contingency is added to most cost estimates. To define the estimate's accuracy, assess the risk, and show the probability of an overrun (underrun) at various levels of contingency, Fluor's computerized risk analysis program is used. This program uses the Monte Carlo simulation technique in which equations involving many probability distributions are evaluated. Risk analysis provides a range of estimated costs and a probability of overrun (underrun) for all possible outcomes within this range. The cumulative probability distribution curve is a result of these analyses.

  For the purposes of this estimate, a contingency corresponding to 50 percent probability of underrun is used (Figure 4-1). If a different probability of underrun is desired, then corresponding total capital cost should be extracted from the curve.

  In general terms, the following items are considered in deriving the minimum and maximum values around the base estimate variables:

  a. Process experience

  b. Accuracy of pricing

  c. Accuracy of quantities

  d. Accuracy of labor rate

  e. Accuracy of productivity factor

  f. Engineering/design development

  Items which are <u>not</u> considered in deriving the minimum and maximum values included:

  a. Government regulations

  b. Major design changes

  c. Labor strikes

  d. Unusual field conditions

The total cost of the plant includes a cost allowance for a 15-mile conveyor. This will be used to transport coal from the mine(s) to the plant. An allowance is also made for a 138 kV power line. The power source is Charquedas, located 40 km from the plant. It is assumed that the plant is located five km from the nearest highway; therefore the cost for a five km road is also provided.

Total Capital Cost does not include the owner's costs. This cost is included in the preoperational costs of the plant (Section 4.3).

Conversion of this estimate to the Brazilian location is based on data furnished by Jaakko Poyry Engenharia. Their study provided relative values for each element of the estimate as it relates to a Brazilian location:

- Comparative labor efficiencies and their impact on labor manhours.
- Comparative labor wage rates and their impact on labor costs.
- Comparative construction support activities including temporary facilities, support services, social benefits, construction staff, construction equipment costs, and their impact on total cost.
- Comparative cost of machinery and equipment and other materials, since the estimate basis is for procurement of material available within Brazil to be provided from Brazil. Except for minor amounts of equipment and instrumentation, based on U.S. supply, procurement is anticipated to be from Brazilian supply.
- Since the estimate basis is to procure outside only materials not available within Brazil, no provision has been made for import duties.
- Because of the uncertainties concerning the application of sales and use taxes, no provision for these taxes has been made.

4.2 OPERATING AND MAINTENANCE COSTS

The plant operating and maintenance costs have been estimated and are presented in Table 4-2. Catalysts and chemicals costs are based on U.S. prices, and are detailed in Table 2-6.

The operating labor costs are based on an average local wage rate of $1 115 per month, including social benefits for all plant personnel.

Maintenance costs were assumed to be two percent of total plant installed costs, 90 percent in materials, and 10 percent in labor. Overhead costs for support and administrative expenses were estimated to be five percent of operating labor and maintenance.

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AID BRAZIL - SNG PLANT

COST RISK ANALYSIS

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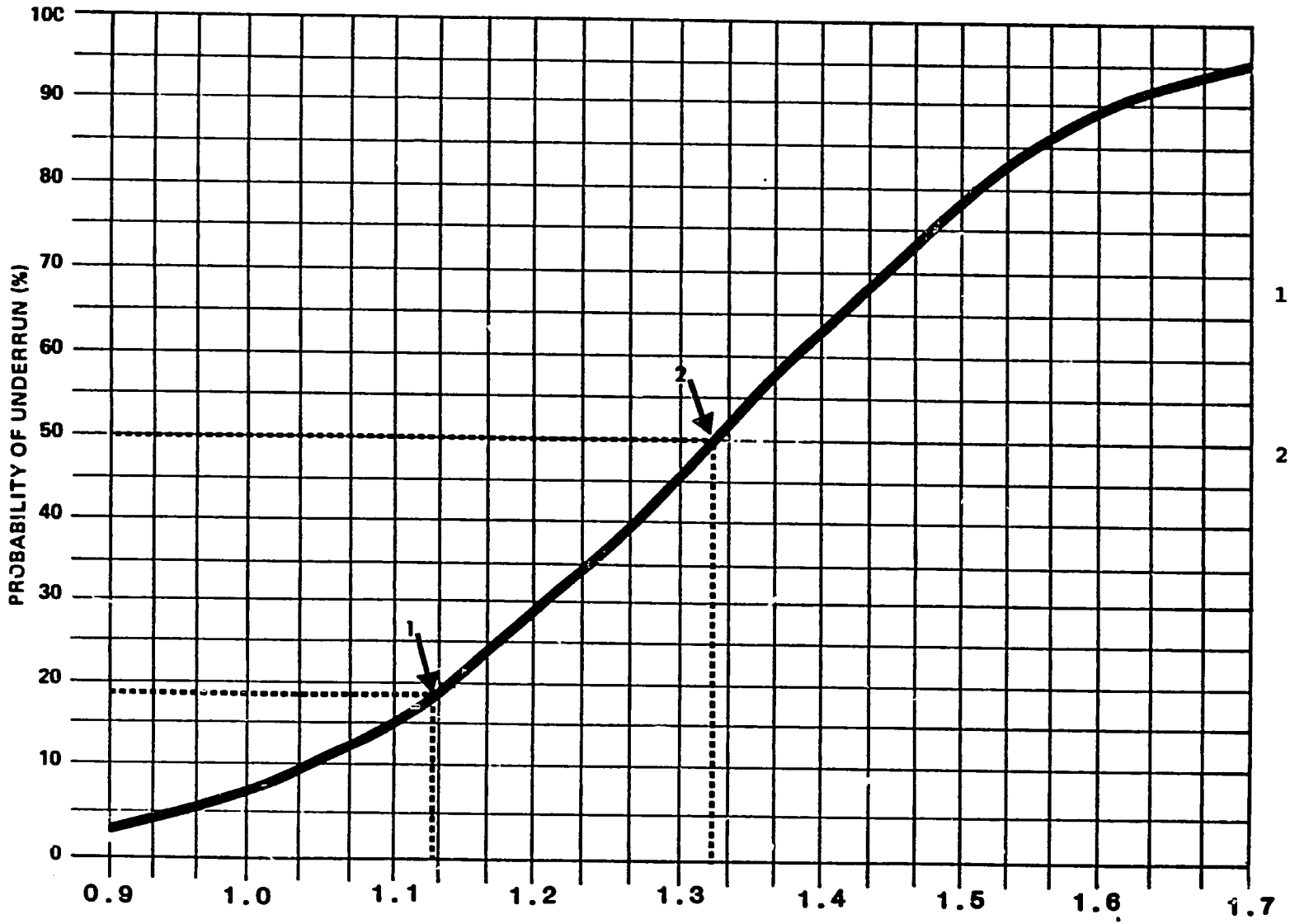
FLUOR ENGINEERS AND CONSTRUCTORS, INC.

CUMULATIVE PROBABILITY DISTRIBUTION



1. Base estimate of $1,129.6 million (without contingency) at 19.1% probability of underrun.

2. Total Capital Cost of $1,326 million at 50% probability of underrun

TOTAL CAPITAL COST ($1000 MILLION)

Figure 4-1

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TABLE 4-1

CAPITAL COST ESTIMATE SUMMARY

COST COMPONENT	INSTANTANEOUS JANUARY 1982 U.S. DOLLARS x 1000
Direct Field Cost	760 100
Indirect Field Cost	236 400
Office Cost	133 100
Total Field and Office Cost	1 129 600
Contingency	196 400
Total Capital Cost	1 326 000

4.3 PREOPERATIONAL COSTS

Preoperational costs represent costs not customarily handled by the contractor. Items included are:

- Initial catalysts and chemicals
- Warehouse spare parts
- Mobile equipment
- Building furniture, shop equipment, and laboratory equipment
- Royalties and license fees
- Owner's costs

Estimated preoperational costs are presented in Table 4-3. The most significant number is for Owner Costs and is a function of the level of supervision the owner selects. The costs reflect the size of the project, the relatively new technology, permitting, testing, environmental, etc.

TABLE 4-2

OPERATING AND MAINTENANCE COST SUMMARY

Cost Component	Annual Amount, ($ x 1000)	Base for Estimate
Catalysts and Chemicals	9 755*	Table 2-6
Operating Labor	6 182	462 men @ $1 115/mo.
Maintenance Labor	2 179	0.2% of total field and office costs
Maintenance Materials	19 613	1.3% of total field and office costs
Overhead	1 399	5% of operating labor and maintenance, for support and administrative expenses
TOTAL	39 128	

* For 90 Percent On-stream Factor

TABLE 4-3

PREOPERATION COST ALLOWANCE

Cost Component	Cost (x$1000)
Initial Catalyst and Chemicals (See Table 2-6)	7 190
Warehouse Spare Parts (5% of Material) (Includes items such as spare pumps, motors, spare rotors, etc., which are normally purchased with the permanent plant machinery and equipment).	36 550
Mobile Equipment (3.0% of Indirect Field Costs) (Includes items such as cranes, maintenance vehicles, fire trucks, ambulances, cars, etc.)	5 892
Building Furniture, Shop Equipment, and Laboratory Equipment (0.5% DFC)	3 800
Royalties and License Fees (5% of Material) (One time cost, which does not allow for annual royalty and licensor fees.)	36 550
Owner Costs (5% of total Capital Costs) (Includes owner's supervision, permitting and staffing, recruiting and training of operating and supervisory personnel)	56 480
TOTAL	146 462

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5.0 ECONOMIC ANALYSIS - GASIFICATION PLANT

The following analysis was performed in order to determine the product price required for the Brazil Southern Cone Energy Network coal gasification project to achieve a target real return on investment. The analysis incorporates conventional time discounting methods to solve for a January 1982 SNG price. This is a plant gates price, and does not include distribution costs.

The analysis includes pro forma cash flow projections and a sensitivity analysis which establishes the effect of key variables on the required product price. A more detailed description of the facilities required by the project, their estimated capital costs, and operating expenses is presented in Sections 2 and 4.

5.1 METHODOLOGY

The economic analysis was conducted on the basis that the project should generate a real post-tax return on investment (ROI) of 8 percent. The analysis method incorporates coal and other feedstock costs, capital costs, operating expenses, by-product revenues and product quantities, and solves for the product price which would result in the predetermined ROI. By-product revenues reflect January 1982 prices and were input into the economic model.

An economic computer model was developed to generate the pro forma cash flows associated with the project. New cash flows were derived using nominal (inflated) dollars in order that the correct relationship between income, depreciation, and taxes would be reflected. These net cash flows were then deflated at the rate of inflation prior to performing the ROI calculation. The resulting ROI is thus expressed in real (as opposed to nominal) terms.

All computations were done on a semiannual basis. All time-related cash flow assumed a project release date of 1 January 1983. For convenience, in referring to the timing of expenses and revenues in the computer-generated pro forma financial reports, the convention of minus years is used prior to the construction completion data (for example, year -1 indicates the 12-month period from 1 July 1987 through 30 June 1988). Positive years indicate operating periods (for example, year 1 indicates the 12-month period from 1 July 1988 through 30 June 1989). Investments were assumed to occur at the start of a time period, while all other cash flows were assumed to be end of period.

Descriptions, definitions, and other information related to this analysis are given in Section 5.5.

5.2 SUMMARY OF BASE CASE RESULTS

The results of the base case analysis are presented in Table 5-1. The base case required a January 1982 SNG gas price of U.S. $31.22 per gigacalorie (U.S. $7.87 per million BTU) to satisfy the post-tax return on investment (ROI) goal of 8 percent. This price is assumed to escalate at 13.3 percent per year.

Detailed pro forma cash flow projections for the base case are presented in Appendix H. Semiannual disbursements of debt and equity funds during the construction period are presented in Figure 5-1. Figure 5-2 graphically presents the uses of revenues produced during the project's operating life.

TABLE 5-1

SUMMARY OF RESULTS

CAPITAL INVESTMENT	U.S. $ (Millions) January 1982 Basis	U.S. $ (Millions) Escalated Basis
Plant and Equipment	$1 326.0	$2 104.5
Owner's Costs	56.5	89.6
Preoperational Costs	90.0	179.5
Interest During Construction	--	445.9
Total Depreciable Assets	$1 472.5	$2 819.5
Initial Working Capital	15.3	38.5
Total Capital Investment	$1 487.8	$2 858.0

SNG PRICE	U.S. $ (January 1982 Basis)
Per Gigacalorie (Million kcal)	$ 31.22
Per Million BTU	7.87
Per 1000 normal cubic meters (Nm^3)	285.30
Per 1000 standard cubic feet (SCF)	7.64

RATES OF RETURN	Nominal	Real
ROE	23.7%	12.5%
Pretax ROI	21.1	10.1
Post-tax ROI	18.8	8.0

POST-TAX NET PRESENT VALUE	U.S. $ (January 1982 Basis)
at 5% discount rate	$475 million
at 10% discount rate	- 187 million

DEBT SERVICE COVERAGE RATIOS	
Year 1	0.66
Year 2	1.08
Year 3	1.32
Year 4	1.59
Year 5	1.93

TABLE 5-2

REVENUE & OPERATING COST SUMMARY (1982 $ Millions)

REVENUES	
SNG	339.962*
Sulfur	10.450
Ammonia	2.640
Naphtha	5.834
Total	358.886*
OPERATING EXPENSES	
Coal	155.071
Other Variable Costs	
Catalysts and Chemicals	9.755
Fixed Costs	
Operating Labor	6.182
Maintenance Labor	2.179
Maintenance Material	19.613
Overhead	1.399
Total Non-Coal	39.128
Total	194.199
OPERATING INCOME	164.687*

*Base case result for 8% real post-tax ROI.

5.3 BASIS OF ANALYSIS

The following premises were followed in the base case analysis. All figures are expressed in January 1982 terms.

- Currency - U.S. Dollars

- Exchange Rate - All Brazilian Cruzeiro estimates were converted to U.S. Dollars at the rate of CR$134.20 = $1.00.

- Plant and Equipment - Engineering, procurement, and construction costs, including contingency, of $1 326 million.

- Preoperational Costs - Royalties, license fees, initial catalyst and chemicals, spare parts, mobile equipment, building furniture, laboratory, and shop equipment. $89.982 million expended and capitalized in the last semester of construction.

- Owner's Costs - Owner's supervision, permitting, staffing, and recruiting and training of operating and supervisory personnel. $56.480 million expended according to the plant and equipment drawdown schedule.

- Drawdown Schedule - Drawdown of funds (disbursement) for plant and equipment and owner's costs as follows:

Semester (Beginning 1 January 1983)	Percent Completed Per Semester
1	0.6%
2	1.1
3	1.1
4	3.7
5	11.9
6	19.6
7	23.8
8	20.3
9	12.5
10	4.6
11	0.8
Total	100.0%

- Operating Expenses - Variable costs include coal, catalysts and chemicals.

  Fixed costs include operating labor, maintenance labor and materials, and overhead costs (insurance and other general and administrative).

  Operating expenses are detailed in Section 4, and summarized in Table 5-2.

- Coal Price - Subsidized price of $32.90/ton.

- Coal Volume - 14 283 T/D.

- By-Products -

	Volume	Price*	Revenue
Sulfur	226.2 T/D	$140/T	$10.5 million/yr
Ammonia	45.2 T/D	177/T	2.6 million/yr
Naphtha	109 800 1/D	0.161/1	5.8 million/yr

* at plant gate

- Major Product Volume - Production of SNG:

33 000	gigacalorie/D
130.9×10^3	million BTU/D
3.61×10^6	Nm^3/D
134.7×10^6	SCF/D

- Major Product Price - Determined by the model such that the target ROI is obtained.

- Land - No land costs or property taxes are assumed.

- Inflation/Real Price Increases -

Monetary Price Inflation	10% per annum
Real Price Increases on:	
Capital Costs	3% per annum
Non-Labor-Intensive Operating Costs	3% per annum
Labor-Intensive Operating Costs	5% per annum
Feedstock Costs	3% per annum
Product Prices	3% per annum

Labor-intensive operating costs include operating and maintenance labor, and the labor dependent portion of overhead. Non-labor intensive costs include coal, catalysts and chemicals, maintenance materials, and the remaining portion of overhead.

- Working Capital - 10 percent of total annual operating expenses. Funded in the last semester of construction for the first year of operation by debt and equity. Increases during operations are taken from operating income. Working capital is returned to equity holders at the end of the project.

- Project Release Date - 1 January 1983 (initiation of engineering, procurement, and construction activity).

- Project Life - 20 years of operation.

a3

- Operating Year - Annual product quantities and operating expenses based on a 330 day operating year.

- Operating Capacity - 50 percent of product volume and variable operating expenses during the first semester of operation, 100 percent thereafter.

- Post-Tax Return on Investment (ROI) - Target rate of 8.0 percent (in real terms).

- Debt/Equity - Project funded 70 percent by debt funds and 30 percent by equity funds.

- Depreciation - Depreciation for financial reporting and tax purposes is calculated at a rate of 10 percent per year on the adjusted asset base, with no salvage value, beginning in the first year of operations.

- Tax Rate - 35 percent of operating income less interest and tax depreciation, but recognizing available tax loss carry forward.

- Tax Loss Carry Forward - When applicable, negative taxable income was carried forward up to three years as a future allowance.

- Debt Financing - Two sources of debt financing were assumed: A Project Loan and an Interest During Construction (IDC) Loan. The Project Loan is assumed to represent a mix of commercial, development, and export credit loans, with overall terms as follows:

  - Grace Period - Construction period plus six months.
  - Repayment - Twenty equal semiannual payments.
  - Interest Rate - 12 percent per annum.

  The IDC Loan was assumed to be rolled into the Project Loan at the end of construction and, therefore, was repaid according to the same terms as the latter loan. The interest rate on the IDC Loan was also assumed to be 12 percent.

  Interest charges for the Project Loan were funded during construction by the IDC Loan and computed semiannually on 50 percent of current borrowing plus 100 percent of the outstanding principal. The IDC Loan accrued its own interest charges during the construction period. Interest during construction was paid by a combination of debt funds (70 percent) and equity (30 percent). During operations, interest was computed semiannually on unpaid loan balances and paid as incurred.

5.4 SENSITIVITY ANALYSIS

Changes in the following key variables were measured in terms of their impact on the required SNG selling price. The results of these changes to base case assumptions are presented in tabular form in Table 5-3, and 5-4 and graphically in Figures 5-3 through 5-9.

- Plant and Equipment, plus Preoperational and Owner's Costs (Figure 5-3) — ± 20%
- Coal Price (Figures 5-3 and 5-4) — ± 20%
  - $32.90/T (Base)
  - 41.10 (+25%) removal of user price subsidy
  - 50.00 (+52%)
- Operating Expenses (Figure 5-3) (excluding coal) — ± 20%
- Inflation/Real Price Increases (Figure 5-5 and Table 5-4)
  - Monetary Price Inflation — 8%, 12%
  - With and Without Various Real Price Increases
- Operating Life (Figure 5-6) — 15 years, 25 years
- Target Post-Tax ROI Percentage (Figure 5-7) — 4%, 6%, 10%
- Debt/Equity* (Figure 5-8) — 80%/20%, 50%/50%
- Interest on Debt* (Figure 5-9) — 10%, 15%

* These two sensitivities will affect Return on Equity (ROE), but will not affect the ROI or required SNG price.

Results of the sensitivity analysis, as presented in the accompanying Tables and Figures, are generally self-explanatory. Table 5-3 summarizes all the sensitivity results, allowing the effects of changes in all variables to be compared. Specific comments follow on the effects of inflation and real price changes.

Inflation

The required 1982 SNG price is virtually unaffected by changes in inflation rate assumptions. This is due to two considerations. First,

the post-tax return on investment goal is a real rate of return, adjusted for inflation. As the inflation rate changes, the required nominal rate of return changes, but the real rate does not change:

Real ROI	Inflation Rate	Nominal ROI
8%	8%	16.6%
8%	10%	18.8%
8%	12%	20.1%

Second, Brazilian tax depreciation is based on an inflation adjusted depreciation base (as described in Section 5.3), whereas tax depreciation in the U.S. is based on historical costs unadjusted for teh effects of inflation. Different inflation rate assumptions in a U.S. project analysis would affect the required 1982 SNG price because of the impact on taxes. This is not the case in Brazil.

The rate of increase in the required SNG price after 1982 does change, however. as the rate of inflation changes:

Inflation (% per annum)	Real Price Increase (% per annum)	Nominal Price Increase (% per annum)
8%	3%	11.2%
10%	3%	13.3%
12%	3%	15.4%

It should be noted that the inflation rates used here represent U.S. dollar inflation, not cruzeiro inflation, as all cost and price estimates have been made in U.S. dollars. The difference between dollar and cruzeiro inflation has resulted in a steady devaluation of the cruzeiro against the dollar, and it is assumed that the cruzeiro/dollar exchange rate will continue to adjust for the inflation differential.

Inflation rate sensitivities are summarized in the bottom half of Table 5-4.

Real Price Increases

A change in a cost or price after the effects of general inflation have been removed is termed a real increase or decrease. All costs and prices in this analysis have been assumed to increase at a real rate of 3 percent per annum (except labor costs at 5 percent per annum), that is, 3 percent per annum on top of the general inflation rate. Assuming a 3 percent real rate of increase and a 10 percent inflation rate results in a 13.3 percent nominal rate of increase (1.03 x 1.10 = 1.133).

Unlike inflation rate changes, different real price increase assumptions do have a significant impact on the required 1982 SNG price, as shown in the top half of Table 5-4. For example, assuming that all costs and prices would increase at the rate of inflation only, would require a 1982 SNG price 17 percent higher than the base case.

TABLE 5-3

SENSITIVITY ANALYSIS

January 1982 $/gigacalorie SNG price required to maintain eight percent post-tax ROI (except for target ROI sensitivity) and percent change from Base Case price.

	$/giga-calorie	$/MM BTU	% Change from Base
BASE	31.22	7.87	
PLANT AND EQUIPMENT			
+ 20%	34.46	8.68	+10.4%
- 20%	2[illegible].89	7.03	-10.4
COAL PRICE			
$50.00/T (+ 52%)	38.88	9.80	+24.5
41.10 (+ 25%)	34.85	8.78	+11.6
+ 20%	34.13	8.60	+ 9.3
- 20%	28.23	7.11	- 9.3
OPERATING COSTS (exclusive of coal)			
+ 20%	31.95	8.05	+ 2.3
- 20%	30.41	7.66	- 2.3
OPERATING LIFE			
15 years	34.43	8.68	+ 10.3
25 years	29.59	7.46	- 5.2
INFLATION			
8%	31.08	7.83	- 0.4
12%	31.36	7.90	+ 0.4
REAL PRICE INCREASES			
0%	36.66	9.24	+17.4
TARGET POST-TAX ROI			
4%	25.67	6.47	-17.8
6%	28.16	7.10	- 9.8
10%	35.25	8.88	+12.9

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TABLE 5-3 (Continued)

The following sensitivities impact the ROE:

	Nominal ROE	Real ROE
BASE	23.7%	12.5%
DEBT/EQUITY		
80%/20%	25.4	14.0
50%/50%	21.6	10.5
INTEREST ON DEBT		
10%	24.9	13.5
15%	22.0	10.9

5.5 DEFINITIONS

Descriptions, definitions, and information relating to the cash flows presented in this report are as follows:

- Revenues - Income generated from sale of SNG and by-products (sulfur, ammonia, and naphtha).

- Operating Expenses - Raw material, consumable supplies, insurance, labor, maintenance, and general/administrative expenses.

- Operating Income - Revenue less operating expenses, less annual increases in working capital plus recovered working capital. This item represents the pretax cash flow to be discounted against capital investment when calculating pretax return on investment.

- Depreciation - Defined above under "Basis of Analysis."

- Income Before Tax - Operating income less interest expense and depreciation.

- Income Tax - Taxes are computed as discussed under "Basis of Analysis."

- Income After Taxes - Income before taxes, less income tax, after recognition of available tax loss carry forward.

- Cash Flow from Operations - Net income after taxes, plus depreciation and recovered working capital, less annual increases in working capital.

- Net Cash Flow - Cash flow from operations less debt principal repayment. This is the cash available to the equity holders. This cash flow is discounted against equity investments to determine the time-value return on equity.

- Available Funds - Funds in excess of operating costs and debt service (interest and principal repayment) are assumed to be available to equity holders as dividends or for other uses outside the project. Should operating funds be insufficient to meet debt service requirements, it is assumed that additional equity funds will be provided to make up the differential. Working capital is returned to equity holders at the end of the project.

Analytical measurements which help management to evaluate the desirability of this project are:

- Pretax Return on Investment (Pretax ROI) - Operating income (income before taxes plus depreciation and interest = revenues less operating expense), less increases in working capital, plus recovered working capital, discounted against capital

investment. This technique allows the project to be analyzed, evaluated, and compared with other investment alternatives without regard to the method of financing used for the projects. Interest during construction and interest expenses during operations are excluded from cash flows utilized in this calculation.

- Post-Tax Return on Investment (Post-Tax ROI) - Operating income, less taxes on operating income less depreciation, less increases in working capital, plus recovered working capital, discounted against capital investment. Interest during construction and interest expenses during operations are excluded from cash flows utilized in this calculation.

- Return on Equity (ROE) - Net cash flow available to equity holders, discounted against equity investment. The financing plan has a significant effect on this figure since the equity holder receives a return after interest and principal payments are made; synonymous with post-tax ROI for 100 percent equity funded projects.

All cash flows are discounted back to 1 January 1982.

Two ratios of significant importance to financial institutions in examining projects of this type are "Interest Cover" and "Debt Service Cover." They are defined as follows:

- Interest Cover - Income before interest and taxes, divided by interest.

- Debt Service Cover - Net cash flow plus principal repayment and interest, divided by principal repayment plus interest.

Figure 5-1

SEMI-ANNUAL FUNDING REQUIREMENTS
(INCLUDING ESCALATION)

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION PLANT

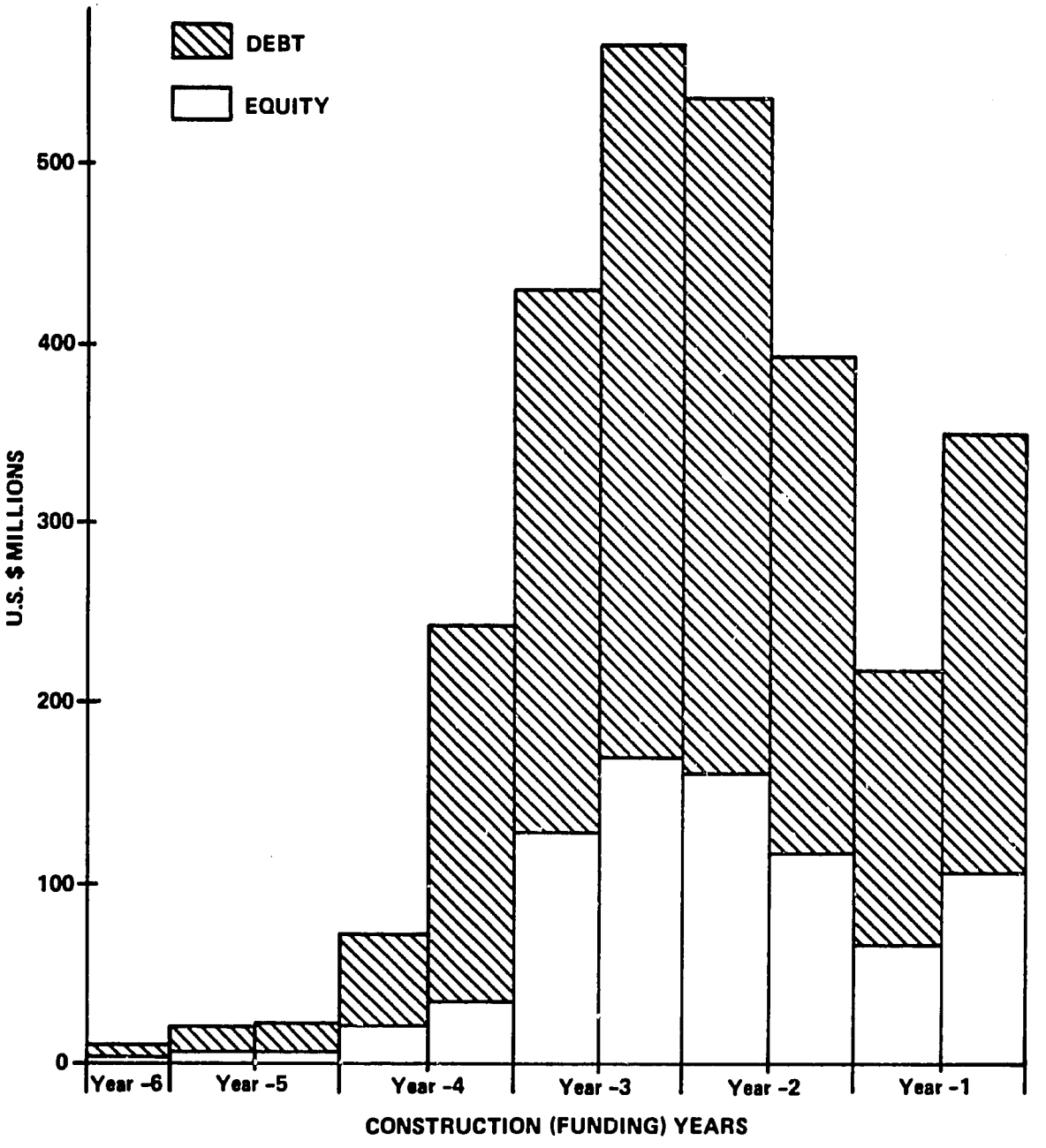

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Figure 5-2

REVENUE UTILIZATION

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION PLANT

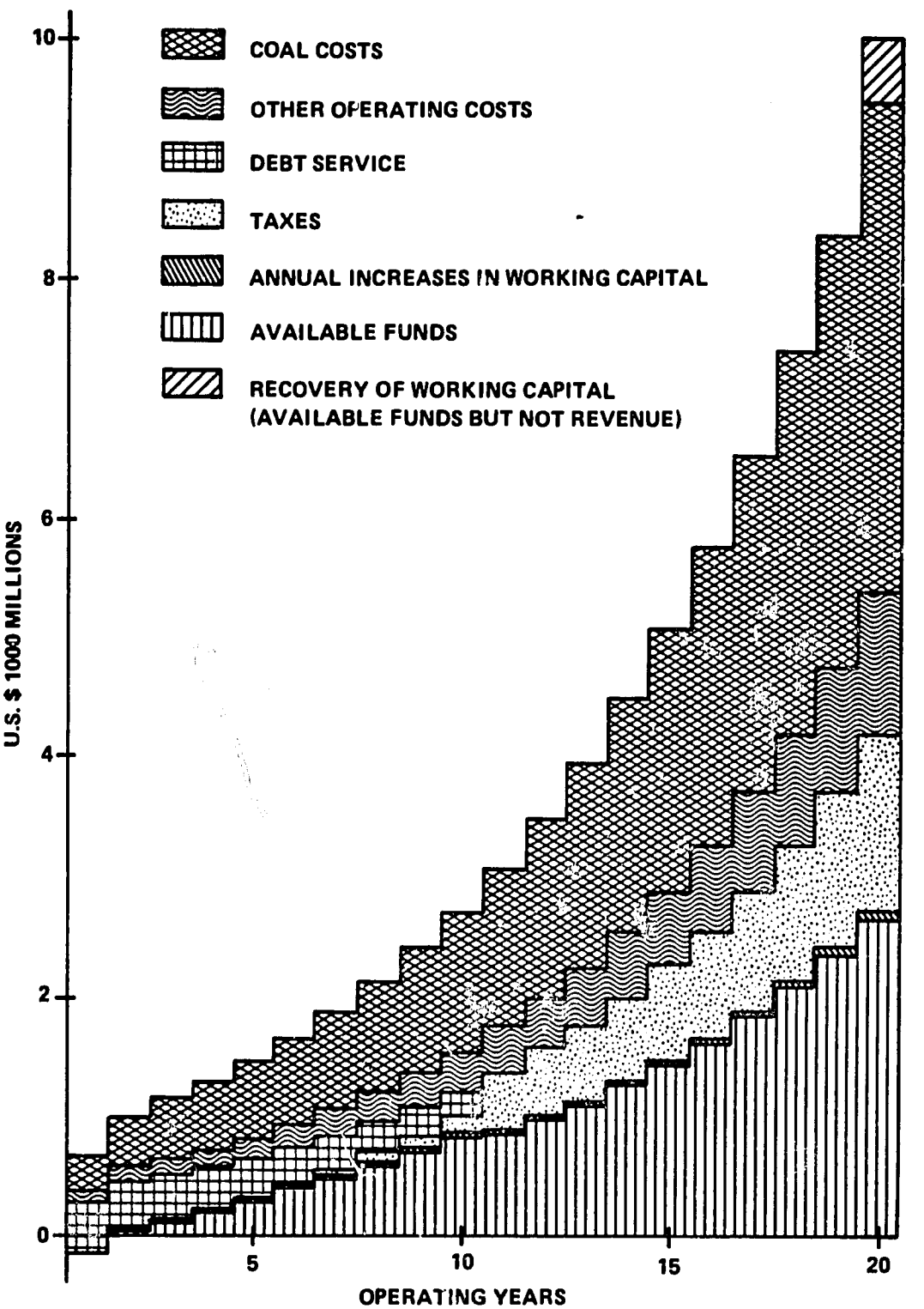

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Figure 5-3

SENSITIVITY ANALYSIS – VARIOUS

SNG PRICE REQUIRED
FOR 8% POST-TAX ROI

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION PLANT

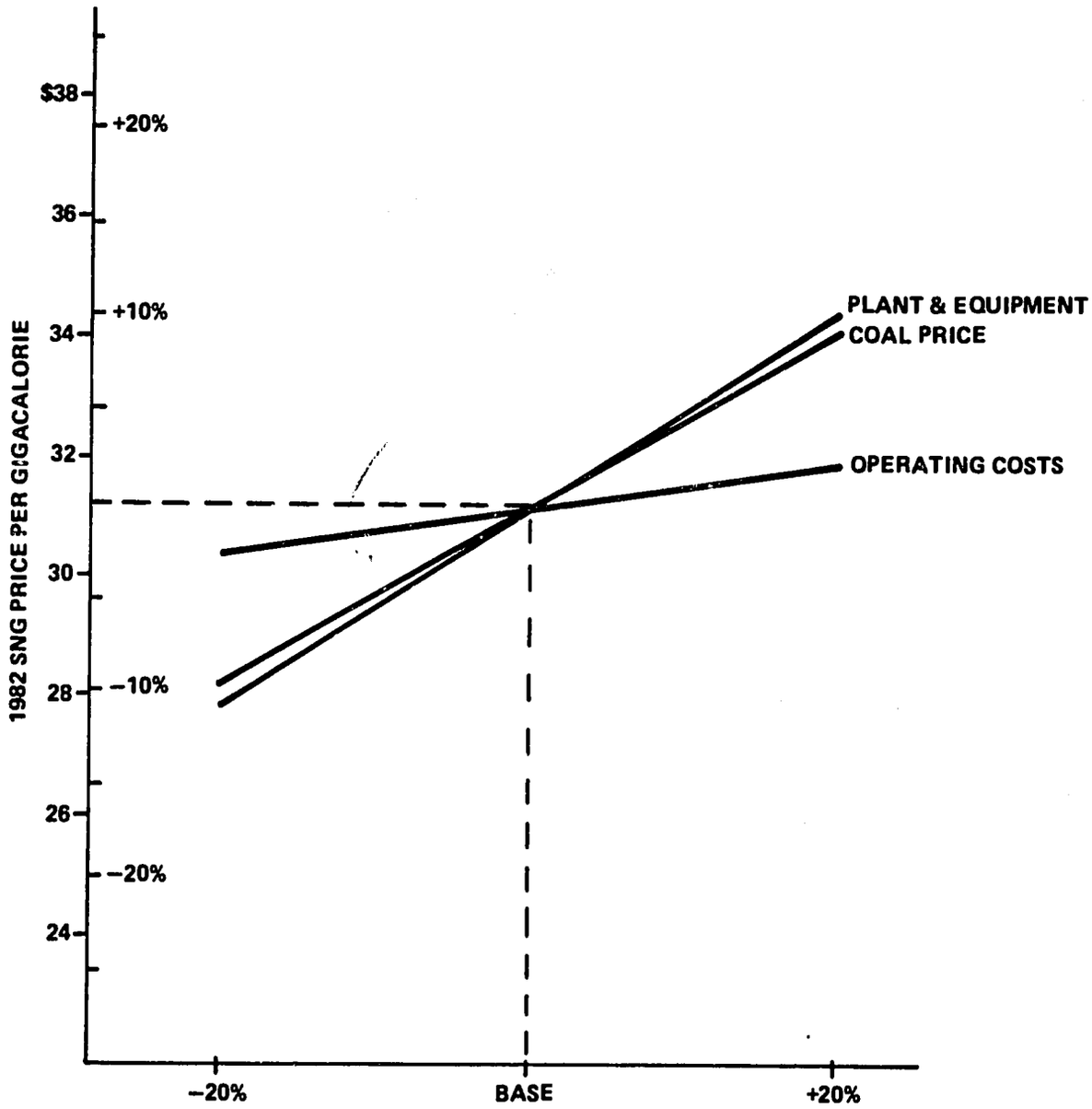

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TABLE 5-4
INFLATION/ESCALATION SENSITIVITIES

BRAZIL SOUTHERN CONE ENERGY NETWORK
GOAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
CASE: GASIFICATION PLANT

ESCALATION ASSUMPTIONS	(1)	(2)	(3)	(4)	(5) BASE	(6)	(7)
GENERAL INFLATION RATE	10%	10%	10%	10%	10%	10%	10%
REAL CAPITAL COST ESCALATION	0%	1%	2%	3%	3%	2%	2%
REAL PRODUCT PRICE ESCALATION	0%	1%	2%	3%	3%	3%	3%
REAL COAL COST ESCALATION	0%	1%	2%	3%	3%	3%	3%
REAL LABOR COST ESCALATION	0%	1%	2%	3%	5%	5%	3%
REAL NON-LABOR COST ESCALATION	0%	1%	2%	3%	3%	3%	3%
JANUARY 1982 SNG PRICE FOR 8% REAL POST-TAX ROI							
$/GCAL	$36.66	$34.65	$32.82	$30.94	$31.22	$30.66	$30.38
$/MMBTU	$9.24	$8.73	$8.27	$7.80	$7.87	$7.73	$7.66
$/1000 NM3	$335.01	$316.69	$299.92	$282.75	$285.30	$280.20	$277.66
$/1000 SCF	$8.98	$8.49	$8.04	$7.58	$7.64	$7.51	$7.44
CHANGE FROM BASE CASE PRICE	17.4%	11.0%	5.1%	-.9%	.0%	-1.8%	-2.7%

ESCALATION ASSUMPTIONS	(8)	(9)	(10) BASE	(11)	(12)
GENERAL INFLATION RATE	6%	8%	10%	12%	14%
REAL CAPITAL COST ESCALATION	3%	3%	3%	3%	3%
REAL PRODUCT PRICE ESCALATION	3%	3%	3%	3%	3%
REAL COAL COST ESCALATION	3%	3%	3%	3%	3%
REAL LABOR COST ESCALATION	5%	5%	5%	5%	5%
REAL NON-LABOR COST ESCALATION	3%	3%	3%	3%	3%
JANUARY 1982 SNG PRICE FOR 8% REAL POST-TAX ROI					
$/GCAL	$31.01	$31.08	$31.22	$31.36	$31.50
$/MMBTU	$7.82	$7.83	$7.87	$7.90	$7.94
$/1000 NM3	$283.43	$284.07	$285.30	$286.58	$287.91
$/1000 SCF	$7.59	$7.61	$7.65	$7.68	$7.71
CHANGE FROM BASE CASE PRICE	-.7%	-.4%	.0%	.4%	.9%

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Figure 5–4

SENSITIVITY ANALYSIS – COAL PRICE

SNG PRICE REQUIRED
FOR 8% POST-TAX ROI

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION PLANT

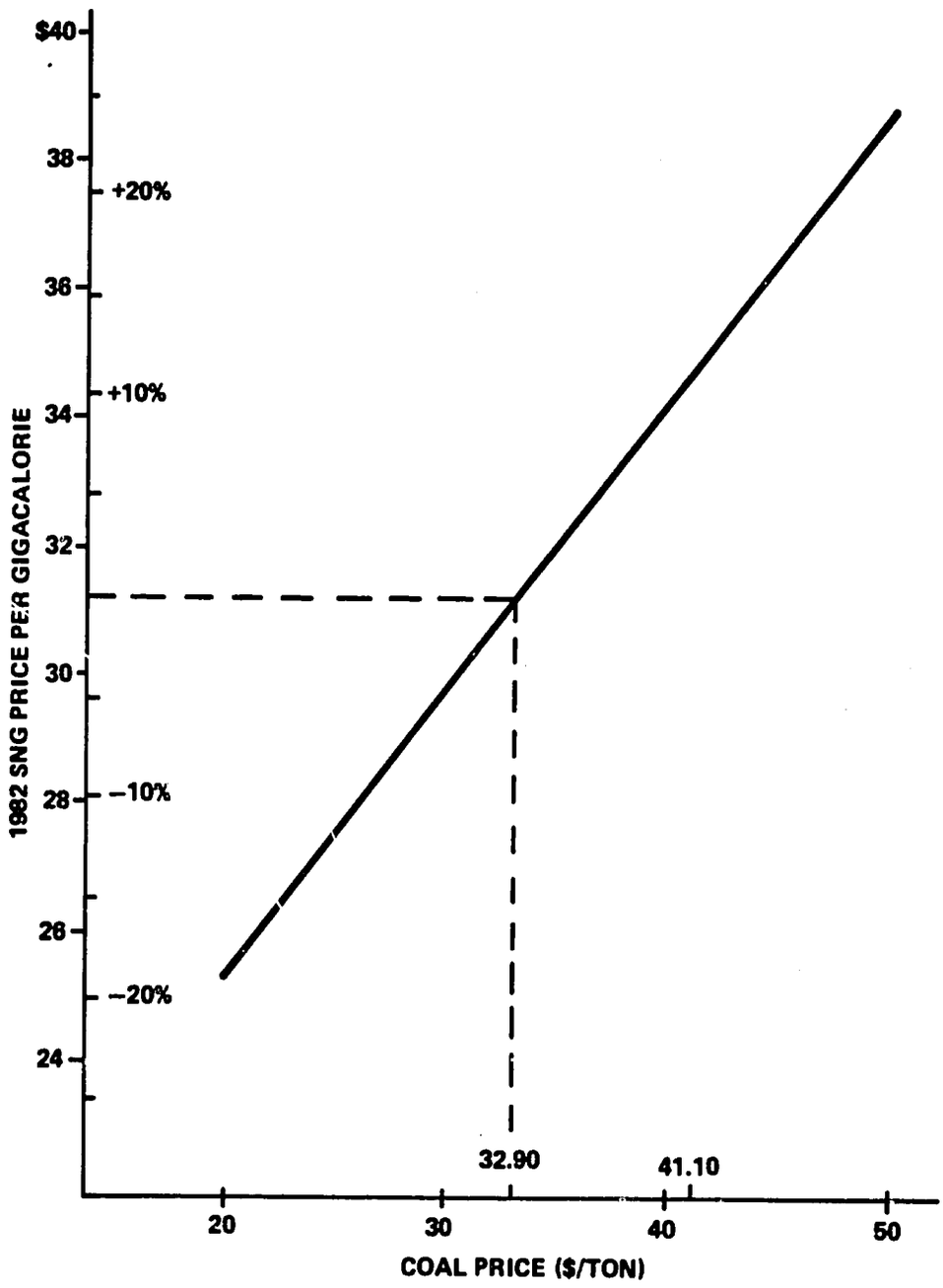

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Figure 5-5

SENSITIVITY ANALYSIS – INFLATION

SNG PRICE REQUIRED
FOR 8% POST-TAX ROI

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION PLANT

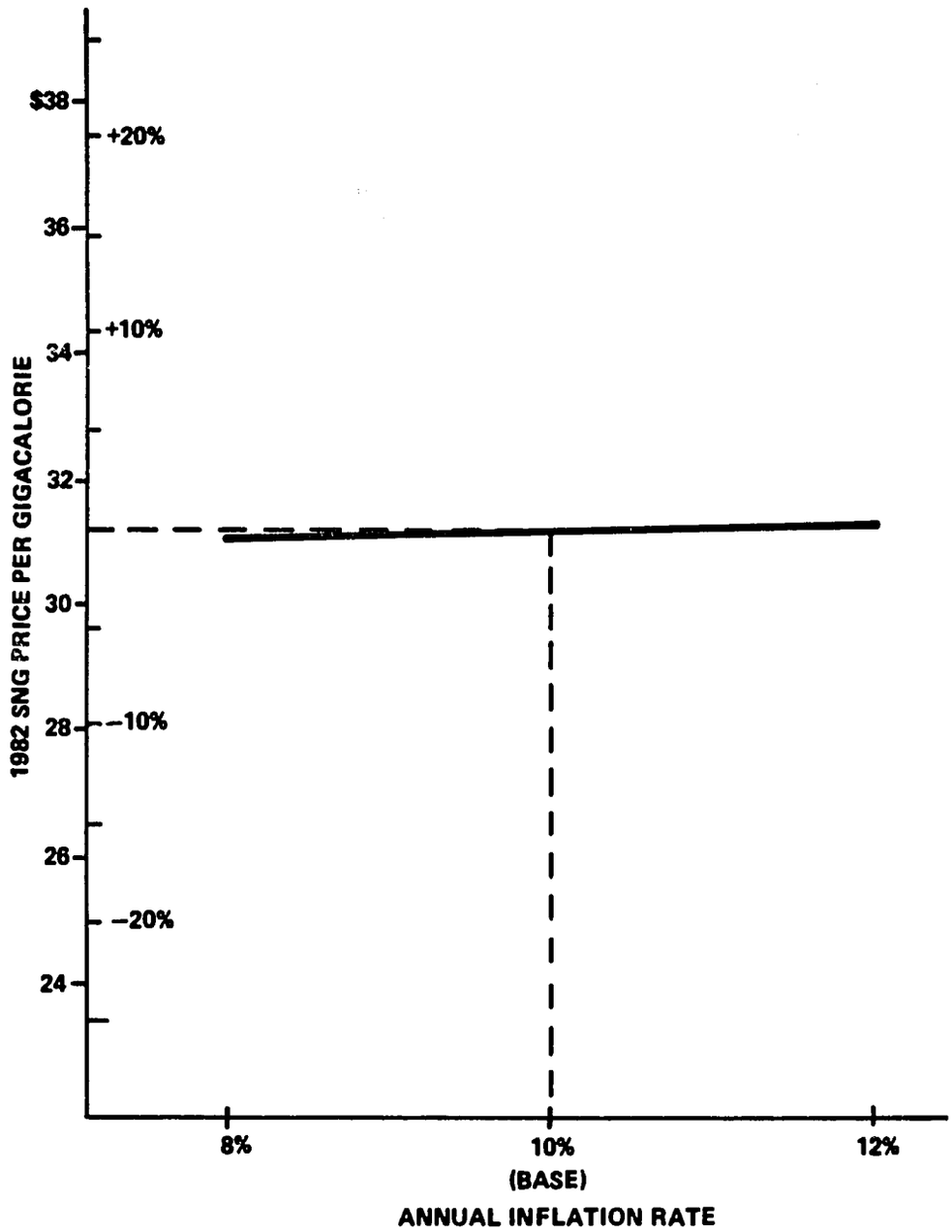

Figure 5-6

SENSITIVITY ANALYSIS – OPERATING LIFE

SNG PRICE REQUIRED
FOR 8% POST-TAX ROI

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION PLANT

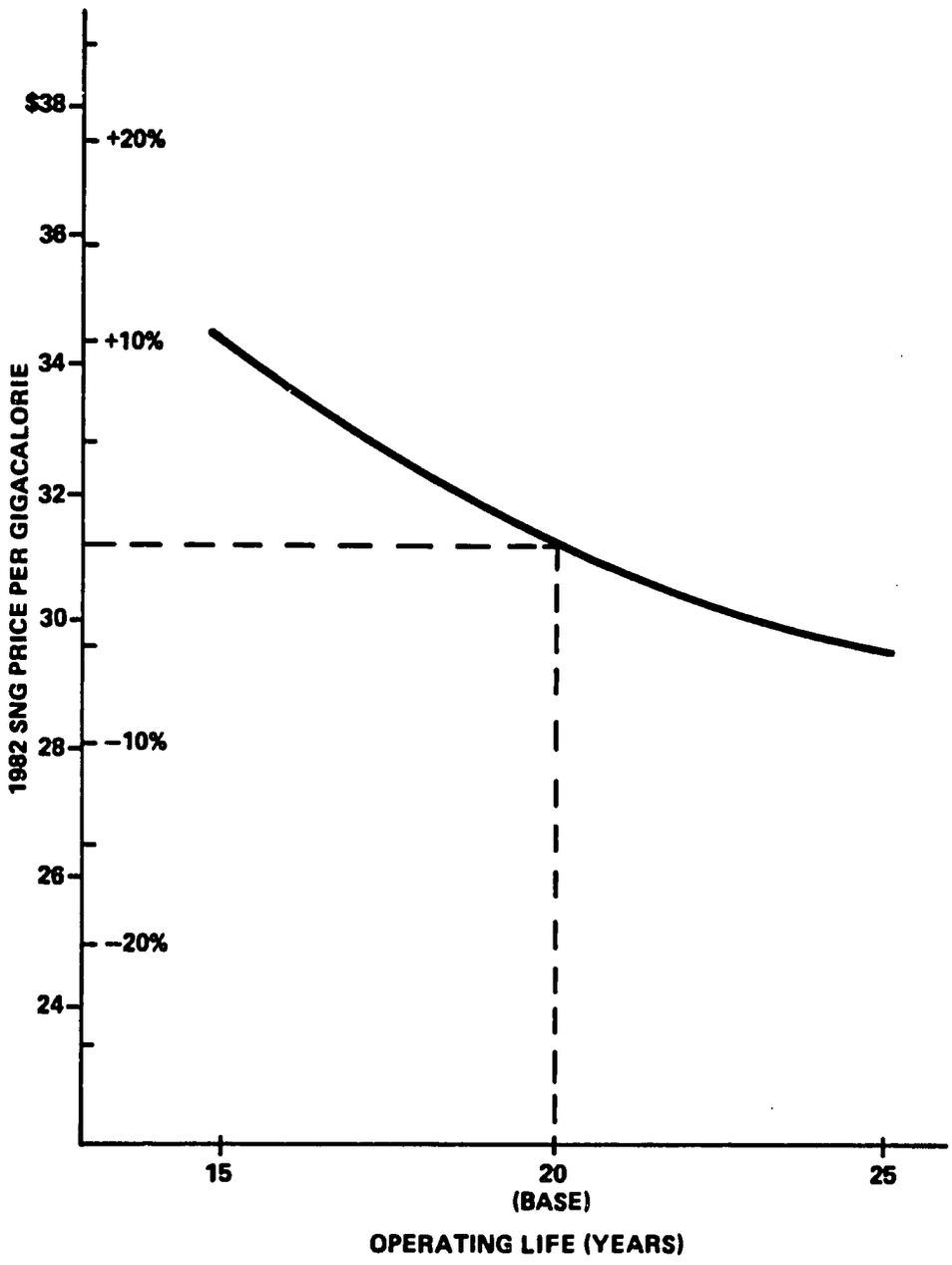

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Figure 5-7

SENSITIVITY ANALYSIS – ROI GOAL

SNG PRICE REQUIRED TO SATISFY
DIFFERENT POST-TAX ROI GOALS

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION PLANT

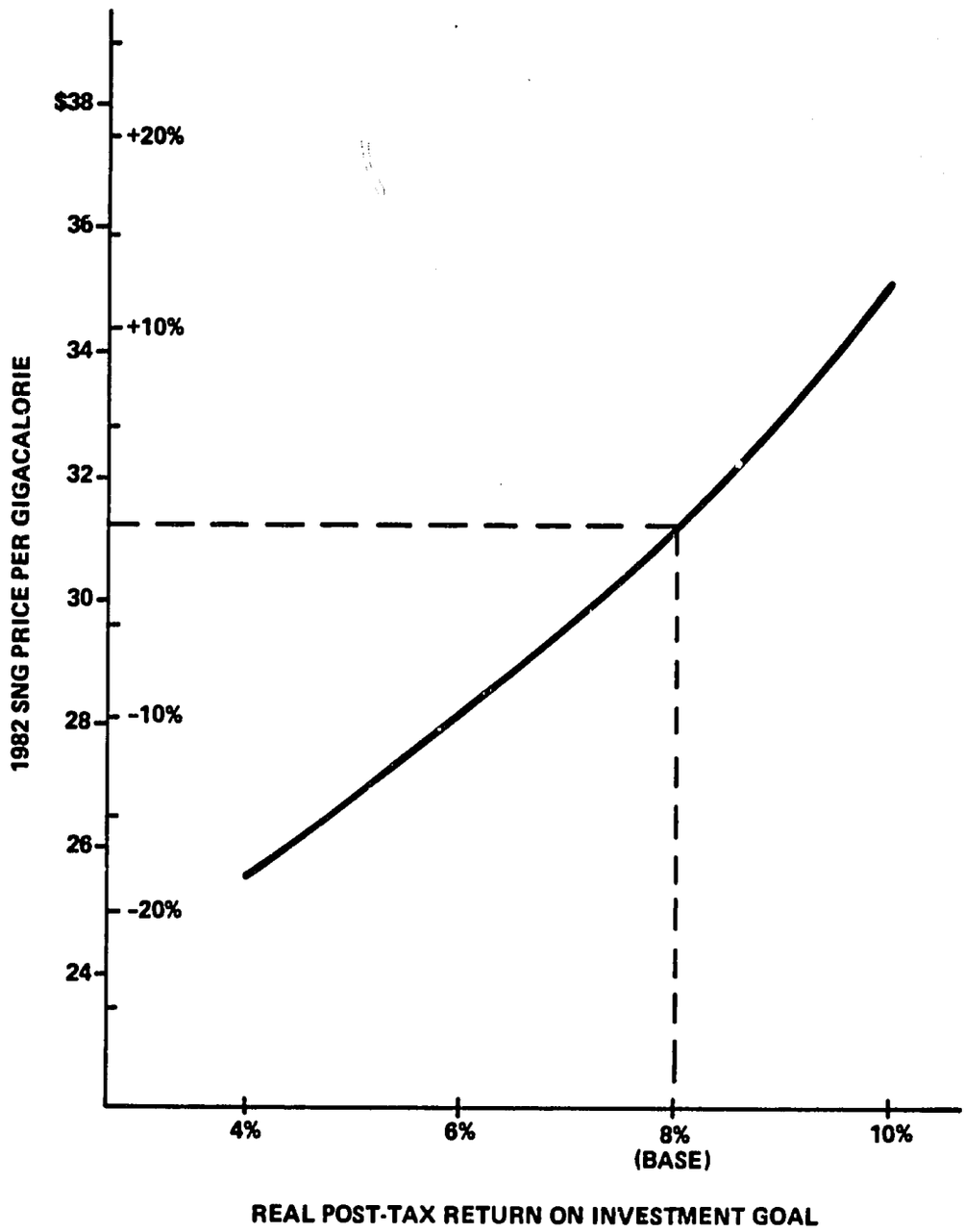

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Figure 5-8

SENSITIVITY ANALYSIS – PERCENT EQUITY

RETURN ON EQUITY AT DIFFERENT DEBT/EQUITY RATIOS

BRAZIL SOUTHERN CONE ENERGY NETWORK COAL GASIFICATION PLANT

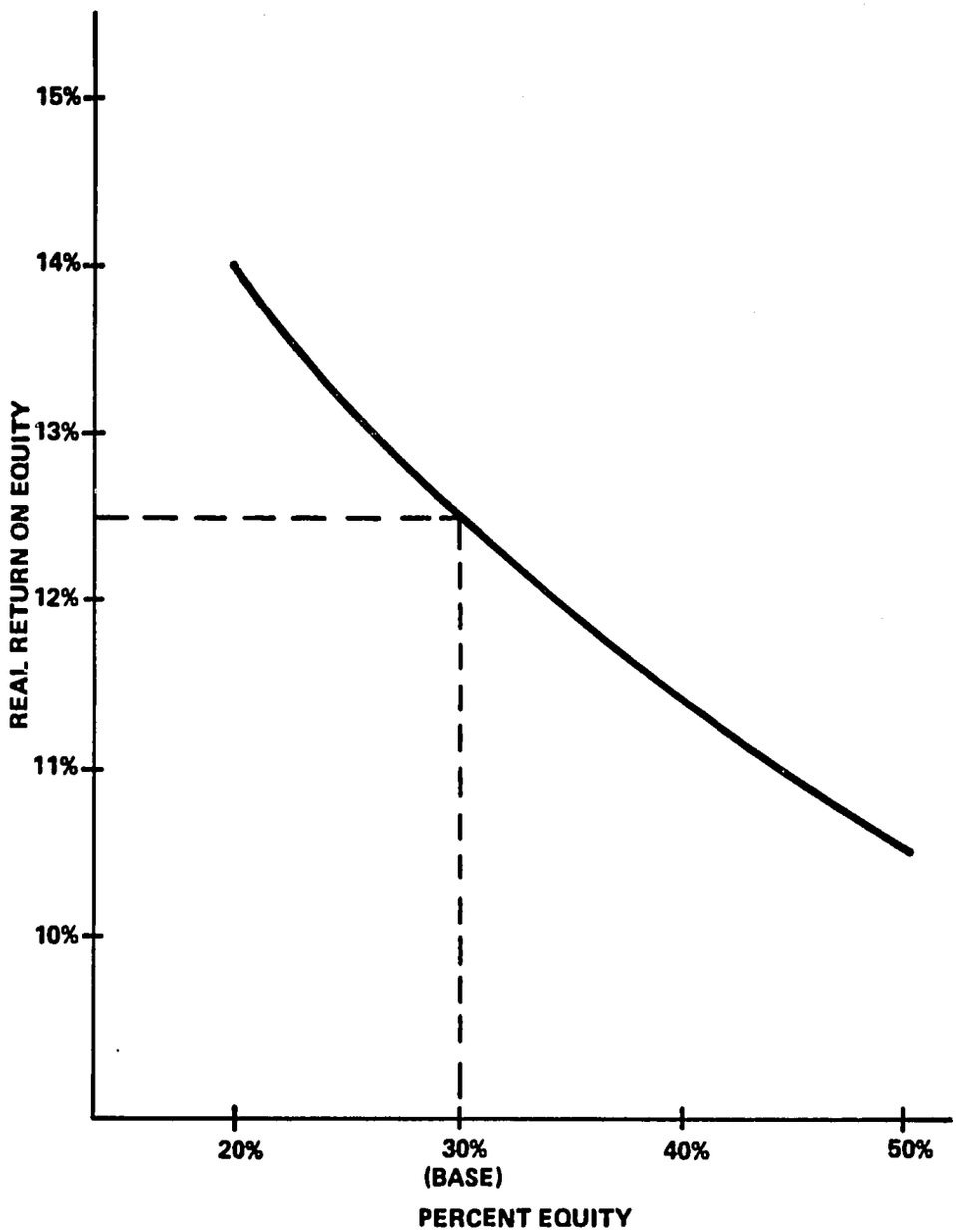

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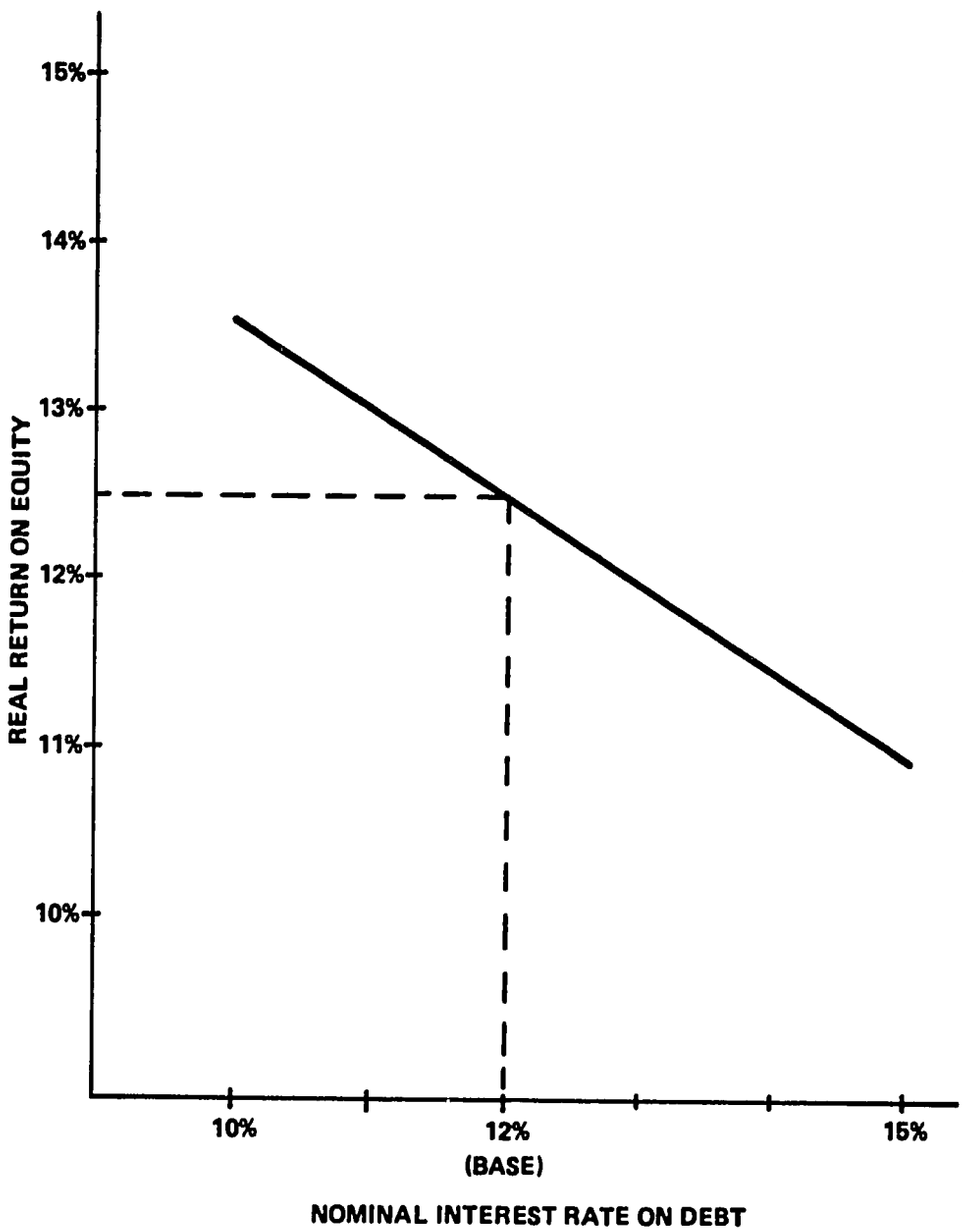
Figure 5-9

SENSITIVITY ANALYSIS – INTEREST ON DEBT

RETURN ON EQUITY AT DIFFERENT
DEBT INTEREST RATES

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION PLANT



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6.0 BASIS OF STUDY

6.1 TECHNICAL CRITERIA

The SNG plant design presented in this feasibility study is based on a set of technical criteria either mutually established by Jaakko Poyry Engenharia, Brazilian government authorities, and Fluor or gathered by Jaakko Poyry during the course of the study. These criteria include geographical data, climatic conditions, raw water availability, general plant requirements, and design philosophy, and pipeline system design requirements.

6.1.1 Plant Description

The plant will gasify coal to produce 33 000 million kilocalories per stream day of SNG. The gas produced will be delivered to the pipeline at a pressure of 68.6 kg/cm^2 (abs.). The characteristics of the feed coal are discussed under Appendix B.

At the onset of this study, an economic evaluation was performed for the production of by-product diesel fuel in the SNG plant involving Lurgi technology, at the Brazilian Government's request. It was determined that for a plant of such size, the production of diesel fuel would be only marginally economical, and hence it was deleted from further consideration.

6.1.2 Plant Location

The SNG plant will be located in the southern coal producing states of Brazil, close to the supporting coal reserve. Section 7 of this report describes site selection.

6.1.3 Meterological Data

The following meterological data were developed and used as basis for plant design:

Dry Bulb Temperature
- Maximum: 31°C (87°F)
- Average: 20°C (67°F)
- Minimum: 10°C (49°F)

Wet Bulb Temperature
- Average: 26°C (78°F)

Ambient Pressure:
- 754 mm Hg (14.6 psia) - Calculated, based on site elevation of 70 meters (230 feet).

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Wind

Prevailing: South, Southeast, East
Periodic: Northwest

Note: Wind loads used in structural design are specified in Brazilian codes as 180 km/h (112 mph).

Rainfall: 1676.4 mm/year (66 in./yr) average

6.1.4 Raw Water Data

Plant makeup water is available from the Jacui River. The Jacui River flow rates are:

Absolute Maximum: 5 700 m^3/sec (201 790 ft^3/sec)
Average maximum: 1 381 m^3/sec (48 7[illegible]0 ft^3/sec)
Average Minimum: 321 m^3/sec (11 340 ft^3/sec)
Absolute Minimum: 42 m^3/sec (1 480 ft^3/sec)
Maximum Temperature: 28.5°C (83°F)
Minimum Temperature: 11.5°C (52°F)
Average Temperature: 20°C (67°F)

Jacui River water analysis is contained in Appendix E.

6.1.5 Plant Reliability/Availability

The technology employed will be commercially demonstrated or have a strong likelihood of being commercially demonstrated in the near future. For the purposes of this study, it is assumed that demonstration of any proposed technology by 1985 would be in time for the proposed plant to take advantage of such commercial experience.

The plant shall be designed on a minimum first cost basis with minimum sparing. However, in critical service, redundant equipment will be installed to achieve an acceptable on-stream factor for the plant.

6.1.6 Design Criteria

The following general design criteria will be used in developing the plant design.

- The plant will provide for on-site coal storage equivalent to 30 days of operation.
- Coal fines will be consumed by the plant.
- Disposal of the coal ash generated in the plant and the sludge will be on-site if the mines are underground; if mines are surface, ash will be returned to the mine.

- The SNG plant, if involving Lurgi technology, will be designed to be self-sufficient in terms of electrical power requirements.

- All equipment for the SNG plant will be shop fabricated.

- The production of sulfur, ammonia, and naphtha by-products will be considered. Sulfur will be produced in solid blocks. All by-products will be dispatched by truck to the nearest rail connection.

6.1.7 Environmental

The plant will be designed to meet U.S. environmental standards. Brazilian standards, as compiled by Jaakko Poyry, were reviewed. This review indicated that the Brazilian environmental standards would be generally satisfied if the plant was designed for U.S. environmental standards. A copy of the available Brazilian standards is attached as Appendix F.

6.1.8 Plant Limit Definition

The plant shall include all necessary process and off-site units, 30-day dead coal storage, four-day live storage, water ponds, ash storage, and by-product storage and dispatch area. SNG will be delivered at the plant limit to a pipeline at a pressure of 68.6 kg/cm^2 (abs.).

Raw water will be brought to the plant by a pipeline from the Jacui River.

By-products will be transported from the plant by truck to the nearest rail connection.

Ash will be conveyed to an on-site disposal area.

Areas shall be provided for administration and service buildings, and plant infrastructure.

6.2 COAL CHARACTERIZATION

The specific coal to be used as feed to the proposed plant has not been determined at this time. There exist a number of potential sources from which the plant could draw its feed. For the purpose of this study, the plant design has been based on a "reference" design coal which is representative of the coals presently mined in Brazil. A study was performed to define the Brazilian coal resources. The results of this study are presented in Section 8 of this report.

Of the coal produced in Brazil, 98 percent is mined in the southern states of Santa Catarina and Rio Grande do Sul. For this reason, the selection of the "reference" coal was limited to the coals indigenous to that area. Analyses of the coals that are presently being mined in

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Santa Catarina and Rio Grande do Sul are presented in Table 6-1. The coals are all ranked as subbituminous and typically contained large quantities of ash on a run-of-mine (ROM) basis.

The reserves in the state of Santa Catarina total about 1 900 million metric tons, mostly contained in two seams: The Barro Branco and the Bonito. The reserves are assumed to be mostly recoverable by underground mining methods because of the depth of burial.

The Barro Branco seam, from which almost all of the Santa Catarina coal production comes, is primarily a metallurgical (coking) coal and, therefore, would probably not be considered as a gasification plant feedstock.

The major portion of the remaining reserves, 900 million metric tons, occurs in the deeper Bonito seam. These reserves show acceptable quality, washing recover, and mining recover for a gasification complex; however, these reserves are not being mined in significant quantities at the present time.

The total stated reserves of nonmetallurgical coal in Rio Grande do Sul are about 19 000 million metric tons. Only about 12 percent of these reserves are shallow enough to be mined by surface methods. However, due to the size of the reserves, the feedstock "reference" coal for this study could be well represented by one of the Rio Grande do Sul deep coals. Specifically, the Leao mine was selected because it has the largest measured underground reserves in the state of Rio Grande do Sul. Additionally, the coal from the Leao mine exhibits good weight and carbon recoveries after washing. This is probably due to the lower raw coal ash content.

Based on the information compiled by Jaakko Poyry and consultation with the selected gasification process licensors (Lurgi and Westinghouse), the Leao coal washed down to 35 weight percent ash (dry basis) will be used as "reference" coal for plant design. The ultimate and proximate analysis for the "reference" coal is presented in Table 6-2.

6.3 COST ESTIMATE BASIS

The capital cost estimate will be developed from the conceptual process design of the plant. All costs wherever possible will be developed from Fluor's in-house data. Relative costs between a U.S. location and the Brazilian jobsite location will be developed from data provided by Jaakko Poyry. The capital cost will include the cost of erecting the permanent facility field costs in support of the construction including construction camp, and the engineering office costs to engineer, design, and procure equipment and material for the project.

TABLE 6-1

COAL ANALYSES

State	SANTA CATARINA			RIO GRANDE DO SUL									
Mine	Several			Leao I			Candiota		Charqueadas	Recreio			
Seam	Camada Barro Branco			Camada Inferior			Camada Superior and Inferior		Camada I₁F	Camada Superior and Inferior			
Designation	CV-40[2]	CV-35[2]	CM 18.5[2]	ROM	CV-20[2]	CV-40[2]	ROM CS[3]	ROM CI[3]	ROM	ROM CS[3]	ROM CI[3]	CV-335[2]	CV-55[2]
Proximate Analysis, Wt% (dry basis)													
Ash	41.6		18.5	46.0	20.0	40.0	51.7	50.1	59.2	46.7	52.8	35.0	55.0
Volatile Matter	23.0		33.0	29.4	33.1	25.2	22.5	22.1	19.3	24.9	22.2	26.4	21.0
Fixed Carbon	35.4		48.5	24.6	46.9	34.8	25.8	27.8	21.5	28.4	25.0	38.6	24.0
Total	100.0		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Hydroscopic Moisture, Wt%	1.6			10.7			3.1	4.7	6.5	9.8	8.4	9.1	8.7
Total Moisture, Wt%			6.0		17.5	13.8							
HHV, kcal/kg (dry basis)	4,351		6,800	3,826	6,150	4,350	3,208	3,416	2,677	3,719	3,245	5,200	3,070
Ultimate Analysis, Wt% (dry basis)													
Carbon	48.68			38.8		45.6	34.3	34.9	29.3	38.7	34.3		
Hydrogen	3.00			2.7		2.9	2.7	2.8	2.2	2.9	2.7		
Nitrogen	0.98			0.6		0.8	0.5	0.7	0.5	0.6	0.6		
Sulfur	2.65			1.7		2.1	1.6	2.0	0.4	2.6	2.0		
Ash	41.60			46.0		40.0	51.7	50.1	59.2	46.7	52.8		
Oxygen	3.09			10.2		8.6	9.2	9.5	8.4	8.5	7.6		
Total	100.00			100.0		100.0	100.0	100.0	100.0	100.0	100.0		
H.G.I.	57			62			107	100	67	73	79		
Carbonate (dry basis)-CO_2				1.25			1.58	3.11	1.35	1.3	1.4		
Chloro (dry basis)				Neg.			0.12	0.09	0.03	0.01	0.04		
F.S.I.			4.5	0			0	0	0	0.5	0	0	0
Ash Fusibility (Oxidizing Atmosphere), °C													
Initial Deformation	1460			1480			1440	1390	1460	1430	1490		
Hemispherical	1545			1585			1560	1490	1585	1540	>1600		
Fluid	1560			1600			1580	1510	1600	1560	>1600		

1. Blended coal available at Lavador Capivari
2. Designates nominal ash content on a dry basis
3. CS-Camada Superior; CI-Camada Inferior

TABLE 6-2

COAL ANALYSIS (AS RECEIVED)

Proximate Analysis (wt%)

Moisture	14.7
Volatile Matter	23.29
Fixed Carbon	32.16
Ash	29.86 (1)

Ultimate Analysis (wt%) (Dry Basis)

Carbon	76.00
Hydrogen	4.77
Nitrogen	1.38
Sulfur	3.54
Oxygen	14.31

Heating value (HHV dry basis) 4712.5 kcal/kg.

(1) 35 wt% on dry basis

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7.0 SITE STUDY

7.1 SITE SELECTION

The site selection study was associated primarily with the availability of sufficient coal resources in an areas to support the proposed gasification plant. Section 8 of this report details the Coal Resource Study. The states of Santa Catarina and Rio Grande do Sul, as the two major coal producing areas of Brazil, were identified as potential plant site locations.

It was concluded that the coal resources in Santa Catarina are probably insufficient to support the plant, primarily because of the lack of large contiguous coal deposits and the numerous small mining concessions which exist in the state.

The two main coal resource areas in Rio Grande do Sul were investigated, these being the Candiota reserve and the mines in the area of the Jacui River. The Candiota area represents the largest single coal resource in Brazil and is the only one with sufficient reserves to possibly support a large gasification plant with only surface mining; however, the area is remote and appears to have a limited water availability. Indications are that a power plant in the area together with its planned expansion will take what water is available. The Candiota coal has about 52 percent ash, is friable and washes poorly.

The mines in the areas of the Jacui River, such as Irui, Leao and Chargueadas, appear capable of supporting the gasification plant by underground mining; also the area has good transportation access, water availability from the Jacui River, and some labor should be available from the Porto Alegre area and nearby towns. There appears to be no unacceptable adverse environmental or economic impacts that would result from the location of the plant is this area. A pipeline from a plant in this area running north to Sao Paulo could readily be extended west to receive imported gas.

In addition to providing acceptable coal reserves, this site provides a reasonable coal quality; the Leao-Butia deposit is regarded as having the best quality coal in Rio Grande do Sul.

It was concluded that this study would be based on a plant located in the general area of the Leao mines near the village of Minas do Leao, as shown on Figure 7-1. No specific location nor coordinate references were determined.

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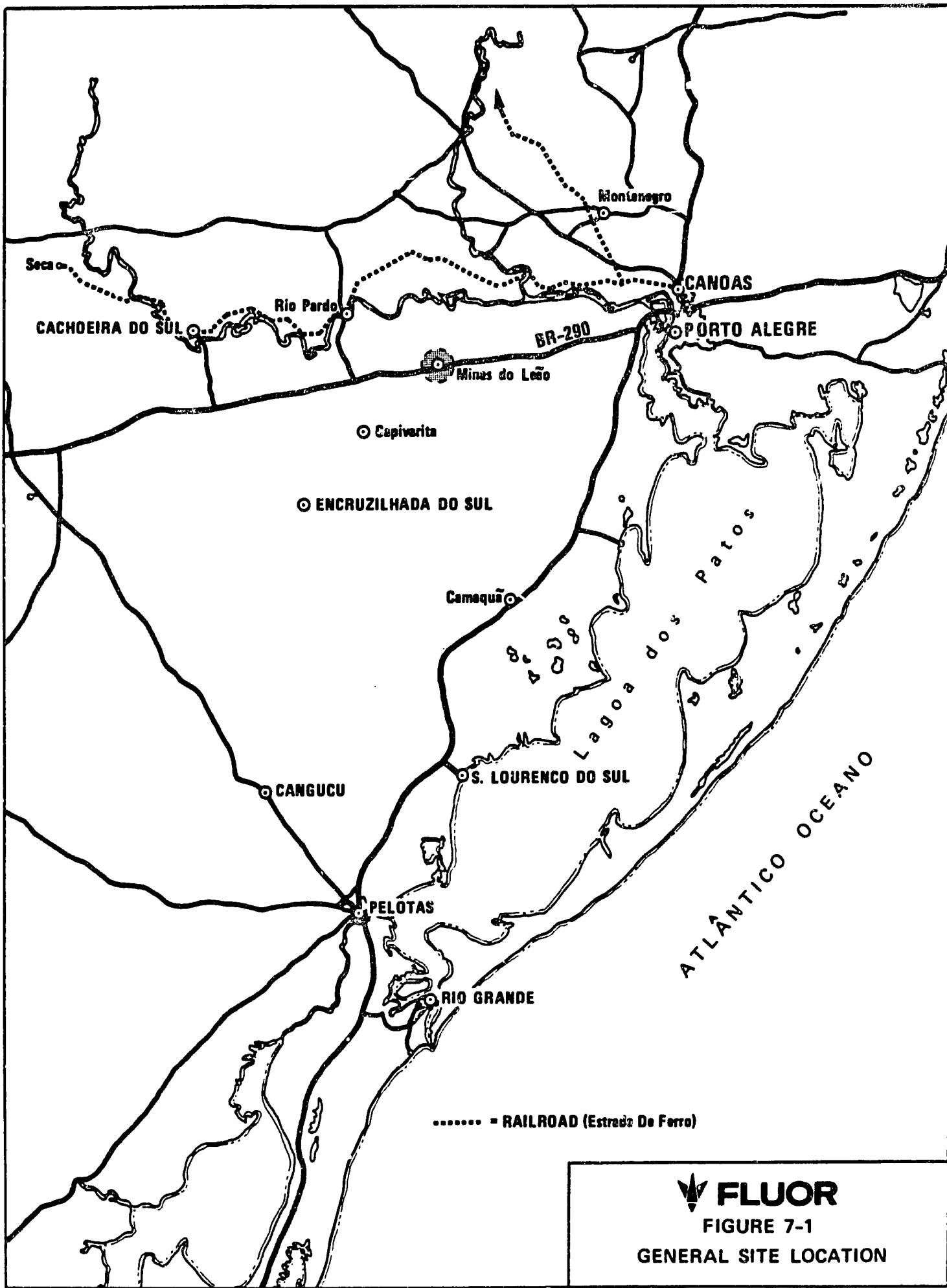

FLUOR

FIGURE 7-1

GENERAL SITE LOCATION

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The Leao area is approximately 1000 km from Sao Paulo, 100 km from Porto Alegre and 20 km from the Jacui River.

A total of 15 kilometers of overland conveyors have been included to bring coal feed to the gasification plant.

7.2 CLIMATIC CONDITIONS

Climate for areas considered for the site were as follows:

	Candiota (1)	Irui (2)	Leao (3)*
Altitude above sea level, m	200	100	70
Temperature, °C: maximum	41	41	41
average, maximum	24	25.5	(4)
average, minimum	13	13.5	(4)
minimum	- 4	- 5	- 2
Humidity, relative	70%	70%	76%
Rainfall (yearly average, min.), mm	1 392.6	1 594.0	1 676.4
Wind - Predominant:	N-NW	NE	S,SE,E
(5) speed, m/s	21/25	(6)	(6)
- Periodic:	S,SW,SE	-	NW
speed, m/s	17/21	(6)	3
Wet bulb temperature, °C	(6)	(6)	26

Notes:

(1) Climate data from Bage, considered representative of Candiota area
(2) Climate data from Cachoeira do Sul, considered representative of the Irui mine region
(3) Climate data from the Copesul project, in Triunfo, considered representative of the Leao/Recreio area*
(4) Not available; average of daily maximum: 31°C, average 20°C, average of daily minimum: 10°C
(5) Brazilian building codes specify use of 180 km/h winds on structural design. Maximum recorded speed in the lower Jacui region is 120 km/h.

*Selected site area.

7.3 WATER AVAILABILITY

In the Jacui valley mining areas the main river is the Jacui, a branch of the Guaiba that goes into Lagoa dos Patos beyond Porto Alegre. Flow information, measured near Triunfo, is as follows:

Absolute maximum water flow	5 700 m^3/s
Average of maximum flow	1 381 m^3/s

Average of minimum flows	321 m^3/s
Absolute minimum flow	42 m^3/s
Maximum water temperature	28.5°C
Minimum water temperature	11.5°C
Average water temperature	20.0°C

Analysis of raw water from Jacui river is given in Appendix E.

The Jacui river according to the SEMA environmental regulations (Appendix F) is Class II.

A 25-kilometer raw water pipeline, with pump station at the Jacui River, has been included in the gasification plant estimate.

The Jacui river is one of the main sources of the Guaiba. Porto Alegre city water is taken from the Guaiba, and a fair amount of political attention has been given in the local press, in the last five years, in efforts to protect this river from industrial pollution. Sizeable sums have been spent for pollution control, and the Copesul petrochemical complex, at Triumfo, on the lower Jacui, pipes waste water for 50 km to a disposal point below Porto Alegre, already in Lagoa dos Patos.

7.4 RAINFALL DATA

Rainfall data along pipeline routes between the gas plant site near Porto Alegre, RS and Sao Paulo, SP are as follows:

Measurement Site	Yearly average, mm
Porto Alegre (RS)	1 320
Osorio (RS)	1 670
Torres (RS)	1 420
Florianopolis (SC)	1 940
Laguna (SC)	1 350
Blumenau (SC)	1 400
Lajes (SC)	1 644
Curitiba (PR)	1 299
Sao Paulo	1 270

7.5 LOCAL LABOR AVAILABILITY

Unskilled labor would be hired locally and live in camps, while skilled labor and supervisory personnel and operating staff would be brought mainly from the Sao Paulo/Rio de Janeiro area (although some could be hired in Porto Alegre) and would live in nearby towns. The nearest supporting town would be Porto Alegre.

Table 7-1 list some major construction projects presently in execution or planned in Rio Grande do Sul.

TABLE 7-1

CURRENT MAJOR CONSTRUCTION PROJECTS

Name	Type	Location	Dates Start	Dates Start-up	Investment (10^6 US$)	Labor Peak (10^3)
Riocell plant expansion	pulp/paper	Guaiba	1979	1982	300	2
Polisul	Chemical	Triunfo	1980	1982	110	1.2
Petrochemical complex(including COPESUL)	Petrochemical	Triunfo	1976	82/86	2 500	13
Candiota II	Power Station	Candiota	1980	1983	470	6
Candiota IIIa	Power Station	Candiota	-	1985	470	6
Candiota IIIb	Power Station	Candiota	-	1988	470	6
Candiota IIIc	Power Station	Candiota	-	1991	470	6
Candiota IIId	Power Station	Candiota	-	1994	470	6
Candiota IIIe	Power Station	Candiota	-	1997	470	6
Candiota IIIf	Power Station	Candiota	-	2000	470	6

7.6 LOCAL EQUIPMENT AVAILABILITY

The availability of local equipment has been reported by Jaakko Poyry as follows.

7.6.1 Supply Breakdown by Typical Project

Approximate percentages based on U.S. dollar values for local versus imported equipment supply for typical major projects are presented below:

	Major Project, Source of Equipment	
	Local	Imported
Minimum	60%	40%
Maximum	100%	0%
Average	80%	20%

7.6.2 Equipment Type

Local availability of equipment by type (mechanical/piping; electrical; instrumentation) is reported to be as follows:

7.6.2.1 Mechanical/Piping.

Local:

Tanks and vessels	Steam boilers
Compressors	Overhead cranes
Exchangers	Electrostatic precipitators
Fired Heaters	Cooling Towers
Pumps	Piping - cast iron
Turbine drives	Piping - carbon steel
Agitators	Painting
Truck and railway scales	Insulation

Imported:

Piping - Alloy (in general material is imported and manufactured in Brazil)

7.6.2.2 Electrical.

Local:

Motors
Transformers
Motor control centers
Panels

7.6.2.3 Instrumentation. Most recent projects show a nationalization index of approximately 85 to 95 percent availability for instrumentation.

7.6.3 Materials

7.6.3.1 Civil. All materials for civil construction and steel structures are available in Brazil.

7.6.3.2 Electrical. Electrical cables and all other electrical material are available in Brazil.

7.6.3.3 Instrumentation. See 7.6.2.3.

7.6.3.4 Equipment and Piping Materials.

Local:

Carbon Steel
Cast iron

Imported:

Alloy steels, in general

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7.7 ELECTRIC POWER

The gasification plant would be power self-sufficient during operation, however, for construction and start-up requirements a 20 MW power line has been included. The line would be approximately 40 km long connecting to the Charquedas thermoelectric power plant, where there is a tie into the southern power grid.

7.8 ENGINEERING AND CONSTRUCTION CODES

7.8.1 Study Basis

For this study, fabrication has generally been assumed to be in accordance with ASME code where applicable.

7.8.2 Standards Followed During Design and Construction in Brazil

The latest editions of the following codes and standards are applicable:

Civil - ABNT - Associacao Brasileira de Normas Tecnicas
Steel structure - ABNT/AISC
Steel material - ASTM
Piping - ABNT/ASTM/DIN/API/AWWA
Tanks and vessels - ASME/JIS/DIN/API/ABNT
Steam generators - ASME
Heat exchangers - TEMA/DIN
Pumps - DIN/ANSI/API
Electrical and instrumentation - NEMA/NEC/IEEE/ISA/ANSI/API/ASME ASTM/NFPA
Fire protection - NFPA, besides insurance regulations and local Fire Brigade regulations
Pollution control - See Appendix F

7.9 PERMITS TO BE OBTAINED

Design (architectural for county approval - assessment of property taxes)
Fire protection - from the local (state/county) Fire Brigade
Pollution control - from the appropriate state authority
Water supply - apply to the state authority
Electrical energy generation - apply to the (federal) Ministry of Mines and Energy

7.10 TRANSPORTATION FACILITIES AND LIMITATIONS

7.10.1 Transportation Facilities

7.10.1.1 Road Access. The following roads shall be used:

From Sao Paulo State to Porto Alegre city by BR 101 or BR 116 (two-lane paved).

From Porto Alegre to Leao and Irui coal mine area by BR 290. It has been assumed that the plant site would be within 5 km of a major highway; a 5 km road from the plant to an existing highway has been included.

7.10.1.2 Railway Access. The coal mine areas are served by RFFSA (Rede Ferrioviaria Federal) railroad.

The railroad follows the left bank of the Jacui River; the mines are on the right bank. Coal must be trucked to the nearest railroad station. An old branch line was used to connect Porto do Conde, on the right bank between General Camara and Triunfo to Minas do Leao. This line has been discontinued for the last 20 years, but there are plans to revive it within two years (although still not crossing the Jacui river).

7.10.1.3 Ports. The nearest ports are Porto Alegre and Rio Grande.

7.10.1.4 Airport. The nearest airport is Salgado Filho International Airport in Porto Alegre. There are small-plane airports in Bage, Cachoeira do Sul and Rio Pardo.

7.10.2 Transportation Limitations

7.10.2.1 Roads. Road mentioned in 7.10.1.1 are federal highways. Loads within the limitations set below can be transported without special permission:

Maximum width:	2.60 meters
Free height:	4.40 meters
Equipment height:	4.40 - 1.20 = 3.20 meters
Length, maximum:	18.00 meters
Load, maximum:	70.00 tons

In any of above limitations are not met, a special license must be obtained. The actual limitations are not known and are decided "ad hoc"

but following limitations are considered to be feasible (individually, not together):

Width	4.00 meters
Equipment height:	3.40 meters
Length:	30 to 40 meters and even 70 meters long equipment have been transported.
Loads:	375.00 tons (additionally there are limits per axle)

7.10.2.2 Railway. Limitations on the railways are as follows:

Width	4.00 meters
Free height	5.90 meters
Equipment height:	5.90 - 1.10 - 4.80
Length:	19.00 meters
Load:	100.00 tons

7.10.2.3 Ports. Limitations at the ports are as follows:

Porto Alegre

Depth:	6.00 meters
Traffic (yearly):	- bulk, solids - 4.0 x 10^6 tons
	- bulk, liquids - 0.6 x 10^6 tons
	- general freight - 0.3 x 10^6tons

Rio Grande

Depth:	14.00 meters
Traffic (yearly):	- bulk, solids - 5.9 x 10^6 tons
	- bulk, liquids - 2.4 x 10^6 tons
	- general freight - 0.7 x 10^6 tons

8.0 COAL RESOURCE STUDY

8.1 INTRODUCTION

Jaakko Poyry Engenharia has gathered and collated available information on Brazilian coal resources, existing and potential coal mines, coal prices, transportation, and other pertinent data relative to the primary coal producing states of Santa Catarina, Rio Grande do Sul, and Parana.

A Fluor geologist visited the southern Brazilian coal producing states to review the data assembled by Jaakko Poyry, and to visit the main coal resource areas in Rio Grande do Sul and Santa Catarina.

This report provides a Fluor review of the data collected and an assessment of the reserves that must be available to support a gasification plant life of 30 years, together with the Jaakko Poyry resource description report.

The report is based on an anticipated plant feed requirement of approximately 12 000 metric tons of coal per day. The gasification plant design resulted in a feed requirement of approximately 14 000 metric tons per day, thus the original reserves stated herein should be increased proportionally; however, this does not alter the validity of the report.

8.2 ASSESSMENT SUMMARY

8.2.1 Conclusions

This assessment is based on existing data which are incomplete and general, with the greatest uncertainties lying in the estimate of coal washability and in the estimates of in-situ coal ash contents. Since reserve calculations are sensitive to variations in these estimates, the reserves presented herein should be recalculated when more specific information is obtained.

Brazilian coals contain large amounts of ash and have locally uniform sulfur contents. Reserves based on existing data are of the following magnitude:

State *	Reserves (Million Metric Tons)
Rio Grande do Sul	19 000
Santa Catarina	1 900
Parana	95

The feedstock required for the gasifier was assumed to be 4.0 million metric tons per year of coal (dry basis, 35 percent nominal ash). However, it should again be emphasized that current estimates of reserve requirements are only approximate because of limited data on coal washability and local coal characteristics.

* See Figure 8-1.

Based on data from Jaakko Poyry, reserve tonnages required to support the specified gasification plant range from 221 million metric tons for 40 percent ash feedstock from a 40 to 46 percent ash raw coal to 1266 million metric tons for 30 percent ash feedstock from a 60 to 65 percent ash raw coal. The 35 percent ash feedstock ranges from 240 to 684 million metric tons depending on the raw ash content.

Of the areas studied (Figure 8-1), only the state of Rio Grande do Sul contains sufficient reserves to support a large gasification plant. The states of Parana and Santa Catarina cannot be considered because of their numerous small mining concessions and their general lack of large, contiguous coal deposits.

According to the Jaakko Poyry report, there are three areas in Rio Grande do Sul where surface mining is feasible (Candiota, Leao, and Irui). Of these three, only the Candiota area has sufficient reserves to support a large gasification complex. However, there may be insufficient reserves at Candiota to support production of a 30 percent ash feed stock because of high ash content and very poor washing recovery of the raw coal.

Only the Leao and Candiota areas can realistically provide sufficient reserves for an underground mine if a 30 percent ash feed stock is required. Theoretically, the Irui area could provide enough reserves; however, the area may be too structurally disturbed to permit efficient underground mining at the required scale.

A 35 percent to 40 percent ash feedstock as compared to a 30 percent ash feedstock will result in both recovering more of the available carbon and decreasing the size of the required mine capacity and required coal reserves. For instance, if Candiota area coals are used, increasing the feedstock ash from 35 percent to 40 percent will increase weight recoveries from 38 percent to 52 percent, and will increase recovery of total carbon from 54 percent to 68 percent. The areas of Candiota, Irui, Leao, and Charqueadas could support the gasification complex, especially for a 40 percent ash content feedstock. More drilling in the other areas of the state will be required before an adequate reserve base can be assured for those areas.

The existing data are insufficient to fully characterize the coals from various areas; however, the following observations may be made:

- Available washed-coal analyses suggest that the moisture content of washed coal in the area ranges from 9 to 14 percent. Based on experience, this seems low.

- Based on observations of surface and underground mines, about 40 to 50 percent of the coal may be smaller than 1/4 inch (6.35mm).

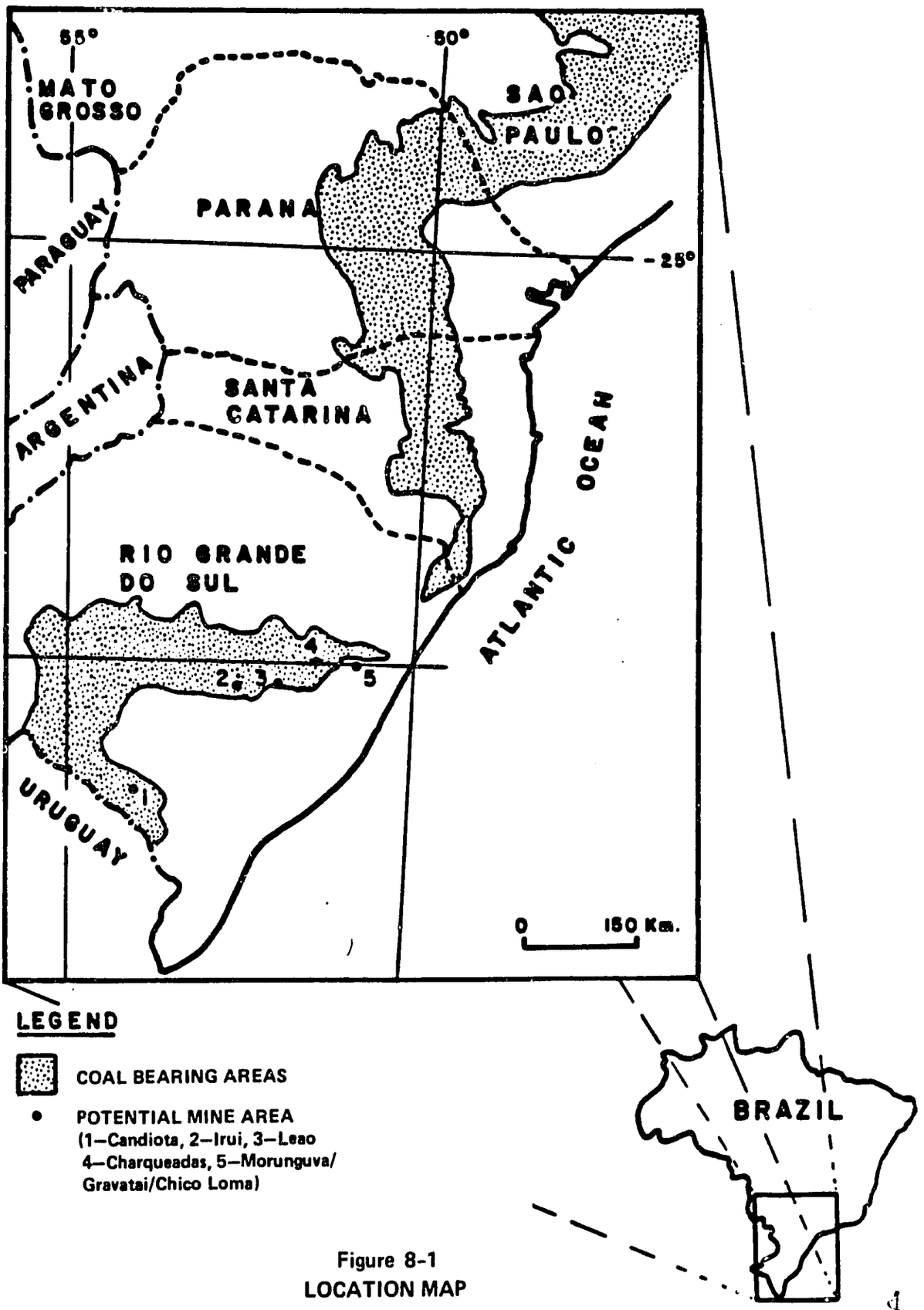

Figure 8-1
LOCATION MAP

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More information is required on coal washability, coal sizing, and coal quality. This data may be available from the companies which hold the mining concessions in the various areas. If it is not, then a program must be developed to gather the information necessary to properly characterize the coal reserves.

8.2.2 General Geology

The coals of southern Brazil occur in sedimentary rocks of the Rio Bonito formation. These rocks are of Permian age and are exposed in a broad sinuous band from the border of Uruguay north to the state of Sao Paulo (Figure 8-1). This formation has been eroded from the underlying crystalline basement rocks to the east, and is covered to the west by younger basalts.

Structurally, the coals are flat-lying, although some areas have numerous faults with vertical displacements of up to 75 feet (23 meters).

All of the in-situ coals have very high ash content, with ranges of 45 percent to over 65 percent ash. The average run-of-mine (ROM) ash content is over 50 percent. Sulfur content ranges from 0.3 percent to over 2.6 percent for the entire coal-bearing region, with a general decrease in sulfur content to the south. Locally, the sulfur content by weight varies less than 1 percent from the average ROM sulfur. Therefore, large sulfur content variations in a feedstock coal are unlikely.

8.2.3 Reserves

The reserve estimates presented in the Resource Description report by Jaakko Poyry and summarized herein are derived from Brazilian government sources. Three categories of reserves are presented in the Jaakko Poyry report: measured, indicated, and inferred. The stated accuracy for the measured reserves is ±20 percent of the given value. No accuracy is presented for the remaining categories. Based on experience, it is acceptable to assume subjective accuracies of ±50 percent for indicated reserves and ±80 percent for inferred reserves. These accuracies, and the categories the reserves are assigned to, are based upon the density of coal seam observations and measurements taken at drill holes, outcrops, or other recordable locations.

8.2.3.1 Rio Grande do Sul. The total stated reserves of nonmetallurgical coal in Rio Grande do Sul are about 19 000 million metric tons. Only about 12 percent of these reserves are shallow enough to be mined by surface methods, and only about 9 percent of the total reserves are contained in the measured reserve category.

Table 8-1 presents the reserves in Rio Grande do Sul by reserve areas. The "conservative" estimate given for each category is the minimum amount of coal. It is derived by deleting an amount of coal equivalent to the accuracy for that reserve category from the stated reserve tonnage. For

TABLE 8-1

IN-SITU RESERVES, STATE OF RIO GRANDE DO SUL (MILLIONS OF METRIC TONS)*

TYPE/AREA	Measured Conservative	Measured Estimated	Indicated Conservative	Indicated Estimated	Inferred Conservative	Inferred Estimated	Total Conservative	Total Estimated
Surface								
Candiota	325.5	406.9	215.1	430.3	74.5	372.8	615.3	1 210.2
Irui	43.3	54.2	10.7	21.5	17.9	89.8	72.0	165.4
Leao	16.5	20.6	6.1	12.3	-	-	22.6	33.0
Subtotal	385.3	481.7	231.9	464.1	92.4	462.6	709.9	1 408.6
Underground								
Candiota	51.7	64.6	167.0	334.0	1 274.8	6 374.3	1 493.6	6 773.0
Irui	97.6	122.0	189.5	378.9	502.4	2 511.9	789.4	3 012.9
Leao	446.6	558.2	135.8	271.7	579.4	2 897.1	1 161.9	3 727.1
Charqueadas	371.2	464.0	255.5	511.1	116.3	581.4	743.0	1 556.5
Santa Rita	58.0	72.6	92.3	184.7	68.3	341.4	218.7	598.7
Morunguva-South	-	-	149.6	299.3	59.8	299.3	209.5	598.7
Morunguva-North	-	-	89.8	179.6	63.8	319.3	153.6	498.9
Chico Loma	-	-	411.2	822.4	-	-	411.2	822.4
Subtotal	1 025.1	1 281.4	1 490.7	2 981.7	2 664.8	13 324.7	5 180.9	17 588.2
TOTAL	1 410.4	1 763.1	1 722.6	3 445.8	2 757.2	13 787.3	5 890.8	18 996.8

* Estimate of 12-31-80, from Jaakko Poyry report

example, the Candiota area has surface-mineable measured reserves of 406.9 million metric tons. The accuracy for measured reserves is ±20 percent, or in this instance, ±81.3 million metric tons. The conservative estimate of 325.6 million metric tons is therefore calculated by subtracting the 81.3 million metric ton maximum uncertainty from the given value of 406.9 million metric tons. The total conservative reserve estimate is derived by adding the conservative reserve estimates from each category.

8.2.3.2 Santa Catarina. The reserves in the state of Santa Catarina total about 1 900 million metric tons, mostly contained in two seams: the Barro Branco and the Bonito. The reserves are assumed to be mostly recoverable by underground mining methods because of the depth of burial.

The Barro Branco seam, from which almost all of the Santa Catarina coal production comes, is primarily a metallurgical (coking) coal and therefore would probably not be considered as a gasification plant feedstock.

Rejecting this seam essentially deletes about 44 percent of the coal reserves in Santa Catarina, or about 851 million metric tons. The major portion of the remaining reserves, 900 million metric tons, occurs in the deeper Bonito seam. Quality, washing recovery and mining recovery estimates indicate that sufficient reserves to support a gasification complex to occur in the Bonito seam, however, the reserves are fragmented by many different mining concessions.

8.2.3.3 Parana. As stated in the Jaakko Poyry report, the state of Parana has reserves of about 94 million metric tons. Additional reserves may be found if further exploration is performed; however, they may not be large.

8.2.4 Mine and Reserve Requirements

Required annual mining capacity and, therefore, reserve requirements are determined largely by four factors: The quality of the feedstock required by the gasification plant, the wash plant recovery, the mining recovery, and the in-situ or ROM coal quality. Feedstock quality, mining recovery, and ROM product can be controlled to a degree. The in-situ coal quality and the washing recovery are variables specific to each deposit and therefore cannot be controlled.

Gasification feedstock specifications call for ash content in the 30 percent to 40 percent range. Based on a feedstock requirement of 12 000 tons per day (dry-basis, 35 percent nominal ash), annual feedstock requirements are 3.8 million tons, 4.0 million, or 4.2 million metric tons for feedstock ash contents of 30 percent, 35 percent, or 40 percent respectively.

Mining efficiencies vary according to the mining methods used, the proficiency of the operating personnel, and the geological conditions encountered. Open pit mines should recover 80 percent of the in-situ reserves with little difficulty, and may achieve recoveries of 90 percent or better under optimal conditions. Underground mining efficiency is much more sensitive to geologic and mining conditions; however, Brazilian underground mines should achieve a recovery rate of at least 50 percent. If longwall methods are used, or if retreat mining (pillar extraction) is practiced with a conventional mining system, recoveries of 60 percent or more of the in situ reserves may be achieved. These assumed extraction efficiencies are used in the reserve requirement estimations.

Three general coal types, based on ash content from information in the Jaakko Poyry report, are:

a. 40 percent to 46 percent ash (Leao area),

b. 50 percent to 55 percent ash (Candiota/Irui areas), and

c. 60 percent to 65 percent ash (Charqueadas area)

Specific, rigorous washability studies for the potential mine sites are not available; therefore, all inferences on potential washing efficiencies of the three coal types are derived from four washing studies performed on coals from existing mines. These inferences are questionable because coals of similar in situ quality do not necessarily exhibit the same washing characteristics. Fluor cannot predict how well the available washability curves will reflect the actual performance of a wash plant at any given mine.

The following estimates of annual mine capacities use the above specified parameters. The total required reserves are calculated by assuming that the stated annual production rate and mining efficiency will result in the mining of a certain reserve tonnage annually, and a certain reserve tonnage over a 30-year period.

These estimates assume a dry product. Tonnage requirements for a moist product may be derived by increasing the weights by the moisture percentage.

8.2.4.1 <u>30 Percent Ash Feedstock</u>. The mining and reserve requirements for a 30 percent ash feedstock are shown in Table 8-2. Assuming that the gasification plant will require 3.8 million metric tons per year of a 30 percent ash coal feedstock, the only area capable of supporting a reasonably sized mine is the Leao area. If the Leao area's in situ ash content is about 42 percent ash with wash recoveries of about 73 percent, an annual underground mine capacity of about 5.2 million metric tons per year is required. Assuming also that reasonable mining recoveries (60 percent) are achieved, then a 30-year reserve of about 260 million metric tons is required.

TABLE 8-2

ESTIMATED PRODUCTION AND RESERVES REQUIRED FOR 3.8 MILLION METRIC TONS PER YEAR (TPY) OF A 30 PERCENT ASH FEEDSTOCK

Raw Coal Ash Content, %	Mining Method (recovery)	Wash Method Recovery, %	Annual Mine Production, 10^6 TPY	Required Annual Reserves, 10^6 ST	Required 30 yr Reserves, 10^6 ST
a. 40 to 46	Underground (60%)	73	5.2	8.7	261.0
	Underground (50%)	73	5.2	10.4	312.0
b. 50 to 55	Surface (90%)	21	18.0	20.0	600.0
	Surface (80%)	21	18.0	22.0	675.0
	Underground (60%)	21	18.0	30.0	900.0
	Underground (50%)	21	18.0	36.0	1080.0
c. 60 to 65	Underground (60%)	18	21.1	35.2	1056.0
	Underground (50%)	18	21.1	42.2	1266.0

Washing recovery curves for the higher ash content coals (50 percent to 60 percent ash, in situ) indicate that very low recoveries for a 30 percent ash product are expected, almost assuredly less than a 25 percent washing recovery. This requires annual mining capacities in the range of 18 million to 21 million metric tons per year. To place this in perspective, the entire Brazilian national coal production during 1980 was only slightly more than 16 million metric tons. Only one area, Candiota, can reasonably support 30 years of surface mining at this rate. Because most of the surface mineable reserves in the Candiota area are not in the measured reserves category, there is a possibility that insufficient coal exists to support this rate of extraction. Four areas - Candiota, Irui, Leao, and Charqueadas - could possibly support this rate of underground extraction, with Irui and Charqueadas being only marginally capable of this rate.

8.2.4.2 35 Percent Ash Feedstock. Table 8-3 shows the reserve and production requirements for producing a 35 percent ash feedstock. Although the amount of feedstock coal is slightly increased to 4.0 million metric tons per year, the increased washing recoveries substantially reduce the annual extraction rates required for the poor quality coals.

Again, only the Candiota area has sufficient reserves for surface mining to be feasible. Only the Candiota, Irui, Leao, and Charqueadas areas contain adequate reserves for underground mining. The Leao area could produce a 35 percent ash feedstock with a 4.8 million metric ton-per-year underground mine. The other areas could require annual production rates of 10 to 11 million metric tons per year to supply a gasification plant with a 35 percent ash feedstock.

8.2.4.3 40 Percent Ash Feedstock. The reserve and production requirements for producing a 40 percent ash feedstock are shown in Table 8-4. An underground mine in the Leao area will be the most efficient, requiring an annual mining capacity of about 4.4 million metric tons per year and recovering in the product essentially all of the carbon put into the wash plant.

A Candiota mine producting about 8.1 million metric tons per year is again the only feasible surface mineable area. All of the known coal areas in Rio Grande do Sul are potentially capable of supporting production of a 40 percent ash feedstock.

8.2.5 Coal Preparation Characteristics

8.2.5.1 Washability. Although specific washability studies are scarce or nonexistent for some reserve areas, the following estimates are made to indicate the possible consequences of washing the various raw coals. Three general raw coal types are assumed:

a. 40 to 46 percent ash (Leao area),

b. 50 to 55 percent ash (Candiota and Irui areas), and
c. 60 to 65 percent ash (Charqueadas area).

TABLE 8-3

ESTIMATED PRODUCTION AND RESERVES REQUIRED FOR 4.0 MILLION METRIC TONS PER YEAR (TPY) OF A 35 PERCENT ASH FEEDSTOCK

Raw Coal Ash Content, %	Mining Method (recovery)	Wash Method Recovery, %	Annual Mine Production, 10^6 TPY	Required Annual Reserves, 10^6 ST	Required 30 yr Reserves, 10^6 ST
a. 40 to 46	Underground (60%)	83	4.8	8.0	240
	Underground (50%)	83	4.8	9.6	288
b. 50 to 55	Surface (90%)	38	10.5	11.7	351
	Surface (80%)	38	10.5	13.1	393
	Underground (60%)	38	10.5	17.5	525
	Underground (50%)	38	10.5	21.0	630
c. 60 to 65	Underground (60%)	35	11.4	19.0	570
	Underground (50%)	35	11.4	22.8	684

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TABLE 8-4

ESTIMATED PRODUCTION AND RESERVES REQUIRED FOR 4.2 MILLION METRIC TONS PER YEAR (TPY) OF A 40 PERCENT ASH FEEDSTOCK

Raw Coal Ash Content, %	Mining Method (recovery)	Wash Method Recovery, %	Annual Mine Production, 10^6 TPY	Required Annual Reserves, 10^6 ST	Required 30 yr Reserves, 10^6 ST
a. 40 to 46	Underground (60%)	95	4.4	7.4	221
	Underground (50%)	95	4.4	8.8	264
b. 50 to 55	Surface (90%)	52	8.1	9.0	270
	Surface (80%)	52	8.1	10.1	303
	Underground (60%)	52	8.1	13.5	405
	Underground (50%)	52	8.1	26.2	486
c. 60 to 65	Underground (60%)	49	8.6	14.3	429
	Underground (50%)	49	8.6	17.2	516

8.2.5.2 Volume Recovery. Volume recoveries after washing of the three different raw coals are approximated as follows:

	Raw Coal (Dry Basis)		Feedstock Weight Recovery (Dry Basis), %		
	% Ash	% Carbon	30% Ash 40% Carbon	35% Ash 37% Carbon	40% Ash 33% Carbon
a.	43	32	73	83	95
b.	52	26	21	38	52
c.	62	19	18	35	49

As is evident, the better weight recoveries occur with the lower ash raw coals typical of the Leao area.

8.2.5.3 Carbon Recovery. The weight percentage of carbon recovered after washing similar amounts of raw coal may be:

	Raw Coal (Dry Basis)		Feedstock Carbon Recovery (Dry Basis), %		
	% Ash	% Carbon	30% Ash 40% Carbon	35% Ash 37% Carbon	40% Ash 33% Carbon
a.	43	32	92	96	100
b.	52	26	33	54	68
c.	62	19	37	67	85

The lower-ash raw coals typical of the Leao area present better carbon recoveries. The apparently better carbon recovery for the 62 percent ash raw coal over the 52 percent ash raw coal may be related to the manner in which the ash is incorporated into the coal seams. It also emphasizes the need to investigate the individual coals rather than depend on general extrapolations of data to other areas.

8.2.5.4 Moisture Content. There is no specific data on coal moisture content available from all areas. However, the moisture content may fall within the range of 9 to 14 percent, if the washed coal analyses in the Jaakko Poyry report are representative.

8.2.5.5 Size Consist. The size analyses of the various coals are generally unknown; however, observations at Brazilian mines indicate that 40 to 50 percent of the mined coal will be smaller than 1/4 inch (6.35 mm) in size, regardless of the original coal quality.

8.3 RESOURCE DESCRIPTION

8.3.1 Introduction

This section of the report presents existing data on Brazilian coals as compiled by Jaakko Poyry. Abbreviations used herein are shown in Appendix A.

8.3.2 Present Reserves

The intense research carried out during the recent years in prospecting and evaluation of coal mines in Brazil shows today's reserves as sevenfold the figures available six years ago.

The occurrence of coal was detected in the regions of Amazonas, Para, Maranhao, Rondonia, Bahia, and in the sedimentary basin of Parana. However, only the latter has deposits with economic significance.

The total coal reserves in situ in the Parana Basin are as follows:

2 200	million tons measured
4 462	million tons indicated
16 152	million tons inferred
22 814	million tons total reserves.

More detailed figures are presented in Appendix B, Table B-1.

8.3.3 Present Production

The Brazilian production of coal run-of-mine (ROM) during 1980 was around 16 million tons. The production of washed coal reached close to 5 million tons, out of which 3.7 million corresponds to steam coal for industrial and power station purposes, and 1.3 million tons corresponding to coking coal.

The state of Rio Grande do Sul contributed 33.2 percent to the total production of washed coal (including coking coal), while the states of Santa Catarina and Parana contributed 62.7 and 4.1 percent respectively. Detailed information about coal production during 1980 is shown on Appendix B, Tables B-2 and B-3.

The ratio between run-of-mine coal and usable coal is quite variable, being 65.4 percent for Rio Grande do Sul, 23.3 percent for Santa Catarina, and 65.6 percent for Parana.

Steam coal production figures in the Southern States are gathered in Table 8-5 and Figures 8-2 and 8-3.

TABLE 8-5

STEAM COAL PRODUCTION IN SANTA CATARINA AND RIO GRANDE DO SUL - 1980

STATE/MINE	TONS	TONS
Santa Catarina		
Lav Capivari	1 784 822	
Carb. Prospera	41 533	
Carb. Criciuma	13 457	
Subtotal		1 839 812
Rio Grande do Sul		
CRM Leao I	243 279	
Candiota	471 979	
COPELMI Recreio	617 702	
Charqueadas	320 941	
Subtotal		1 653 901
TOTAL STEAM COAL		3 493 713

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8.3.4 Types of Coal

8.3.4.1 Santa Catarina. In Santa Catarina State, nearly all the run-of-mine (ROM) coal undergoes a prewashing from the mine then being sent to the washer at Capivari, where the following qualities are recovered:

CM	-	coking coal	-	16 percent ash
CV35	-	steam coal	-	35 percent ash
CV40	-	steam coal	-	40 percent ash

There is only a small amount of steam coal prepared directly by two mining companies and sold as CV35, with 35 percent ash.

8.3.4.2 Rio Grande do Sul. The coal qualities produced by the mining companies of Rio Grande do Sul State are the following:

CV35	-	steam coal, 35 percent ash -- for cement industry
CV40	-	steam coal, 40 percent ash -- for industrial uses
TECH coal	-	ROM steam coal for Power Station of Charqueadas
CV52/54	-	ROM steam coal for Power Station of Candiota

The Leao mine produces a fraction of CV20 (20 percent ash) for a specifical cement industry of Rio Grande do Sul State.

8.3.5 Users

In 1980 the demand of steam coal was 3.5 million tons. Major consumers were power plants and the cement industry with 1.8 million tons (51.8 percent) and 1.05 million tons (29.9 percent) respectively.

Other significant consumers were the ceramics, steel works, and pulp and paper industries.

Figure 8-4 shows consumer demand by industry in the steam coal in Brazil in 1980.

Figure 8-2
TOTAL BRAZILIAN (ROM) COAL PRODUCTION – 1980

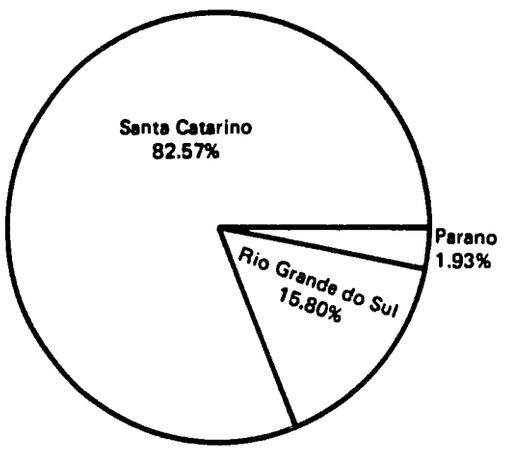


Figure 8-3
TOTAL BRAZILIAN STEAM COAL PRODUCTION – 1980

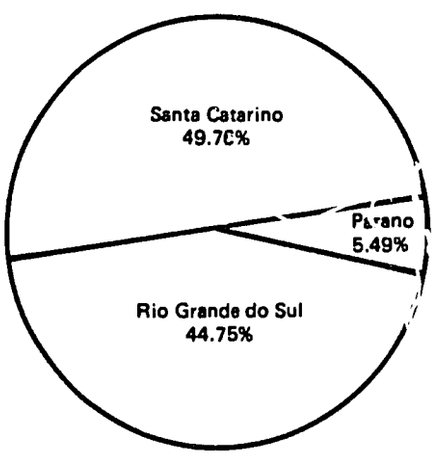
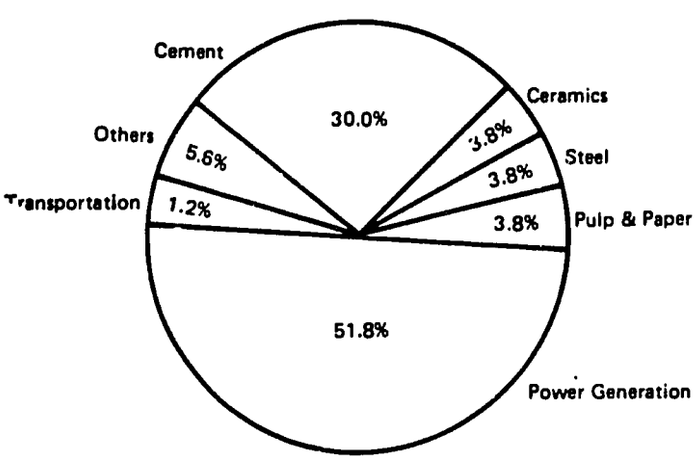


Figure 8-4
TOTAL BRAZILIAN STEAM COAL DEMAND PER TYPE OF CONSUMER – 1980



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8.3.6 Brazilian Government Expansion Plans

The Brazilian Federal Government has established, through the proper entities, the policy to be followed and targets to be met to comply with the Brazilian Energy Program for the next five years, involving substitution of imported energy sources (oil).

The Government official entity responsible for the execution of the coal program is the Companhia Auxiliar de Empresas Eletricas Brasileiras (CAEEB). The policy is set by Conselho Nacional do Petroleo (CNP).

Target contribution of national coal is the replacement of 110 000 daily equivalent barrels of oil, in 1985, by the equivalent 14.6 million tons of steam coal per year.

The projected supply (target) of Brazilian mineral coal in 1985 is 19.7 million tons: 16.8 million of steam coal and 2.9 million of coking coal. Detailed information about Government plans are presented in Appendix B, Table B-4.

8.3.7 Detailed Implementation Plans, Production

There have been 28 proposals of mining projects presented to CAEEB, 11 of which are in Rio Grande do Sul, 16 in Santa Catarina, and one in Parana State.

These proposals correspond to a gross production of 40.7 million tons in 1985. Usable coal totals 14.7 million tons, of which 13.2 million tons are of steam grade, and 1.5 million tons are of coking coal.

This production increase added to the present production totals 19.7 million tons: 16.8 million of steam coal and 2.9 million tons of coking coal.

8.3.7.1 Projects Analyzed/Approved. Up to September 1981, 13 projects of coal mines had been forwarded to the Ministry of Mines and Energy, after being analyzed by CAEEB.

Some of those have already been approved and Government financing has already been given; thus, four in Rio Grande do Sul and seven in Santa Catarina are already being implemented.

The two others still await approval but are expected to be in full production by 1985.

Those projects will add 23.9 million tons ROM after 1985 to the present Brazilian coal production, thus resulting in an increase of 8.93 million tons production of steam coal.

The 15 remaining proposed projects, adding up to the planned 16.8 million tons of steam coal, are still being kept on hold by the mining enterprises, with no implementation schedules, as the miners themselves are not sure coal demand is adequate.

8.3.7.2 Effective Expected Coal Production. Considering present production figures and planned expansions, it is possible to forecast Brazilian coal production in 1985, based on data presently available and information gathered from the mine companies.

Considering that by 1985 some mines will be exhausted (only in Santa Catarina), 3.1 million tons ROM meaning 0.71 million tons steam coal must be subtracted from the present production.

So, in 1985 the situation shown in Table 8-6 may be expected. More detailed information is shown in Appendix B, Table B-5.

TABLE 8-6

EXPECTED COAL PRODUCTION IN 1985

DESCRIPTION	ROM 10^3 tons/year	STEAM COAL 10^3 tons/year
Present production - 1980	16 000	3 700
Mines exhausted up to 1985	- 3 100	- 710
New projects planned to be producing up to 1985	23 900	8 930
Recreio (expansion)	2 100	1 200
Expected coal production in 1985	38 900	13 120

Considering the Government target to produce 16.8 million tons steam coal in 1985, there is still a deficit of nearly 3.5 million tons steam coal between the production targets planned and the expected available coal production.

8.3.8 Characteristics of Rio Grande do Sul and Santa Catarina Coals

8.3.8.1 Rio Grande do Sul Coals. Results of tests made on samples of coals presently being mined in Rio Grande do Sul indicate that these coals:

- Showed a high percent of inorganic matter, the ash varying between 46 and 59 percent with an average of 51 percent. Smallest figure corresponds to the coal from Leao and the highest to coal from Charqueadas;

- Showed the following ash content variation range according to in situ sampling:

  Candiota

Upper seam	51.4 to 53.5 percent
Lower seams	49.1 to 52.4 percent

  Charqueadas

Seam I_1F.	51.7 to 67.5 percent

  Leao

Lower seam	35.4 to 51.8 percent

  Recreio

Upper seam	44.0 to 54.9 percent
Lower seam	51.0 to 64.2 percent

- Showed, in case of global sampling, a high heating value between 3 200 and 3 850 cal/g. Leao shows the highest heating value;

- Cannot become coke by conventional processes. All coals analysed present a Free Swelling Index (FSI) equal to zero, when determined on raw samples. In the tests made on fractions floated on a liquid with density 1.5, a FSI of 1/2 was obtained for coal from Recreio mine - Upper Seam (with approximately 21 percent ash), which is not significant. During the dilatometric tests this coal showed a maximum contraction of 8.3 percent at 43°C, while the other coals did not show any contraction or dilation;

- Showed sulfur contents varying between 0.4 and 2.6 percent for global samples, which can be considered low to moderate. Besides, they contain some combined sulfur in the pyritical form, and are therefore capable of being reduced by gravimetric washing. The coal from Charqueadas showed the lowest sulfur content, lower than 0.5 percent for all samples (by weight);

- Are easily reactive. The reactivity is higher than for cokes from highly volatile coals, normally used in Europe for the production of city gas, indicating that they could be more rapidly and easily gasified than the latter;

- Have a relatively high specific gravity, between 1.9 and 2.1 g/cc which is in agreement with the high inorganic material content;

- When washed coals with ash contents of 20 to 30 percent are required, coals from the Leao and Recreio mines showed the highest weight yields, according to sink/float tests of coal fractions in the one-inch x 28-mesh size.

- Showed a Hardgrove Grindability Index (HGI) between 62 and 107 indicating a moderate to good grindability. The higher the HGI, the better the grindability. Coal from Candiota showed the highest values (around 110);

- Their ash has a high melting point (minimum was 1 390°C in oxidizing atmosphere) with a softening point between 1 390 and 1 490°C for the same conditions;

- Their ash was mainly composed of silica and alumina (SiO_2 + Al_2O_3), the sum varying between 85.0 and 92.6 percent. The high silica contents of ash, which varied between 58.2 and 71.2 percent, must be considered for the selection of grinding machinery.

Figures concerning characteristics of these coals are presented in Appendix B, Table B-6. Washability curves are shown in Appendix C, Figures C-1 through C-6.

8.3.8.2 Santa Catarina Coals. The coal deposits are in two main seams, called Barro Branco and Bonito.

Presently, all the mines explore only the first seam, Barro Branco, located above the Bonito seam. The coal from the Barro Branco seam has a reasonable FSI index; it is thus washed, and a "metallurgical" part is recovered having 16 percent ash and sent to the steel works to produce coke.

The other two products of the washing stage are steam coals, with 35 and 40 percent ash respectively, and designated as CV35 and CV40.

This represents the flow and usage of the coal currently mined in Santa Catarina.

The Bonito seam represents a good potential for development, not mined yet (at least in significant amounts), considering that it has more reserves than the other seam. The only economically feasible recoverable coal in the Bonito seam is a steam coal with 40 percent or more ash content. Tests already made show that the coal from Bonito is more suitable for gasification, as it has lower caking tendencies.

Tables B-7 and B-8 of Appendix B show characteristics of Santa Catarina coals. Washability curves are shown in Appendix C, Figures C-7 through C-9.

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8.3.9 Specific Data On Some Deposits and Mines Of Rio Grande do Sul and Santa Catarina

8.3.9.1 Candiota Deposits. The Candiota deposit is the largest known coal deposit in Brazil. It is located in the Southwest region of Rio Grande do Sul State, in the counties of Bage, Pinheiro Machado, and Herval (see Appendix D Map 1). The total coal reserves "in-situ" are estimated as over 8 000 million tons considering the Candiota seam only.

The coal is classified as a bituminous type with highly volatile, noncokeable carbon. It contains about 52 percent ash, an average content slightly below 2 percent sulfur, it is friable, poorly washable, and it has a good reactivity.

The surface exploitation has been done for over twenty years. Presently all the coal mined is being used for power generation in the President Medici power plant, with an installed capacity of 126 MW. Companhia Riograndense de Mineracao (CRM) is in charge of the mining and produces 600 000 tons of ROM coal which is used without prior washing by Companhia Estadual de Energia Eletrica (CEEE).

There is, in general, the occurrence of 10 to 12 seams of coal in the Grande Candiota region. Of these, only the Candiota seam has been mined, which is the most important considering thickness and surface area. The average thickness of Candiota seam is between 2 and 6 meters.

As far as it is known today, some 20 to 30 percent of the deposit can be surface mined. The maximum known depth for the Candiota seam is 270 meters.

CRM is planning to explore a new open pit mine, Candiota II. The planned mine will produce 4 million tons per year of ROM coal in 1984. The washed coal recovered will amount to 2.4 million tons of CV52 (52 percent ash) for Candiota II Power Station, and 1.0 million tons of CV35 (35 percent ash) for the cement industry.

Concerning the Candiota III Power Station (first phase: 24 350 MW), a new open pit mine is scheduled for 1986/87, supplying 4.3 million tons per year of CV52 (52 percent ash) for the power station and 2.0 million tons per year of CV35 (35 percent ash), for industry.

8.3.9.2 Irui Deposit. Irui is located south of Cachoeira do Sul and Rio Pardo and has an area of 400 km^2 with total reserves of 1 162 million tons of coal.

There are two seams, with thickness varying from 1.5 to 3 meters. In some places in the south side, the seams reach the surface and go down gradually towards the north, reaching depths of 400 meters.

CRM has the concession for a mine in Irui and is expected to mine 780 000 tons per year of ROM coal in 1981 and 1 560 000 tons per year from 1982 on. The mine will be an open pit mine, and the deposits within the concession amount to 120 million tons.

8.3.9.3 Leao - Butia Deposit. The deposit is in the counties of Butia and Rio Pardo. Several small mines have operated in the thirties; in the eastern part, remaining reserves are minor (COPELMI has the concession there and operates a mine in Recreio). CRM has a mine - Leao I - in operation in the southern part and is preparing to start Leao II, where the coal is 100 to 220 meters deep.

There are two to three seams superimposed in most places. Depths are small in the south, reaching 400 meters in the northeast part. Reserves were estimated as 883 million in 1978 and recent surveys have increased this figure by 20 percent. Leao - Butia has the best quality coal of all deposits in Rio Grande do Sul. The seam characteristics vary quite a lot, but coals with ash content from 20 to 52 percent can be obtained with washing. Of course, the smaller the required ash content is, the smaller will be the percent recovery.

8.3.9.4 Charqueadas Deposit. This deposit is in the lower part of the Jacui River basin, between Canoas and Sao Jeronimo. The coal seams form a trough going from west to east, with depths of 400 meters in the middle. Only a small portion in the southeast corner (Guaiba area) is near the surface, making open pit mining possible.

There are three main seams, a few meters apart vertically, and partially superimposed. Reserves were estimated in 1978 as 1 318 million tons of high ash content coal, but new extensions to the northeast (Santa Rita) and southeast (Guaiba) have been discovered since.

COPELMI has the concession in almost all the area. Its mine in Charqueadas sells ROM coal with 52 percent ash to the Charqueadas Power Plant. Washing characteristics are not as good as for Leao - Butia coals, but coals down to 35/40 percent ash content have been obtained in accordance with buyer specifications.

COPELMI is planning mines in Triunfo and Guaiba.

8.3.9.5 Morungava Deposit. This was the first metallurgic coal deposit discovered in Rio Grande do Sul. It is located near the village with the same name, slightly east of Gravatai.

There are three main seams, with a vertical spacing of a few meters, and four more seams of smaller value. The depth varies gradually from 200 meters in the south to 600 meters in the north.

The coal reserves amount to 658 million tons, including the small deposits near East Gravatai and West Gravatai. From this coal, about one third of metallurgic coal of quality similar to that presently mined in Santa Catarina and used for coking can be separated after washing. The remaining two thirds are made up of steam coal of variable qualities, according to the seam.

The southern part of Morungava deposit, under concession to COPELMI, is being surveyed in detail so as to prepare an exploitation plan as soon as possible.

8.3.9.6 Chico Loma Deposit. This is a large deposit of metallurgic coal discovered in 1978. It is located south and southwest from the town of Santo Antonio, and is an extension of the Morungava deposit.

There are two main, thick seams, nearly totally overlapping, besides other less important ones. The depth varies from a few meters in the south to 600 meters near Santo Antonio.

Coal reserves amount to 824 million tons. The seams have heterogeneous features. Washing can separate an average of 40 percent of metallurgic coal of quality similar to the one presently mined in Santa Catarina and used for coke. The remaining part is steam coal of variable grade, according to the seam.

Most of the deposit is located in areas being surveyed by CPRM. Presently the boring grid is spaced by 1 to 4 kilometers. The reserves already identified permit the installation of large underground mines.

8.3.9.7 Deposits in Southern Santa Catarina. Coal has been known in southern Santa Catarina since the last century, mining having started before the First World War. Up to 1970, only medium to low depth seams were considered, close to areas being mined, having in mind medium and short range planning for the existing mines. Studies carried out by DNPM/CPRM have consolidated the area on the deposits, have permitted an approximate shaping on the limits, have duplicated the reserves and detailed the most favorable sectors up to one kilometer or, in exceptional cases, to 0.4 km grid.

The most important seam is the Barro Branco seam which has an extended and broken emerging line, and was mined by small companies in the first half of the 20th century. The total width of the seam is close to 100 km, from the cliffs of Serra Geral moving south toward the Atlantic Ocean under which it sinks. The 80 mining firms existing before 1950 gradually merged into the present enterprises (see Appendix D, Figure D-2):

State owned: Carbonifera Prospera S.A.
Carbonifera Barao do Rio Branco

Privately owned: Carbonifera Metropolitana S.A.
Carbonifera Criciuma S.A.
Companhia Nacional de Mineracao de Carvao Barro Branco
Companhia Brasileira Carbonifera de Ararangua
Companhia Carbonifera Urussanga
Companhia Carbonifera Treviso S.A.
Companhia Carbonifera Palermo S.A.

In parallel with the merging, the mine size has increased up to units producing over 500 000 tons per year of washed coal.

The coal reserves of the Barro Branco seam amount to 847 million tons. These reserves are being mined producing equal fractions: CM_{16} (metallurgic coal with 16 percent ash employed to make coke, recently changed from 18.5 percent ash to 16 percent ash), and CV40 or CE40 (thermo-electric coal or energetic coal with 40 percent ash used for generation, cement manufacture, and miscellaneous industrial purposes).

Since the Barro Branco seam coal is finely interlaid with sterile material, each ton of washed coal requires the extraction of 3 tons of ROM coal in average.

Until now, the coal from this seam was produced mainly for its metallurgic fraction. The 1.3 million tons of coking coal produced in 1980 covered about 20 percent of the consumption of coke for the Brazilian steel mills. Demand of the energy fraction was invariably lower than production, causing the formation of large stocks. From 1980 the replacement of fuel oil by coal has started in earnest especially in the cement industry, and there is thus a tendency now towards the increased use of this portion.

The depth of Barro Branco seam varies between zero, in the northeast as mentioned earlier, to about 400 meters close to Ararangua. Thirty to 70 meters below the Barro Branco seam there is another important coal seam - Bonito. The reserves are 1 264 million tons, in three main locations: west from Lauro Muller, between Criciuma and Ararangua and on both sides of Mampituba River. The seam is thick, in some parts exceeding 3 meters. The depth grows from NE to SW: the seam emerges in some points close to Lauro Muller, Urussanga, and Icara and reaches 1 100 meters under the sea level southwest from Torres.

The quality is quite different from the Barro Branco seam and varies with the location from north to south, the average ratio CM/CE (CM = coking coal, CE = steam coal) is 1:8 west from Lauro Muller, 1:4 south from Criciuma, and 1:2 close to Torres. Because of this reason, the Bonito seam was only occasionally mined in the locations of easiest access. The recent expansion in demand of energy coal increased its importance. In several sectors detailed boring grids have been done, to define exploitation plants to be implemented between 1982 and 1985. The southern part of the deposit, due to its larger depth, is not expected to be exploited before the end of the present decade.

The Irapua seam exists in some specific places 7 to 15 meters below Barro Branco and contains coal of similar quality.

The exploitation has been done with good economic results, but the reserves are of minor importance in national terms.

The Ponta Alta seam is located a few meters above Bonito in two isolated points: close to Torres and south from Icara. The estimated reserves, of about 119 million tons, have not been studied with more detail due to its poor quality, to the depth of the seam, and to the small seam thickness close to Icara.

Typical coal analyses from the Capivari Washer Plant are shown in Appendix B, Table B-9.

Maps with the location of the principal reserves and mines of Rio Grande do Sul and Santa Catarina States are shown in Appendix D, Figures D-1 and D-2.

8.3.10 Coal Distribution - The Role of CAEEB

Companhia Auxiliar das Empresas Eletricas Brasileiras (CAEEB) is responsible for the marketing of all the coal produced in Brazil. CAEEB is thus involved in purchasing, transport, handling, storage, selling, and delivery of the coal.

All Government entities related directly with the transport infrastructure, i.e., PETROBRAS, RFFSA, EFRD, Charters, etc., act under CAEEB coordination.

The coal price policy is determined by the National Petroleum Council (CNP) and executed by CAEEB. Coal price is defined in cruzeiros every six months and remains fixed through the semester. For the purposes of the economic analysis the coal feed price in U.S. dollars is that forecast for the mid-point of the first semester of 1982.

The present pricing policy allows for two subsidies, one for the coal price itself, and the other for transportation.

The customer pays only 70* percent of the amount paid to the producer; in addition to that, the transportation costs to the several CAEEB warehouses all over Brazil are paid for by CAEEB.

The Government policy foresees a gradual extinction of the subsidies. However, the subsidies will only be withdrawn after similar subsidies for fuel oil are also withdrawn.

The coal price structure in Brazilian cruizeiros for the period July 1, 1981 through January 1, 1982 is illustrated in Section 9.

*Recently changed to 80 percent, indicating a reduction of the coal price subsidy.

9.0 COAL MARKET

9.1 TYPES OF COAL

Two basic types of coal are used in Brazil: coking coals and the so-called steam coals.

Coking coals have been the more important in the past. They are used in steel works to produce coke, after mixing with imported coals. They are a specially prepared type of coal, with 16 percent ash and a suitable Free Swelling Index (FSI), and are produced only in the state of Santa Catarina. Demand for coking coals is not expected to grow substantially in future years, as it depends on steel demand. Considering that the reserves of this coal are not large, and considering its use as a substitute for imported coal, all production of coking coal is assigned by the Brazilian Government to supply the steel works demand as a strategic necessity.

Steam coals include all other coals, and are expected to dominate the coal market in the future. A large growth is forecasted for steam coal demand, according to the Brazilian Energy Program, as a substitute for fuel oil. Steam coals cover basically three subtypes of coal: CV 35, CV 40, and CV 50.

CV 35 is a washed coal with 35 percent ash, to be used in the cement industry for fuel oil substitution. Recovery rates in washing depend on the specific process and on the source of the ROM coal.

CV 40 is also a washed coal, with 40 percent ash, meant to replace fuel oil in industry in general. It is also used in power stations (i.e., Jorge Lacerda Power Station in Tubarao, SC).

CV 50 may be either a ROM coal or a recovered fraction of the washing process. It is used only in thermoelectric generation and has an average content of 50 to 52 percent ash.

9.2 EVOLUTION OF COAL DEMAND

With the exception of power generation, coal in Brazil has had significance as an energy source only during the last five years. Production in Santa Catarina has always been oriented to obtain coking coal. The only user of the CV 40 obtained as a by-product of the large washing plant in Tubarao has been the Jorge Lacerda Power Station, near the washing plant.

Production of steam coal historically has exceeded demand by far, and stocks of unsold coal have piled up.

In Rio Grande do Sul, for many years the only coal users were two local power stations, Candiota and Charqueadas.

It was only after the first oil crisis that some industrial sectors started to consider coal as an energy source.

After 1976 the demand pattern started to change, and some new users became an increasingly significant part of the total demand, as shown in Table 9-1. It is thus possible to foresee an important role for the new users and, as shown later, the power generation users are expected to consume only 48 percent of coal demand by 1985.

The market share for the different types of coals in the last five years is presented in Table 9-2, where the increasing market share of CV 35, mainly used in the cement industry, can be seen.

The amounts of coal sold are at present are quite close to the amounts produced, following the start-up of the new units of the Jorge Lacerda Power Station, and the increasing demand of the cement and the pulp and paper industries.

In 1981, with the sale of the coal that has been stockpiled for many years in Santa Catarina, total coal sales are expected to be higher than actual production.

This new trend, in which demand is catching up with production, can be seen in Figure 9-1.

9.3 PRESENT DEMAND

The last available figures for coal demand (1980) are presented in Table 9-3, per user sector and type of coal.

A more detailed study of the expected development of demand for each sector will be shown in Section 9.5, but some introductory comments are presented here.

1979 and 1980 were particularly bad years for the thermoelectric sector due to a big surplus of installed capacity of hydroelectric power. Although some new thermoelectric units started up in this period (Jorge Lacerda Power Station - Phase 3), all the thermoelectric power plants had very low utilization rates. This situation changed in 1981, and it is thus possible that coal demand in this sector will grow in future years even though installed capacity remains the same.

The coal consumption indicated for the steel mill sector covers only energy purposes, in steam boilers and furnaces, and one mill that uses coal for direct reduction.

Transportation uses refers to coal consumed in the Thereza Cristina Railway, which still uses coal-fired steam engines, and transports all the coal in the state of Santa Catarina.

Other users are general industrial users in the southern and southeastern states.

TABLE 9-1

STEAM COAL DEMAND STRUCTURE (1976-1980)
(1 000 ton)

CONSUMER SECTOR	1976 ton	1976 %	1977 ton	1977 %	1978 ton	1978 %	1979 ton	1979 %	1980 ton	1980 %
Traditional Users	1358	91	1583	82	2639	86	2236	73	2019	57
Power Generation	1258		1512		2558		2144		1840	
Transportation	26		32		39		38		44	
Direct Reduction	74		39		42		54		135	
New Users	142	9	347	18	434	14	818	27	1506	43
Cement	130		316		385		700		1056	
Others	13		31		49		118		450	
TOTAL	1501	100	1930	100	2073	100	3054	100	3525	100

TABLE 9-2

BREAKDOWN OF THE COAL MARKET

YEAR	COKING COAL, %	STEAM COAL, %			TOTAL, %
	CM	CV35	CV40	CV50	
1978	25.7	10.0	32.8	31.5	100
1979	25.4	11.1	36.9	26.6	100
1980	25.8	22.1	29.5	22.6	100
1981	19.1	37.8	21.9	21.2	100

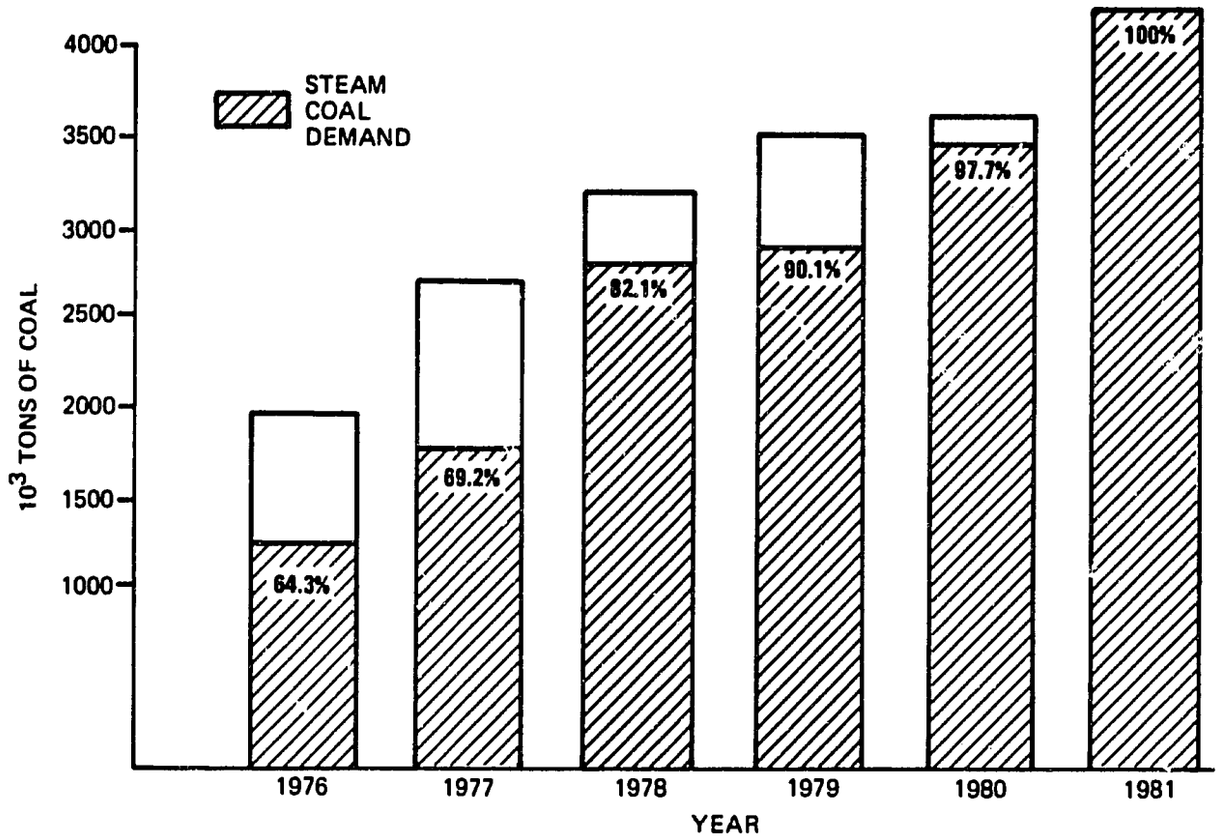

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FIGURE 9-1
STEAM COAL PRODUCTION/DEMAND RATIOS

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TABLE 9-3

STEAM COAL SOLD IN 1980
(1 000 ton)

CONSUMER AREA	CV 35	CV 40	CV 50	TOTAL (10^3 ton)	TOTAL (%)
Thermoelectric	139.3	867.0	833.4	1840	52.0
Transport	43.9	-	-	44	1.4
Cement	688.7	367.2	-	1056	30.0
Steel Mills	31.9	8.6	95.6	136	3.9
Pulp and Paper	126.1	7.1	-	133	3.8
Ceramic	7.9	124.0	-	132	3.7
Other	4.1	180.0	-	184	5.2
TOTAL	1042	1554	929	3525	100.0

9.4 DISTRIBUTION INFRASTRUCTURE

Companhia Auxiliar de Empresas Electricas Brasileiras (CAEEB), a public company subordinated to the Ministry of Mines and Energy through National Petroleum Council (CNP), is responsible for the marketing of all the coal produced in Brazil. CAEEB is thus involved in purchasing, transporting, handling, storing, selling, and delivering the coal.

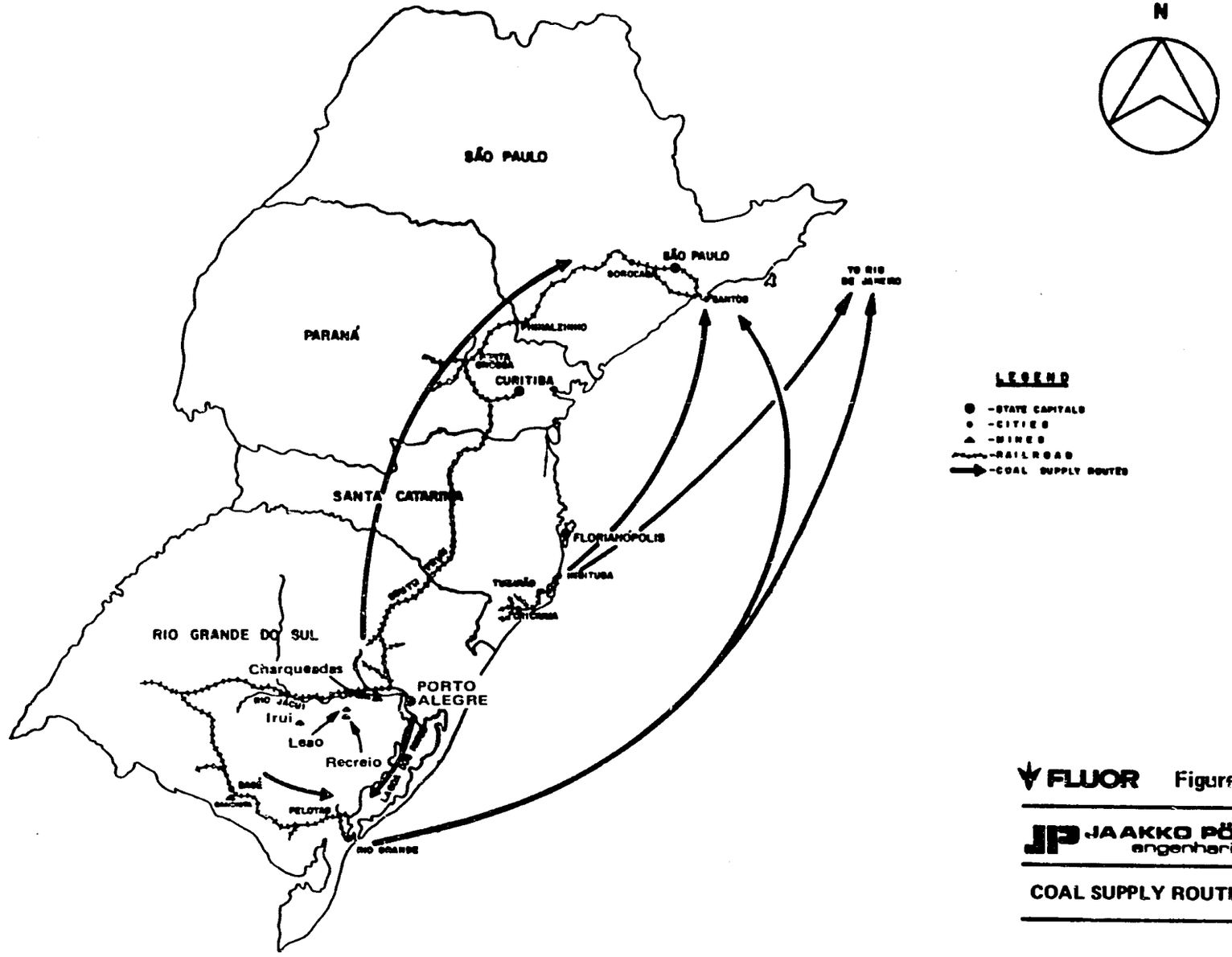
All government entities related directly with the transport infrastructure, i.e., PETROBAS, RFFSA, EFVRD, Charters, etc., act under CAEEB coordination.

The coal pricing policy is determined by CNP and executed by CAEEB.

Among the various activities and coordination performed by CAEEB, two have a vital importance, and are discussed in detail as follows:

9.4.1 Transport

Coal has to be transported from the production areas to the CAEEB warehouses close to the main users. Coal transport is a responsibility of the Transportation Ministry, that is preparing the projects necessary to enlarge and improve the transportation network. Feasible routes of coal transportation are given in Figure 9-2.



FLUOR Figura 9-2

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COAL SUPPLY ROUTES

9.4.1.1 Railway. Railway transportation of coal is expected to experience large growth as it is the chief distribution route for the coal produced in the Jacui region.

Railways in Brazil are state-owned, and in the southern states, two companies are involved, RFFSA and FEPASA: the first, a federal company, operates in Rio Grande do Sul and makes the connection to S. Paulo; the second, state-owned, operates in Sao Paulo. Figure 9-2 presents relevant routes.

About 200 000 tons per year of coal are being shipped by the RFFSA southern trunk line into the state of S. Paulo. This amount corresponds to 37 percent of the total load handled (540 000 tons per year) by this line in 1980. The coal shipped through the southern trunk is expected to reach 1.4 million tons per year in 1985, for the cement industry only. This amounts to three times the present total capacity.

The railway network thus needs sizeable investments to be able to handle these additional flows. Some action is already being taken by the Transportation Ministry, but basically everything is still to be done. Many doubts have been expressed about the feasibility of transporting the forecasted coal production, as no major improvements on the railway system have actually started.

The three main items of transportation required are:

- Enlargement of the fleet of rail cars and locomotives
- Modernization of the southern trunk line with basic improvements
- Construction of new sidings to reach the mines

9.4.1.2 Water Transportation. Figure 9-2 shows the two water transportation routes used to ship coal from mines to warehouses. The first one applies to all coal produced in Santa Catarina. From the port of Imbituba, coal is shipped to the ports of Santos and Rio de Janeiro. In 1980, 560 000 tons of steam coal were delivered this way. All coking coal (1.3 million tons in 1980) produced was also shipped to the steel works by the same route. From the port to the final users (or to warehouses located farther away), coal is transported either by train or truck.

Presently, the fleet operates with 11 coal transport ships, and two more will be added by 1982, totaling 290 000 ton gross capacity.

About 220 000 ton additional gross capacity will be required in order to meet the coal demand forecast for 1985.

The second route, with small present significance, is down the Jacui River to the CAEEB warehouse in Porto Alegre. Part of the production of the Jacui area mines (Leao, Irui, and Recreio) are presently shipped through this route.

It is expected that most of the coal produced in the Jacui area will be barged in the future down the Jacui, and there cross the Lagoa dos Patos to the port of Rio Grande do Sul, where it will be transshipped to ocean-going ships taking it to Santos and Rio de Janeiro.

Approximately 1.1 million tons of general freight were transported by barges down the Jacui in 1981, and this flow is expected to increase to 5.0 million tons in 1985.

To meet this target, the total transportation capacity (barges) will have to grow to 500 000 ton gross capacity.

Table 9-4 presents a summary of transportation needs in 1985 according to the estimates made by CAEEB. It can be seen that 10.4 million tons (62 percent) of the 16.81 million tons of steam coal estimated as the demand in 1985 will be consumed outside the producing stages, thus requiring long distance transportation.

9.4.2 Warehouses

CAEEB has planned the installation of several warehouses to be able to handle the distribution of the huge increases in coal demand foreseen for future years.

The existing and planned warehouses are indicated in Figure 9-3.

9.5 COAL DEMAND PROJECTIONS

9.5.1 Initial Forecast

As stated in the Brazilian Coal Program, CAEEB identified in 1979 a total potential coal demand of 25.2 million tons per year by 1985. These figures covered all the existing and new coal users, i.e., power stations (including expansions and retrofit into coal), several gasification units, and all possible substitution of oil by coal.

Detailed figures for this demand by type of user are given in Table 9-5.

Demand figures for steel mills (coking coal) in Table 9-5 cover basically the three large steel mills in operation: COSIPA, CSN, and USIMINAS, and the new ones expected to be in operation in the next 5 years: ACOMINAS and TUBARAO.

Demand for steel mills (energy purposes) covers the same mills cited above, plus coal for direct reduction in the Acos Finos Piratini mill in Rio Grande do Sul.

Figures for the cement industry cover many individual users of CV 35 coal replacing fuel oil. According to the agreement signed between the

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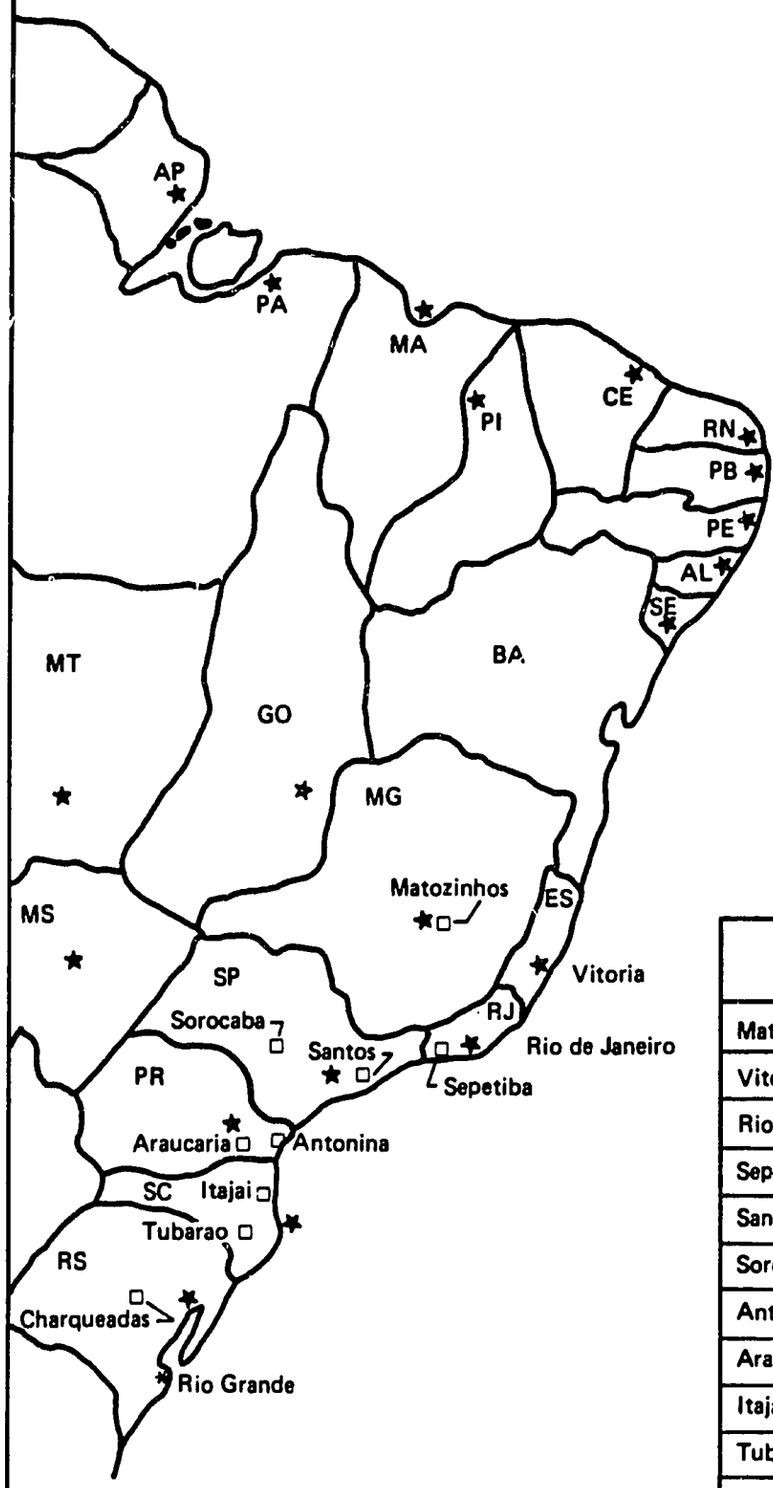
TABLE 9-4

STEAM COAL TRANSPORTATION SCHEME - 1985

SECTOR	WATER TRANSPORTATION FROM:	TO:	10^3TPY	RAILWAY TRANSPORTATION FROM:	TO:	10^3TPY	TOTAL 10^3TPY
Thermoelectric	Rio Grande	Santos	1 000				
		R.Janeiro	1 500				
Subtotal			2 500				2 500
Steel Mills	Rio Grande	Santos	260				
		R.Janeiro	330				
		Vitoria	620				
Subtotal			1 210				1 210
Cement	Imbituba	R.Janeiro	621	Recreio	Eng. Bley	410	
		Vitoria	752	Irui/Leao	Sorocaba	1 425	
		Salvador	107				
		Cabedelo	335				
	Rio Grande	R.Janeiro	619				
		Vitoria	737				
		Salvador	105				
		Cabedelo	329				
Subtotal			3 615			1 835	5 450
Pulp/Paper, Ceramic, Gasification, Others	Imbituba	R.Janeiro	90	Irui/Leao	Eng. Bley	270	
		Santos	170				
		Vitoria	200				
	Rio Grande	R.Janeiro	130				
		Santos	210				
		Vitoria	180				
Subtotal			980			270	1 250
TOTAL, tons per year (TPY)			8 305			2 105	10 410



* TO BE DEFINED

✱ STATE CAPITAL

□ COAL WAREHOUSES

CITY	AREA, m^2	STORAGE CAPACITY, TONS
Matozinhos	100 000	280 000
Vitoria	100 000	300 000
Rio de Janeiro	8 000	30 000
Sepetiba	80 000	200 000
Santos	50 000	160 000
Sorocaba	100 000	260 000
Antonina		80 000
Araucaria	40 000	140 000
Itajai	30 000	100 000
Tubarao		5 000 000
Charqueadas		100 000
Rio Grande	*	*

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FIGURE 9-3
LOCATION
AND CHARACTERISTICS OF
COAL WAREHOUSES

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TABLE 9-5

COAL DEMAND - INITIAL FORECAST
(1 000 tons per year)

SECTOR	COAL FROM S.CATARINA LOCAL	COAL FROM S.CATARINA OTHER STATES	COAL FROM RIO G. SUL LOCAL	COAL FROM RIO G. SUL OTHER STATES	TOTAL
Steel Mills (CM)		(8) 2400			2 400
Steel Mills			(1) 300	(2) 1 600	1 900
Cement	77	1 825	100	3 604	(3) 5 606
Thermoelectricity	1 300		2 300	2 500	6 100
Petrochemical			(4) 840		840
Gasification	(5) 1 900		(6) 1 245	(7) 1 300	4 445
Others	100		750	3 000	3 850
TOTAL	3 377	4 225	5 535	12 004	25 141

Notes:

(1) Direct reduction - Acos Finos Piratini Steel mill
(2) Heat generation in steel mills
(3) According to specific program with cement industry
(4) Demand of Copesul
(5) Sidersul steel mill, Le Gas Integral
(6) CRN, Carbogas (Petrobras)
(7) Gasification plant, CEG - (RJ)
(8) Coking coal for steel mills

government and the cement industry, the target is to replace 100 percent of the oil demand by coal up to 1985. The following demand figures were then established:

Area	Number of Plants	Tons per year
Rio Grande do Sul	2 plants	100×10^3
S. Catarina	1 plant	77×10^3
Parana	3 plants	391×10^3
S. Paulo	10 plants	1422×10^3
R. Janeiro	12 plants	1249×10^3
Minas Gerais	10 plants	1493×10^3
Bahia	3 plants	211×10^3
North	8 plants	663×10^3
Total		5606×10^3

Data for thermoelectricity in Table 9-5 include figures for the four existing power stations using coal:

Presidente Medici	(Candiota - RS)
Jorge Lacerda	(Tubarao - SC)
Charqueadas	(S. Jeronimo - RS)
Figueiras	(Cambui - PR)

A huge expansion is planned for the first station including some new units (duplication); and one new unit for Jorge Lacerda, resulting in a 50 percent increase in present coal consumption. The retrofit of two other power stations, Santa Cruz in Rio de Janeiro and Piratininga in Sao Paulo, have also been considered. At present, both are operating on oil and are expected to be adapted to coal around 1985.

Detailed demand figures for the sector are:

	Tons per year
Presidente Medici I/II	- 2 000 x 10^3
Jorge Lacerda	- 1 300 x 10^3
Charqueadas	- 300 x 10^3
Figueiras	- 250 x 10^3
Santa Cruz	- 1 250 x 10^3
Piratininga	- 1 000 x 10^3
Total	6 100 x 10^3

In the petrochemical sector the main user is COPESUL at the new petrochemical center of Rio Grande do Sul, representing a demand of 840 x 10^3 tons per year of steam coal for two boilers from 1983 on.

Gasification figures cover four big projects, the Sidersul steel mill in Tubarao, SC; the Le Gas Integrale plant in Criciuma, SC; the CEG plant in Rio de Janeiro (RJ); and the CRN (Petrobras) plant in S. Jeronimo, RS.

Sidersul would use the gas for direct reduction of ore. CRN is planned to produce ammonia and fuel gas to be used in Porto Alegre. The CEG project intends to substitute the naphtha-based gas presently supplying the city of Rio de Janeiro. The Le Gas Integrale plant is planned to substitute fuel oil in general industrial usage.

Under the heading "others" are presented demand figures due to oil substitution in the pulp and paper, ceramic, and food industries.

9.5.2 Revised Estimates

A formal review of the targets set in 1979 for the Coal Program, done by the Federal Government in 1981, indicated that the targets for production, demand, and transportation of coal were not being met. Not enough financing was made available, so not enough mines were started, and not one of the gasification projects was actually funded. Also, insufficient funds were assigned in the Federal budget for improvements in the transportation system. As a consequence, CAEEB established new, more realistic targets for 1985.

The new figures presented by CAEEB show 2.4 million tons per year of coking coal and 16.8 million tons per year of steam coal, totalling 19.2 million tons per year of coal for 1985. Latest information available indicates that even these new figures might not be met by 1985. Table 9-6 presents expected demand for coal in 1985, compared to the revised CAEEB figures.

TABLE 9-6

REVISED ESTIMATES, COAL DEMAND - 1985
(1 000 tons per year)

SECTOR	REVISED CAEEB ESTIMATES	EXPECTED DEMAND
Steel Mills (CM)	2 400 (1)	2 100
Steel Mills	1 210	400 (2)
Cement	5 560	3 336
Thermoelectricity	6 560	5 680 (3)
Petrochemical	840	840 (4)
Gasification	700	700 (5)
Others	1 940	1 200 (6)
TOTAL	19 210	14 256

Notes:

(1) Coking coal - Cosipa/CSN/Usiminas/Acominas
(2) Direct reduction - (Acos Finos Piratini) and oil replacement
(3) Power generation - Candiota I and II/Jorge Lacerda/Charqueadas/retrofit of Santa Cruz
(4) Copesul - steam generation
(5) CRN (Petrobras), in Sao Jeronimo and in Rio Grande
(6) Ceramic/pulp and paper/food industries

9.5.3 Future Coal Demand

The diagram shown in Figure 9-4 presents the three estimates mentioned above for 1985, and expected behavior of demand figures in the future can be inferred from the diagram.

Line (A) can be considered an optimistic forecast, only feasible if huge amounts of funds were assigned very soon to the Coal Program. Line (B) shows the forecast according to the latest Government goals, and can be considered an intermediate estimate.

Line (C) is the most probable estimate for future demand, and considers that, while the 25 million tons per year of the initial targets are not realistic for 1985, they are probably a fair order of magnitude assessment of coal demand by the end of this decade.

9.5.4 Coal Versus SNG

In several oil substitution plans, alternate energy sources have not yet been defined; consequently, both coal and SNG could be considered. Part of the oil demand in the steel industry, for instance, can be substituted by coal or by gas, and has been included in both demands. Gasification plants also count in both demands, that is, they are coal users, and at the same time supply the gas market. Consequently, figures for coal demand shown above should not be added to gas demand figures to obtain a total demand of coal-based energy. Figure 9-5 illustrates this consideration.

9.5.5 Coal Prices

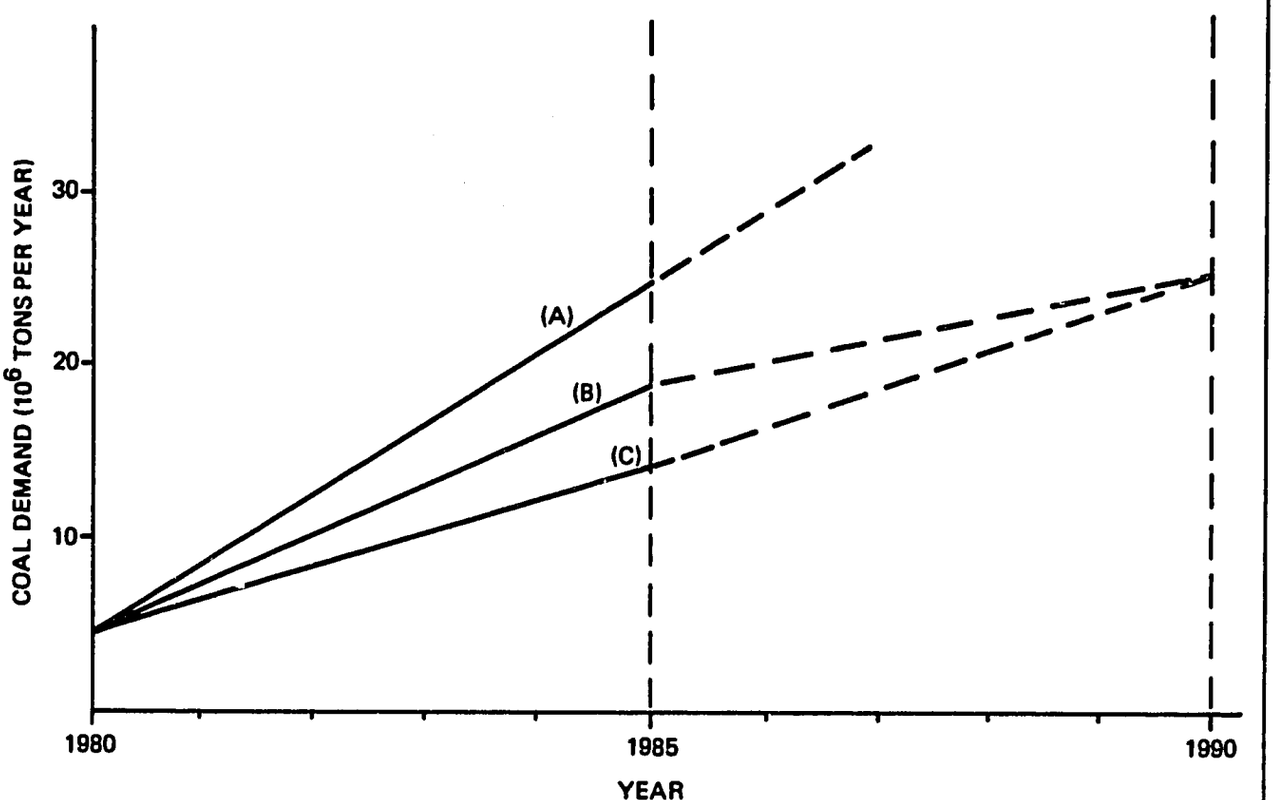
The coal pricing policy is determined by the National Petroleum Council (CNP) and executed by CAEEB.

The present pricing policy allows for two subsides, one for the coal price itself, and the other for transportation.

The customer pays only 80 percent of the amount paid to the producer as of January 1982. Prior to that date, the consumer paid only 70 percent of the amount to the producer; in addition to that, the transportation costs to the several CAEEB warehouses all over Brazil were paid by CAEEB.

The Government foresees a gradual extinction of the subsidies. However, the subsidies will only be withdrawn after similar subsidies for fuel oil are also withdrawn.

Prices set for the producers and consumers from July 1, 1981 are presented in Table 9-7.



LEGEND

(A) OPTIMISTIC ESTIMATE
(B) INTERMEDIATE ESTIMATE
(C) MOST PROBABLE ESTIMATE

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FIGURE 9-4
FUTURE COAL DEMAND

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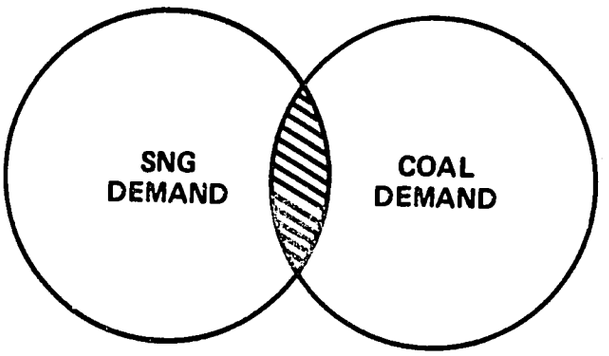

FIGURE 9-5

JOINT SNG/COAL DEMAND

The real cost to CAEEB of coal placed in the warehouses is at present the price paid to the producer plus the cost of the freight up to the warehouse, and this cost will tend to be, in the long run, the price paid by the consumer.

The transportation costs by railway, by truck, and by boat between different places of origin and destination are presented in Table 9-8.

In Table 9-9 the effective (real) cost of coal CIF Santos and Sorocaba warehouses has been estimated. The data shows that the effective cost of coal today, CIF CAEEB warehouses in Sao Paulo, is about 2.5 times the official price. The significant price difference should be taken into account in feasibility studies, as the subsidies will be withdrawn in the long run. The Economic Analysis performed as part of this study (Section 5.0) uses the subsidized price of coal, but sensitivities are shown reflecting the effect of reduction and of removal of the subsidies.

TABLE 9-7

PRICES OF BRAZILIAN COAL

VALIDITY: July 1st, 1981/January 1st, 1982

State Miner	Type/Mine/Situation	For Producer, Cr$/t	For Consumer, Cr$/t
RS/	ROM (Candiota)	655.66	460.00
CRM	CV 40 (Leao I)	4 271.00	2 990.00
	CV 35 (Leao I)	4 563.00	3 195.00
RS/	CV TECH 3100 (DB) FOB - Charqueadas	2 974.51	2 082.00
COPELMI	CV 4.400 (DB) FOB - Recreio	4 271.00	2 990.00
	CV 35 - 4700 (DB) FOB - Charqueadas	4 563.00	3 195.00
S.CATARINA	CV 40 (Sotelca) FOB - Capivari	3 870.77	2 710.00
	CV 35 Property of CSN/Cosipa/ Usiminas FOB - Capivari	4 644.92	3 252.00
	CV 35 Other Mines FOB - Mine	4 644.92	3 252.00
Parana	ROM (Dry basis) FOB - Mine	2 997.66	2 100.00
	Prepared (Dry basis) FOB - Mine	4 744.20	3 320.00

Note: US dollar rates: basis July 81 - CR $ 96.17/US$
October 81 - CR $114.83/US$

TABLE 9-8

TRANSPORTATION PRICE PER TON OF COAL
(US$)

	RAILWAY TRANSPORTATION					SHIP TRANSPORTATION			TRUCK TRANSPORTATION	
DESTINATION:	CAPIVARI	IMBITUBA	CURITIBA	SOROCABA	MOGI GUACU	ANTONINA	SANTOS	R.JANEIRO	P.ALEGRE	R.GALVAO
ORIGIN										
FIRST JOURNEY										
CRICIUMA	2.42	3.12								
URUSSANGA	2.42									
CAPIVARI		2.04								
CHARQUEADAS									5.94	
LEAO										6.41
SECOND JOURNEY										
IMBITUBA						20.56	23.17	22.69		
PORTO ALEGRE			15.74	24.51	27.51					
R. GALVAO				25.42	28.42					

SOURCE: RFFSA/CNP/CAEEB

Price basis October 1981

TABLE 9-9

REAL COST OF COAL, FOB S.PAULO WAREHOUSES
(US$/ton)

Type Coal/Origin	For Producer	Truck/Railway Freight to Sorocaba	Shipping Freight to Santos	Real Cost
CV 35/Leao	39.74	31.83	-	71.57
CV 40/Leao	37.19	31.83	-	69.02
CV 35/Capivari	40.44	-	25.21	65.65
CV 40/Capivari	33.71	-	25.21	58.92

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10.0 GASIFICATION BY-PRODUCT MARKET

10.1 INTRODUCTION

This report present considerations which define the potential market for gasification by-products.

The demand for oil, phenols, and heavy tars is not significant in Brazil, consequently they should be used as fuel inside battery limits of the gasification plant.

The market study thus covers briefly the following by-products:

- o Sulfur
  - Production capacity
  - Demand in metric tons per year
  - Uses
- o Ammonia
  - Production capacity
  - Demand in metric tons per year
  - Uses
- o Naphtha
  - Brazilian refinery capacity
  - Demand forecast

10.2 SULFUR MARKET

Brazil has no sulfur deposits available. Brazilian sulfur production comes primarily from desulfurization of refinery acid gases or from recovery roasting operations.

10.2.1 Sulfur Production Capacity

10.2.1.1 Present Capacity. Present sulfur production capacity is shown in Table 10-1.

TABLE 10-1

SULFUR PRODUCTION CAPACITY

Producer	State	Capacity Metric tons per year
Petroflex Ind. Com. S/A	Rio de Janeiro (Duque de Caxias)	14 900
Ultriafertil S/A.	Sao Paulo (Cubatao)	16 500
Petrobras - REPLAN	Sao Paulo (Paulinia)	15 800
Petrobras - REGAP	Minas Gerais (Betim)	7 000
Petrobras - RECAP	Sao Paulo (Capoava)	8 800
Petrobras - REPAR	Parana (Araucaria)	21 500
Petrobras - REVAP	Sao Paulo (Sao Jose dos Campos)	50 000
Petrobras - REFAP	Rio Grande do Sul (Canoas)	70 000
Ind. Carbonifera Catari nese S.A. - I.C.C.	Santa Catarina (Imbituba)	100 000
Total Present Capacity		241 500

10.2.1.2 New Plants Planned. Additional capacity planned is shown in Table 10-2.

TABLE 10-2

PROPOSED SULFUR CAPACITY

Producer	State	Capacity, ton/year
Petrobras - Six (shale oil plant)	Parana	150 000 (by 1986)

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10.2.2 Sulfur Demand

Sulfur demand is shown in Table 10-3.

TABLE 10-3

SULFUR DEMAND

Year	Source, metric tons per year		Demand, metric ton per year
	Domestic Production	Imports	
1970	6 300	261 500	267 800
1972	5 200	379 500	384 500
1974	4 200	601 000	601 500
1976	29 700	597 300	627 000
1978	57 000	653 200	710 200
1981	241 500	469 800	711 300
1985	241 500	663 700	905 200

10.2.3 Sulfur Uses

The sulfuric acid industries associated with fertilizer complexes are responsible for the consumption of 80 percent of available sulfur.

The sugar industry is responsible for some additional 15 percent, while bleaching products are responsible for the remaining 5 percent of sulfur use.

10.3 AMMONIA MARKET

Ammonia in Brazil is primarily produced from four major sources: natural gas, naphtha, refinery gas, and heavy oil.

10.3.1 Ammonia Production Capacity

10.3.1.1 Present Capacity. Present ammonia production capacity is shown in Table 10-4.

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TABLE 10-4

AMMONIA PRODUCTION CAPACITY

Producer	State	Capacity, Metric tons per year
Cia Siderurgica Nacional	Rio de Janeiro (Volta Redonda)	8 400
Nitrofertil I	Bahia (Camacari)	66 100
Nitrofertil II	Bahia (Camacari)	300 000
Petrofertil I	Sergipe (Laranjeiras)	300 000
Petrofertil II	Parana (Araucaria)	400 000
Rhodia S/A	Sao Paulo (Paulinia)	12 700
Ultrafertil S/A (2)	Sao Paulo (Piacaguera and Cubatao)	180 000
Usiminas	Minas Gerais (Ipatinga)	16 000
Total Brazil Capacity		1 283 200

10.3.1.2 New Plants Planned. Additional capacity planned is shown in Table 10-5.

TABLE 10-5

PROPOSED AMMONIA CAPACITY

Producer	State	Capacity Metric tons per year
Petrofertil III	Rio de Janeiro	300 000 (by 1985)
Petrobras	Rio Grande do Sul (Sao Jeronimo)	400 000 (by 1986)

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10.3.2 Anhydrous Ammonia Demand

Ammonia demand is shown in Table 10-6.

TABLE 10-6

AMMONIA DEMAND

Year	Source, metric tons per year: Domestic Production	Source, metric tons per year: Imports	Demand, metric tons per year
1970	25 800	22 500	48 300
1972	149 600	30 700	180 300
1974	208 000	85 000	293 000
1976	170 600	160 300	330 900
1978	234 200	221 200	455 400
1981	706 000	124 000	830 000
1985	1 284 000	108 000	1 382 000

10.3.3 Ammonia Uses

Ammonia is primarily used as nitrogen source in the fertilizer industry.

The forecast of 1985 demand of ammonia for the fertilizer industry was made in 1978, assuming a steady growth in demand of 8.4 percent a year, which is consistent with the present situation.

10.4 NAPHTHA MARKET

Naphtha in Brazil is primarily used as a raw material for the petrochemical industry, basically to produce ethylene. Some petrochemical naphtha is also used to produce ammonia.

Present breakdown on naphtha uses is the following:

Petrochemical naphtha	86.2%
Naphtha to produce town gas	12.0%
Naphtha for other various uses	1.8%

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10.4.1 Naphtha Produced by Brazilian Refineries

Table 10-7 shows naphtha production from 1973 to 1981.

TABLE 10-7

NAPHTHA PRODUCTION

Year	Naphtha Production, Metric tons per year
1973	975 000
1974	1 000 000
1975	1 211 000
1976	1 424 000
1977	1 491 000
1978	1 975 000
1979	2 500 000
1980	2 500 000
1981	2 500 000

10.4.2 Forecast of Naphtha Demand

Table 10-8 shows the demand forecast to 1985. The most probable rate of growth in naphtha demand is expected to be 3 percent per year, the 7 percent per year being an optimistic forecast.

TABLE 10-8

NAPHTHA DEMAND

Year	Naphtha Demand, Metric Tons Per Year			
	Actual	Forecast		
		1% Growth Minimum	3% Growth Average	7% Growth Maximum
1979	2 500 000			
1980	2 875 000			
1981	-	2 875 000	2 875 000	2 875 000
1982	-	2 903 000	2 961 000	3 076 000
1983	-	2 933 000	3 050 000	3 291 000
1984	-	2 962 000	3 141 000	3 521 000
1985	-	2 992 000	3 235 000	3 235 000

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11.0 GAS DEMAND SURVEY

11.1 INTRODUCTION

This report covers the assessment of Brazilian resources and gas demand, as part of the feasibility study of coal gasification for SNG production and pipeline system for the Brazil Southern Cone Energy Network.

The report covers the following states:

Sao Paulo	(SP)
Parana	(PR)
Santa Catarina	(SC)
Rio Grande do Sul	(RS)

Demand based on 1979 figures was determined, then adjusted to allow for the effects of conservation, substitution, industrial production levels, and increased plant capacities to forecast SNG demand for 1985 and 1990. Demand exceeds the gasification plant design capacity.

Gas demand is shown by region for the southern states of Brazil considered.

11.2 CRITERIA ADOPTED

Energy unit adopted is TOE - Metric Ton of Oil Equivalent - corresponding to a fuel oil similar to Bunker C, with a HHV of 10.4 Gcal/ton.

11.2.2 Forecast of Fuel Demand

Fuel oil demand in Brazil has grown steadily by 9 percent per year from 1972 to 1979. This trend has gone through a sharp inversion in 1980/1981. Demand figures for 1980 are similar to 1979, but forecasts for 1981 indicate a sharp fall, estimated to be about 15 percent lower than 1980.

Demand for fuel oil has then been passing through an unstable period, and future behavior of demand figures is thus difficult to predict. Two main trends can be identified:

- The federal government imposed in 1978 a rationing system to curb fuel oil demand in industry through the establishment of quotas for individual users. Quotas have been lowered each year, and users have thus adjusted their energy requirements initially through fuel conservation programs, and lately, through fuel substitution programs.

- The Brazilian economy has been through a sharp recession in 1981, and for the first time since 1966, industrial production is expected to decrease, with consequent decrease in fuel demand.

The trend of decreased demand due to governmental action is expected to continue in the next years. The same is not true, however, for production levels, as these are projected to start climbing again in 1982. To assess future fuel demand from the 1979 figures, the effects of these two factors have been kept separate, to account for the expected differences in behavior.

11.3 FUEL GAS DEMAND

The use of fuel gas in the southern states is at present restricted to LPG, and to city gas in the Sao Paulo metropolitan area. Table 11-1 presents consumption data for 1979.

TABLE 11-1

CONSUMPTION OF FUEL GAS - 1979

	RESIDENTIAL		COMMERCIAL		INDUSTRIAL		TOTAL	
STATE	TOEx10^3	%	TOEx10^3	%	TOEx10^3	%	TOEx10^3	%
Sao Paulo: LGP	896	34	43	32	101	36	1040	34
Sao Paulo: City Gas	33	1	15	11	43	15	91	3
Sao Paulo: Total	929	35	58	43	144	51	1131	37
Parana: LPG	145	5	9	6	5	2	159	5
Santa Catarina: LPG	59	2	4	3	10	3	73	2
R.G. do Sul: LPG	201	8	14	10	8	3	223	7
Total, Southern States	1334	50	85	62	167	59	1586	51
Other States	1330	50	51	38	116	41	1497	49
Total, Brazil	2664	100	136	100	283	100	3083	100

Potential demand for fuel gas in the southern states is much larger than present usage. Order of magnitude for the industrial market can be inferred from the demand of liquid fuels for industrial use, in 1979, of 7600 x 10^3 TOE.

TABLE 11-2

INDUSTRIAL DEMAND, LIQUID FUELS - 1979

STATE	FUEL OIL TOEx10³	%	DIESEL OIL TOEx10³	%	KEROSENE TOEx10³	%	TOTAL TOEx10³	%
Sao Paulo	5227	40	613	36	102	46	5942	40
Parana	512	4	102	6	13	6	627	4
Santa Catarina	383	3	55	3	9	4	447	3
Rio Grande do Sul	531	4	62	4	13	6	606	4
Total, Southern States	6653	51	832	49	137	62	7622	51
Other States	6446	49	873	51	85	38	7404	49
Total, Brazil	13099	100	1705	100	222	100	15026	100

Considering the figures shown in Table 11-1 and 11-2, demand for SNG in the southern states can be assessed as 9 x 10^6 TOE/year if all LPG, fuel oil, diesel oil, and kerosene were substituted. The potential market is thus about 6 times present gas consumption, and 100 times present (city) gas production.

Data presented in Tables 11-1 and 11-2 originated from the sales of fuels as reported by the distributors to the CNP - National Petroleum Council. Similar data, but on a much more detailed level, can also be obtained by tabulating individual fuel consumption figures presented by each manufacturing company in the yearly questionnaires sent to the CNP. Table 11-3 presents a comparison of data shown in Table 11-2 with data from the questionnaires.

TABLE 11-3

INDUSTRIAL FUEL CONSUMPTION - 1979
COMPARISON OF DATA - 10^3 TOE

STATE	FUEL OILS SALES	FUEL OILS QUEST.	DIESEL OIL SALES	DIESEL OIL QUEST.	KEROSENE SALES	KEROSENE QUEST.	TOTAL SALES	TOTAL QUEST.
Sao Paulo	5227	5140	613	234	102	62	5942	5436
Parana	512	501	102	11	13	7	627	519
Santa Catarina	383	354	55	11	9	3	447	368
Rio Grande do Sul	531	493	62	22	13	2	606	517
Total, Southern States	6653	6488	832	278	137	75	7622	6840
Other States	6446	6128	873	264	85	28	7404	6420
Total, Brazil	13099	12616	1705	542	222	102	15026	13260

The reason for this difference is that only companies buying more than 500 tons of fuel oil per year have to present the questionnaires to CNP to maintain their quotas.

These companies consume 90 to 95 percent of demand. Small consumers of fuel oil, as well as companies that use diesel or LPG (and not fuel oil) as main fuel, are excluded.

11.4 FUEL USAGE, 1979

CNP - National Petroleum Council - has prepared computer reports presenting fuel consumption figures for 1979, as submitted by the individual companies in the questionnaires. These figures are broken down by type of fuel and by type of equipment (boilers, furnaces, etc.), for each individual user.

Figures from the reports covering the southern states have been sorted by county and transformed in a common unit (TOE). Demands per county, in each state, have then been sorted in decreasing order and are presented in Tables 11-4 through 11-7.

Tables 11-8 through 11-11 present the major users for each state in 1979.

TABLE 11-4

FUEL CONSUMPTION PER COUNTY - 1979
STATE OF SAO PAULO

NO.	COUNTY	CONSUMPTION, TOE	NO.	COUNTY	CONSUMPTION TOE
1.	Sao Paulo	653 420	32.	Jacupirange	40 842
2.	Santo Andre	520 247	33.	Cacapava	39 945
3.	Cubatao	419 945	34.	Sumare	37 436
4.	Votorantim	254 994	35.	Santa Rosa do Viterbo	36 694
5.	Mogi Guacu	187 467	36.	Piracicaba	34 866
6.	Sao Bernardo do Campo	181 236	37.	Pindamonhangaba	33 279
7.	Suzano	169 459	38.	Araras	33 038
8.	Paulinia	166 277	39.	Diadema	28 026
9.	Maua	129 398	40.	Itu	24 933
10.	Sao Caetano do Sul	127 527	41.	Pedreira	24 705
11.	Limeira	123 732	42.	Caieiras	23 500
12.	Mogi das Cruzes	116 508	43.	Poa	21 269
13.	Jundiai	89 665	44.	Porto Ferreira	19 441
14.	Sorocaba	84 205	45.	Botucatu	19 016
15.	Sao Jose dos Campos	83 429	46.	Ribeirao Preto	18 381
16.	Itapevi	81 660	47.	Agudos	17 843
17.	Osasco	81 254	48.	Aracatuba	17 361
18.	Guarulhos	79 595	49.	Aparecida	16 946
19.	Campinas	76 359	50.	Catanduva	16 849
20.	Mairinque	67 469	51.	Rio Claro	16 828
21.	Salto	64 218	52.	Cotia	14 415
22.	Capao Bonito	60 710	53.	Amparo	14 268
23.	Jacarei	54 208	54.	Sao Vicente	14 186
24.	Bebedouro	54 070	55.	Itatiba	13 489
25.	Apiai	53 954	56.	Santa Gertrudes	13 163
26.	Itapeva	52 738	57.	Cruzeiro	12 931
27.	Valinhos	51 286	58.	Taubate	12 671
28.	Lorena	50 213	59.	Vinhedo	12 543
29.	Matao	49 696	60.	Tambau	11 850
30.	Americana	43 757	61.	Sao Carlos	11 186
31.	Araraquara	41 116	62.	Sao Roque	11 017

TOTAL - 4 932 729

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TABLE 11-5
FUEL CONSUMPTION PER COUNTY - 1979
STATE OF PARANA

NO.	COUNTY	CONSUMPTION, TOE
1.	Rio Branco do Sul	112 866
2.	Ponta Grossa	78 296
3.	Curitiba	62 537
4.	Londrina	33 377
5.	Balsa Nova	32 816
6.	Maringa	32 729
7.	Campo Largo	30 567
8.	Araucaria	27 707
9.	Telemaco Borba	14 008
10.	Cambe	12 698
11.	Cornelio Procopio	10 167
	TOTAL	447 768

TABLE 11-6
FUEL CONSUMPTION PER COUNTY - 1979
STATE OF SANTA CATARINA

NO.	COUNTY	CONSUMPTION, TOE
1.	Lages	74 957
2.	Blumenau	52 052
3.	Criciuma	35 543
4.	Urussunga	34 412
5.	Joinville	29 772
6.	Tres Barras	21 759
7.	Tubarao	17 208
8.	Imbituba	12 338
9.	Sao Joao Batista	11 436
10.	Campos Novos	11 353
11.	Brusque	9 358
12.	Gaspar	9 196
	TOTAL	319 402

TABLE 11-7
FUEL CONSUMPTION PER COUNTY - 1979
STATE OF RIO GRANDE DO SUL

NO.	COUNTY	CONSUMPTION, TOE
1.	Guaiba	58 780
2.	Canoas	52 199
3.	Pelotas	43 615
4.	Porto Alegre	42 929
5.	Rio Grande	35 382
6.	Esteio	34 053
7.	Sapucaia do Sul	28 350
8.	Pinheiro Machado	22 314
9.	Sao Jeronimo	21 153
10.	Gravatai	17 784
11.	Estrela	17 401
12.	Bento Goncalves	14 229
13.	Caxias do Sul	12 203
14.	Passo Fundo	9 637
15.	Santa Cruz	9 591
16.	Triunfo	-
	TOTAL	419 620

TABLE 11-8

MAJOR INDIVIDUAL FUEL CONSUMERS - STATE OF SAO PAULO

No.	NAME	COUNTY	INDUSTRY	CONSUMPTION (TOE)
01	Petrobras - Ref. do Planalto - REPLAN	Paulinia	Chemical/Petrochem.	630 000
02	Petrobrass - Ref. do Vale do Paraiba - REVAP	Sao Jose dos Campos	Chemical/Petrochem.	475 000
03	Petrobras - Ref. Presidente Bernardes - RPBC	Cubatao	Chemical/Petrochem.	425 000
04	Petroquimica Uniao S.A.	Santo Andre	Chemical/Petrochem.	250 000
05	Cia. Siderurguca Paulista - COSIPA	Cubatao	Metalworking	248 000
06	S.A. Inds. Votorantim	Votorantim	Cement	219 000
07	Rhodia S.A.	Paulinia	Chemical/Petrochem.	173 000
08	Cia. Suzano de Papel e Celulose	Suzano	Pulp/Paper	104 000
09	Cimento Santa Rita	Itapevi	Cement	80 000
10	Cia. Vidraria Santa Marina	Sao Paulo	Glass	75 000
11	Cia. Siderurgica de Mogi das Cruzes	Mogi das Cruzes	Metalworking	65 000
12	Itabira Agro Industrial S.A.	Capao Bonito	Cement	61 000
13	Villares Inds. Bras. S.A. - VIBASA	Pindamonhangaba	Metalworking	60 000
14	Siderurgica J. L. Aliperti	Sao Paulo	Metalworking	59 000
15	Inds. Quimicas Electrocloro S.A.	Santo Andre	Chemical/Petrochem.	58 000
16	Rhodia S.A.	Santo Andre	Textiles	56 000
17	Cia. Industrial Sao Paulo Rio	Sao Paulo	Glass	54 000
18	Camargo Correa Industrial S.A.	Apiai	Cement	54 000
19	Cia. Brazileira de Aluminio - CBA	Mairinque	Metalworking	53 500
20	Rhodia S.A.	Sao Jose dos Campos	Textiles	47 000
21	Cia. Brasileira de Estireno - CBE	Cubatao	Chemical/Petrochem.	46 000
22	Citrosuco Paulista	Matao	Food	45 000
23	Suco Citrico Cutrale S.A.	Araraquara	Food	44 000
24	Refinacoes de Milho, Brasil Ltda. - RMBL	Mogi Guacu	Food	44 000
25	Cia. Nitroquimica Brasileira S.A.	Sao Paulo	Chemical/Petrochem.	42 000
26	Cia. Cimento Portland Maringa	Itapeva	Cement	42 000
27	Agro Industrial Amalia S.A.	Santa Rosa do Viterbo	Food	40 000
28	Eucatex S.A. Ind. e Com.	Salto	Wood	40 000
29	Serrana S.A. Mineracao	Jacupiranga	Cement	39 000
30	Ultrafertil S.A.	Cubatao	Chemical/Petrochem.	39 000
31	Union Carbide do Brasil	Cubatao	Chemical/Petrochem.	36 000
32	Providro	Cacapava	Glass	33 500
33	Wheaton do Brasil S.A. Ind. e Com.	Sao Bernardo do Campo	Glass	33 000
34	Cia. Bras. de Cimento Portland Perus	Sao Paulo	Cement	32 500
35	Explo Ind. Quimica e Expl. S.A.	Lorena	Chemical/Petrochem.	30 500
36	Oxiteno S.A. Ind. e Com.	Maua	Chemical/Petrochem.	30 500
37	Pirelli S.A. Cia. Ind. Brasil	Santo Andre	Rubber	30 000
38	Ceramica Sao Caetano	Sao Caetano do Sul	Ceramics	29 000
39	Cicero Prado Celulose e Papel S.A.	Pindamonhangaba	Pulp, Paper	28 600
40	Ind. de Pneumaticos Firestone S.A.	Santo Andre	Rubber	28 600
41	Rhodia S.A.	Santo Andre	Chemical/Petrochem.	28 000
42	Nadir Figueiredo Ind. e Com. S.A.	Sao Paulo	Glass	27 500
43	Cia. Uniao Ref. Acucar e Cafe	Limeira	Food	27 000
44	Ripasa S.A. Celulose e Papel	Limeira	Pulp, Paper	27 000
45	S.A. Ind. Reunidas F. Matarazzo	Sao Paulo	Pulp, Paper	26 000
46	Cargill Industrial Ltda.	Bebedouro	Food	26 000
47	Inds. Votorantim - Fab. Votocel	Votorantim	Pulp, Paper	26 000
48	Copebrass S.A.	Cubatao	Chemical/Petrochem.	25 000
49	Sanbra Soc. Alg. Nord. Bras. S.A.	Sao Paulo	Food	25 000
50	Acos Villares S.A.	Sao Caetano do Sul	Metalworking	24 500
51	Volkswagen do Brasil S.A.	Sao Bernardo do Campo	Transportation	24 500
52	Fabrica de Tecidos Tatuape S.A.	Osasco	Textiles	24 500

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TABLE 11-8 (Continued)

MAJOR INDIVIDUAL FUEL CONSUMERS - STATE OF SAO PAULO

No.	NAME	COUNTY	INDUSTRY	CONSUMPTION (TOE)
53	Ferro Enamel Brasil Ind. e Com. Ltda.	Sao Bernardo do Campo	Chemical/Petrochem.	22 500
54	Unipar Quimica Ltda.	Maua	Chemical/Petrochem.	22 000
55	Champion Papel e Celulose	Mogi Guacu	Pulp, Paper	22 000
56	Duratex S.A.	Botucatu	Wood	21 000
57	Frutesp S.A. Agro Industrial	Bebedouro	Food	21 000
58	Ind. Bras. Artigos Refratarios S.A.	Poa	Ceramics	20 000
59	Ind. Metalurgica N.S. Aparecida	Sorocaba	Metalworking	20 000
60	S.A. Ind. Matarazzo do Parana	Sao Paulo	Textiles	18 500
61	Ind. Gessy Lever Ltda.	Valinhos	Pharmaceutical	18 500
62	Cia. Vidraria Santa Marina	Maua	Glass	18 000
63	Cia. Antartica Paulista	Sao Paulo	Beverages	18 000
64	Acos Anhanguera S.A.	Mogi das Cruzes	Metalworking	17 500
65	Alba Adria S.A. Ind. Reunidas	Cubatao	Chemical/Petrochem.	17 000
66	Ceramica Mogi Guacu	Mogi Guacu	Ceramics	17 000
67	Vidros Corning Brasil Ltda.	Suzano	Glass	17 000
68	General Motors do Brasil S.A.	Sao Jose dos Campos	Transportation	17 000
69	Cocam Cafe Soluvel e Derivados	Catanduva	Food	17 000
70	Ajinomoto Interam Ind. e Com. Ltda.	Limeira	Food	17 000
71	Ceramica Martini S.A.	Mogi Guacu	Ceramics	16 500
72	Cia. de Cimento Ipanema	Sorocaba	Cement	16 500
73	S.A. Ind. Reunidas F. Matarazzo	Sao Caetano do Sul	Textiles	16 500
74	Fabrica de Papel N. Sa. Aparecida	Aparecida	Pulp, Paper	16 000
75	Duratex S.A.	Jundiai	Wood	16 000
76	Cia. Goodyear do Brasil	Sao Paulo	Rubber	16 000
77	Cia. Uniao de Refinadores Acucar e Cafe	Sao Paulo	Food	16 000
78	Sider Coferraz S.A.	Santo Andre	Metalworking	16 000
79	Cargill Agricola S.A.	Mairinque	Food	15 500
80	Cia. Nacional de Estamparia	Sorocaba	Textiles	15 000
81	Rigesa Celulose e Papel e Embalagens Ltda.	Valinhos	Pulp, Paper	15 000
82	Pirelli S.A. Cia. Indl. Brasileira	Campinas	Rubber	14 500
83	Sifco do Brasil S.A.	Jundiai	Metalworking	14 500
84	Ind. Papel S.A.	Sao Paulo	Pulp, Paper	14 000
85	Cia. Santista de Papels	Cubatao	Pulp, Paper	14 000
86	Irmaos Sabieni Ltda.	Sorocaba	Ceramics	14 000
87	Hoechst do Brasil Quim. e Farm. S.A.	Suzano	Chemical/Petrochem.	14 000
88	Anderson Clayton S.A. Ind. e Com.	Sao Paulo	Food	14 000
89	Ind. de Papel Piracicaba S.A.	Piracicaba	Pulp, Paper	13 500
90	Cia. Vidraria Santa Marina	Sao Vicente	Glass	13 000
91	Citrosuco Paulista S.A.	Limeira	Food	13 000
92	Cia. Ind. Com. Bras. Prod. Alimentares	Araras	Food	13 000
93	S.A. Inds. Reunidas F. Matarazzo	Sao Paulo	Food	13 000
94	Polibrasil S.A. Ind. e Com.	Maua	Chemical/Petrochem.	13 000
95	Ceramica Chiarelli	Mogi Guacu	Ceramics	12 500
96	General Motors do Brasil S.A.	Sao Caetano do Sul	Transportation	12 000
97	Sucorrico S.A. Ind. e Com.	Araras	Food	12 000
98	Cia. Melhoramentos de Sao Paulo	Caieiras	Pulp, Paper	12 000
99	Ford Brasil S.A.	Sao Bernardo do Campo	Transportation	12 000
100	Ind. Papel Simao S.A.	Jacarei	Pulp, Paper	12 000
101	Cia. Goodyear do Brasil Prod. Borracha	Americana	Rubber	11 500
102	Cia. Fabricadora de Papel	Sao Paulo	Pulp, Paper	11 000
103	M.D. Nicolaus Ind. Papeis Ltda.	Caieiras	Pulp, Paper	11 000
104	S.A. Ind. Reunidas F. Matarazzo	Sao Caetano do Sul	Ceramics	10 000

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TABLE 11-9

MAJOR INDIVIDUAL FUEL CONSUMERS - STATE OF PARANA

NO.	NAME	COUNTY	INDUSTRY	CONSUMPTION (TOE)
01	Cia. de Cimento Portland Rio Branco	Rio Branco do Sul	Cement	87 000
02	Cia. de Cimento Itambe	Balsa Nova	Cement	33 000
03	Ind. Ceramica Parana S.A.	Campo Largo	Ceramics	26 000
04	Cimento Itau do Parana S.A.	Rio Branco do Sul	Cement	26 000
05	Sanbra Soc. Alg. Nord. Brasileiro S.A.	Ponta Grossa	Food	24 500
06	Com. Ind. Brasil Coimbra S.A.	Ponta Grossa	Food	16 000
07	Cocelpa Cia. de Celulose e Papel	Araucaria	Pulp, Paper	14 500
08	Inds. Klabin do Parana de Celulose S.A.	Telemaco Borba	Pulp, Paper	14 000
09	Continental de Oleos Vegetais S.A	Maringa	Chemical/Petrochemical	13 500
10	Fab. do Celulose e Papel S.A.	Curitiba	Pulp, Paper	12 000
11	Braswey S.A. Ind. e Com.	Cambe	Food	10 500
12	Cargill Agricola S.A	Ponta Grossa	Food	10 000
			TOTAL	287 000

TABLE 11-10

MAJOR INDIVIDUAL FUEL CONSUMERS - STATE OF SANTA CATARINA

NO.	NAME	COUNTY	INDUSTRY	CONSUMPTION (TOE)
01	Olinkraft Celulose e Papel Ltda.	Lages	Pulp, Paper	66 000
02	Maximiliano Gaidzinski S.A	Urussanga	Ceramics	29 000
03	Rigesa Cel. Papel e Embalagens Ltda.	Tres Barras	Pulp, Paper	22 000
04	Artex S.A. Fab. de Artefatos Texteis	Blumenau	Textiles	15 000
05	Ind. Com. e Ceramica S.A.	Tubarao	Ceramics	14 500
06	Ind. Ceramica Imbituba	Imbituba	Ceramics	11 500
07	Usati S.A. Refinadora Catarinense	Sao Joso Batista	Food	11 500
08	Ind. e Com. de Papelao Ibicui Ltda.	Ibicui	Pulp, Paper	11 500
			TOTAL	181 000

TABLE 11-11

MAJOR INDIVIDUAL FUEL CONSUMERS - STATE OF RIO GRANDE DO SUL

NO.	NAME	COUNTY	INDUSTRY	CONSUMPTION (TOE)
01	RIOCELL - Rio Grande Cia.	Guaiba	Pulp, Paper	40 500
	De Celulose do Sul	Esteio	Food	24 500
02	S.A. Moinhos Riograndenses	Pinheiro Machado	Cement	22 500
03	Cia. de Cimento Portland Guaucho	Pinheiro Machado	Cement	21 000
04	Acos Finos Piratini S.A.	Sao Jeronimo	Metalworking	20 500
05	Sider. Rio Grandense S.A.	Sapucaia do Sul	Metalworking	15 500
06	Cia. Vidraria Sta. Marina	Canoas	Glass	11 000
07	Olvebra S.A. Ind. e Com. Oleos Vegetais	Pelotas	Food	10 500
08	Kaspe e Cia. Ltda.	Pelotas	Food	10 500
09	Bianchini S.A. Ind. Com. e Agricultura	Canoas	Food	10 000
10	Inds. Luchsinger Madorin S.A.	Rio Grande	Chemical/Petrochemical	10 000
			TOTAL	186 000

11.5 ADJUSTMENTS TO 1979 FUEL CONSUMPTION

11.5.1 Introduction

To obtain the demand of fuel gas for industrial use, in 1985 to 1990, from 1979 figures of fuel consumption, adjustments must be made for the following factors:

a. Fuel conservation programs
b. Industry-wide fuel substitution plants
c. Forecast of industrial production levels
d. New capacity: expansion programs, new plants.

11.5.2 Fuel Conservation Programs

Most companies have started fuel conservation programs during recent years, due both to increases in fuel oil prices and to the establishment by CNP of yearly quotas for fuels. The net effect of these programs, on the state/national level, is a unit reduction of fuel demand, that is, for the same level of industrial production, fuel demand tends to decrease.

Effect of these programs of future fuel demand is expected to be smaller for large consumers (more than 10 000 TOE/year) than for small consumers. Fuel usage by large consumers has been controlled by the government for a long time, and their conservation programs date from the mid-seventies. Most conservation measures (insulation, air preheating, etc.) had already been put into effect by 1979, and further saving can only be achieved by fuel substitution programs, process changes, or by decreasing production.

For small consumers, on the other hand, there is still a margin for fuel economies, as their programs started more recently. The effect of fuel conservation programs has been estimated by adopting, for the same production level, a 10 percent future decrease in fuel utilization over the 1979 level for small consumers, and 0 percent for the large consumers.

11.5.3 Fuel Substitution Programs

Industry-wide fuel substitution plans have been agreed upon between representatives of the industrial sectors and the Federal Government. Lines of credit have been created in government banks to finance these plans; some of the plans have a marked influence on future demand, such as the plans for the cement and the pulp and paper industry.

The cement industry intends to substitute with coal by 1985, 100 percent of the fuel oil used in 1979. For cement manufacture, the high ash content of Brazilian coals is actually beneficial, as the ash is a useful input in the clinker composition. This plan implies the substitution in the southern states of 700 000 TOE of fuel oil, amounting to about 11 percent of total oil demand.

The increase in coal shipments and the investments being made by the cement companies indicate that the plan, as stated, is being substantially implemented. Recent statements lead to the conclusion that the goal of 50 percent substitution by 1982 will be met, but that 100 percent substitution by 1985 will be delayed. It is judged this last target will, however, be met by 1990. The fuel consumption figures for the counties affected have then been adjusted by eliminating the figures for cement manufacturers.

Representatives of the pulp and paper industries have also agreed with the Federal Government on a program to cut 90 percent of fuel oil demand by 1989. The major pulp producers are investing in the substitution of the fuel oil used in steam generation by wood, bark, and coal, and several large new steam boilers have been ordered. The majority of the small paper manufacturers have not yet decided on alternate fuels, however, and the long planning horizon indicates that part of the stated substitution targets could be met by using SNG. Consequently, a large part of 1979 demand is expected to remain as potential gas demand.

The 1979 figures have been adjusted only for boilers already ordered or planned to be ordered until 1985, as shown in Table 11-12. About 300 000 TOE are thus expected to be the adjustment due to the substitution plan in the pulp and paper industry.

The steel industry has also initiated a program to decrease its fuel consumption by 30 percent in 1981 and 50 percent by 1985. The initial target is considered feasible, but the substitute fuel sources for the 1985 target seem not to have been defined yet and these targets are thus expected to be delayed. The only adjustment made was in the demand of COSIPA, which was decreased by 30 percent (80 000 TOE), for the remainder. SNG is considered to be a feasible alternate source and thus the oil demand is kept as part of the potential SNG market.

Substitution plans are therefore expected to decrease fuel consumption in the southern states by 17 percent (1 080 000 TOE).

11.5.4 Production Levels

Fuel demand figures can rise or fall with rise or fall of production levels, irrespective of fuel conservation/substitution.

Table 11-13 presents forecasts of production levels up to 1990.

Figures for 1980 and 1981 take into account the latest indicators available. Percent changes adopted as base estimate from then on (3.5% per year) are thought to be conservative in the long run although perhaps optimistic for 1982. A high (optimistic) estimate would be the return in 1983 of the high growth rates of the seventies, and a low estimate would be the return of steady growth only in 1984.

TABLE 11-12

FUEL SUBSTITUTION PLANS - PULP AND PAPER INDUSTRY

NAME	COUNTY	DEMAND 1979 (10^3 TOE)	BOILERS ORDERED/PLANNED FUEL	START-UP	CAPACITY TPH STEAM	OIL SUBSTITUTION 10^3 TOE/YR	ESTIMATED REMAINING DEMAND	NOTES
Cia. Suzano de Papel e Celulose	Suzano/SP	104	W/B	82	100	52	25	Included savings due to process changes
Champion Papel e Celulose	Mogi Guacu/SP	77	W/B	82	105	55	22	
Ripasa Papel e Celulose	Limeira/SP	41	W	82	60	31	20	Included plant expansion
Inds. Papel Simao	Jacarei/SP	36	W/B	82	30	31	10	
Cicero Prado Celulose Papel	Pindamonhangaba/SP	26	ND	84	30	16	10	Not confirmed
Fab. Papel N. S. Aparecida	Aparecida/SP	14	W	81/88	6/20	4/12	10/5	
Cia. Santista de Papeis	Cubatao/SP	14	A	81	22	14	5	
Cia. Melhoramentos de Sao Paulo	Caieiras/SP	12	W	81	10	6	6	Estimated savings of 216/221 x 10^3 TOE/YR
Subtotal, Sao Paulo State		324					108/113	
Olinkraft Celulose e Papel	Lajes/SC	66	W/B	84	80	42	24	Not confirmed
Ind. Com. Papelao Ibicui Ltda.	Campos Novos/SC	11	W	81	36	19	5	
Papel Celulose Catarinense S.A.	Lajes/SC	9	-	-	-	-	9	80 tph boiler ordered and cancelled
Subtotal, Santa Catarina State		86					38	Estimated savings of 48 x 10^3 TOE/YR
Cocelpa - Cia. Celulose e Papel	Araucaria/PR	14					14	Possible Expansion and thus increase;
Ind. Klabin do Parana de Celulose S.AT.	Borba/PR	14	W	81	150	(79)	5	New boiler will substitute old wood boiler; biomass in lime kiln
Fab. Celulose e Papel S.A.	Curitiba/PR	12	W	81	21	13	5	
Subtotal		40					24	Estimated savings 16 x 10^3 TOE/YR
Riocell	Guaiba, RS	41	C	82	160	84	15	
Subtotal, Rio Grande do Sul State		41					15	Estimated savings, 26 x 10^3 TOE/YR
Total, Pulp and Paper		491					185	Estimated savings, 306/311 x 10^3 TOE/YR

C - Coal, W - Wood, B - Bark, A - Alcohol ND - not defined

TABLE 11-13

FORECAST, PRODUCTION LEVELS, SOUTHERN STATES

YEAR	HIGH ESTIMATE		LOW ESTIMATE		BASE ESTIMATE	
	% CHANGE	INDEX	% CHANGE	INDEX	% CHANGE	INDEX
1979	-	100	-	100	-	100
1980	+ 7.6	107.6	+ 7.6	107.6	+ 7.6	107.6
1981	- 6	101	-10	97	- 7	100
1982	+ 3.5	105	0	97	+ 3.5	103.5
1983	+ 7	112	+ 2.5	99	+ 3.5	107
1984	+ 7	120	+ 3.5	103	+ 3.5	111
1985	+ 7	128	+ 3.5	106	+ 3.5	115
1986	+ 7	137	+ 3.5	110	+ 3.5	119
1987	+ 7	147	+ 3.5	114	+ 3.5	123
1988	+ 7	157	+ 3.5	118	+ 3.5	127
1989	+ 7	168	+ 3.5	122	+ 3.5	132
1990	+ 7	180	+ 3.5	126	+ 3.5	136

11.5.5 New Plant Capacity

Three major projects that could affect fuel demand figures in the time period considered have been identified.

The first is the VIBASA steel foundry in Pindamonhangaba, SP, that started up in 1981. Estimated fuel demand for full production is 60 000 TOE/yr.

The second is the Guatapara pulp mill in Ribeirao Preto, SP, with start-up expected after 1985. Fuel substitution is expected to be designed into the plant, so no significant additional fuel oil consumption is expected.

The third is the Petrochemical Complex of Rio Grande do Sul in Triunfo, RS. The Ethylene Complex - COPESUL is expected to need 620 x 10^3 TOE/yr of fuel when full production is reached. The major part of the fuel used will be coal and fuel gas generated inside the Ethylene Complex battery limits; only 70 000 TOE/yr will be fuel oil.

For the planned second generation plants of Triunfo Petrochemical Complex, no firm data are available either for fuel demand or start-up dates, but fuel consumption is not expected to be significant compared to COPESUL, because almost all of their steam requirements will be generated inside COPESUL. Considering difficulty in forecasting when COPESUL production figures will approach nominal capacity, and start-up dates for the other industries, the figure of 70 000 TOE/yr has been adopted as fuel consumption for the whole Petrochemical Complex after 1985.

11.5.6 Refineries

Computer reports with data from the questionnaires do not present demand data of the largest users, the Petrobras oil refineries, as they are considered by CNP as internal consumption.

Data from Petrobras indicate that energy usage in all refineries in 1978 amounted to 3 000 x 10^3 TOE, including 1 737 x 10^3 TOE of fuel oil and 764 x 10^3 TOE of refinery gas. Both the gas and the oil used as fuels could be substituted by SNG, and refineries in the southern states are thus part of the gas market. Order of magnitude of fuel/gas demand for these refineries is then estimated as indicated in Table 11-14.

TABLE 11-14

REFINERIES ESTIMATED FUEL CONSUMPTION FOR THE NEXT 10 YEARS

NAME	LOCATION	DEMAND (10^3 TOE/YEAR)
REPLAN	Paulinia, SP	450
RPBC	Cubatao, SP	300
REVAP	Sao Jose dos Campos, SP	340
RECAP	Capuava, SP	55
REPAR	Araucaria, PR	225
REFAP	Canoas, RS	225
IPIRANGA	Rio Grande, RS	20
Subtotal	Southern states	1 615
Others	Other states	885
TOTAL	Brazil	2 500

Petrobras has already invested over US$ 100 million to reduce fuel consumption in all its refineries, and additional funds will be allocated to this purpose. Present plan is to burn the vacuum residue straight, while hot, instead of cooling it, mixing it with diesel and then selling or burning the resulting fuel oil.

The fact of these recent investments, combined with the fact that no distribution costs are incurred in the oil/gas burned in the refineries, makes the substitution of these fuels by SNG the least attractive of all fuel substitutions. The industrial market for SNG can thus be segmented in two parts; the first, covering fuel substitution in industry in general, is more attractive than the second, which covers fuel substitution in refineries. This market segmentation will be considered in the definition of the SNG market.

11.5.7 Industrial Market Summary

Industrial demand figures, including all adjustments above except refinery figures, are shown in Tables 11-15, 11-16, 11-17, and 11-18, for the major industrial centers in southern states.

TABLE 11-15

INDUSTRIAL DEMAND - STATE OF SAO PAULO
(TOE X 10^3)

		1979	1985	1990
1.	SAO PAULO			
	Sao Paulo	600	690	816
	Santo Andre	515	592	700
	Sao Bernardo	172	198	234
	Maua	125	144	170
	Sao Caetano	124	143	169
	Mogi das Cruzes	113	130	154
	Suzano	87	100	118
	Osasco	76	87	103
	Guarulhos	72	83	98
	Diadema	25	29	34
	Poa	21	24	29
	Caieiras	18	21	24
	Cotia	13	15	18
	Subtotal	1 961	2 256	2 667
2.	CAMPINAS			
	Paulinia	165	190	224
	Campinas	70	81	95
	Valinhos	49	56	67
	Sumare	34	39	46
	Americana	40	46	54
	Subtotal	358	412	486
3.	CUBATAO			
	Cubatao	328	376	446
	Sao Vicente	14	16	19
	Subtotal	342	392	465
4.	SOROCABA			
	Sorocaba	65	75	88
	Votorantim	35	40	48
	Mairinque	67	77	91
	Subtotal	167	192	227
5.	SAO JOSE DOS CAMPOS			
	Sao Jose	81	93	110
	Jacarei	26	30	35
	Cacapava	39	45	53
	Subtotal	146	168	198
6.	LIMEIRA			
	Limeira	100	115	136
	Araras	32	37	44
	Subtotal	132	152	180
7.	MOGI GUACU	130	150	177
8.	PINDAMONHANGABA			
	Pinda	77	89	105
	Taubate	11	13	16
	Subtotal	88	102	121
9.	JUNDIAI	83	95	113
10.	SALTO			
	Salto	61	70	83
	Itu	22	26	31
	Subtotal	83	96	114
11.	BEBEDOURO	53	61	72
12.	MATAO	49	56	66
13.	LORENA	48	55	65
14.	ARARAQUARA	41	47	56
15.	SANTA ROSA DO VITERBO	37	43	50
16.	PIRACICABA	33	38	45
17.	PEDREIRA	22	25	30
18.	BOTUCATU	19	22	26
19.	PORTO FERREIRA	17	20	24
20.	CATANDUVA	17	19	23
21.	RIBEIRAO PRETO	17	19	22
22.	AGUDOS	16	18	22
23.	ARACATUBA	16	18	21
24.	RIO CLARO	15	17	21
25.	AMPARO	13	15	18
26.	ITATIBA	12	14	17
27.	SANTA GERTRUDES	12	14	16
28.	CRUZEIRO	12	13	16
29.	VINHEDO	11	13	15
30.	TAMBAU	11	12	15
31.	SAO CARLOS	10	12	14
32.	SAO ROQUE	10	11	13
	TOTAL	3 981	4 577	5 415

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TABLE 11-16

INDUSTRIAL DEMAND
STATE OF PARANA (TOE x 10^3)

	1979	1985	1990
1. CURITIBA			
Curitiba	51	59	69
Araucaria	26	30	35
Campo Largo	30	35	41
Subtotal	107	124	145
2. PONTA GROSSA	76	87	103
3. LONDRINA			
Londrina	30	35	41
Cambe	12	14	16
Subtotal	42	49	57
4. MARINGA	31	35	42
5. CORNELIO PROCOPIO	9	10	12
TOTAL	265	305	359

TABLE 11-17

INDUSTRIAL DEMAND
STATE OF SANTA CATARINA (TOE x 10^3)

	1979	1985	1990
1. CRICIUMA			
Criciuma	32	37	44
Urussanga	34	39	46
Subtotal	66	76	90
2. BLUMENAU			
Blumenau	48	55	65
Brusque	8	10	11
Gaspar	8	10	11
Subtotal	64	75	87
3. LAGES	33	38	45
4. JOINVILLE	27	31	37
5. TRES BARRAS	22	25	30
6. TUBARAO	17	20	23
7. IMBITUBA	12	14	16
8. SAO JOAO BATISTA	11	13	15
TOTAL	252	292	343

TABLE 11-18

INDUSTRIAL DEMAND
STATE OF RIO GRANDE DO SUL (TOE x 10^3)

	1979	1985	1990
1. PORTO ALEGRE			
Porto Alegre	39	45	53
Canoas	45	52	61
Esteio	33	38	45
Sapucaia do Sul	28	32	38
Gravatai	16	18	22
Subtotal	161	185	219
2. TRIUNFO			
Triunfo	(70)	70	70
Sao Jeronimo	21	24	29
Subtotal	(91)	94	99
3. PELOTAS	41	47	56
4. RIO GRANDE	33	38	45
5. ESTRELA	16	18	22
6. BENTO GONCALVES	13	15	18
7. CAXIAS DO SUL	11	13	15
TOTAL	(366)	410	474

11.6 NONINDUSTRIAL MARKET

11.6.1 Introduction

The nonindustrial market for gas has been traditionally separated into household and business segments. Table 11-1 has presented demand figures for 1979 covering these segments, showing consumption of LPG and town gas manufactured by COMGAS and distributed in the Sao Paulo Metropolitan Area.

Distribution of town gas in metropolitan areas as a public service is at present undeveloped in Brazil. The only distribution grids in operation are in Sao Paulo and Rio de Janeiro, manufacturing gas of 4 750 kcal/Nm^3 from naphtha. Although in the forties several other cities did distribute city gas (from imported coal or coke), these services were discontinued in the fifties/sixties, and household users turned to LPG. The reason for this change included obsolescence of pro' er installations, the low price at that time of oil (and thus of LPG), a.. the ease of supplying LPG to new users in a booming market without major capital investment.

The last of these reasons still applies; that is, the sizeable amounts that must be invested in the distribution grid to supply the urban population with fuel gas instead of LPG. Considering these huge amounts, it is more attractive to supply industrial users first, because this does not require investing in an extensive grid. The nonindustrial demand could be included in the priority market only in the case of the COMGAS system in Sao Paulo, where the distribution system already exists. On the other hand, COMGAS is planning to expand its naphtha-based production. It is thus deemed more prudent not to include the COMGAS system in the priority segment.

11.6.2 Household Demand

Gas demand is usually expressed as an average unit demand times the number of customers (households) supplied. Unit demand of the COMGAS system is 44 m^3/month per household, or, in terms of TOE, 0.22 TOE/yr. This figure is accepted as representative.

The first steps to determine the number of households where SNG could replace LPG are the assessment of the cities to be supplied, their size, and the distance to the pipeline.

Assuming that in the initial SNG distribution system, the most attractive markets should be served first, only cities relatively near the pipeline (for instance, not farther than 100 km) and of a certain size (assumed larger than 200 000 inhabitants) should be considered. Table 11-19 presents all major cities in the southern states. It can be observed that only six cities in Sao Paulo, Londrina in Parana, and Joinville in Santa Catarina are large enough, besides the state capitals. Of these, Florianopolis, in Santa Catarina, is not large enough.

Only Londrina and Ribeirao Preto are farther than 100 km from possible pipeline routes and are then included in the demand.

Table 11-19 also presents data (obtained from the 1980 demographic survey) on number of total households in the urban areas of the cities listed.

Not all households should be included in the household market. Table 11-20 shows data on number of households, in some metropolitan areas, served by essential public services. This table also shows that a sizeable percent of the households are not supplied with water from the public network. Considering that water supply is a more essential service than gas distribution, the number of households to be considered in the SNG demand is limited by the number of households that are supplied with water from the public network.

The maximum number of households in the SNG market is thus obtained, in Table 11-21, by using the percentages of Table 11-20 and the total number of households from Table 11-19. Potential household demand is then obtained using unit demand determined from COMGAS data.

TABLE 11-19

POPULATION, MAJOR CITIES, 1980

STATE	CITY	POPULATION (COUNTY) x 10^3	POPULATION (URBAN) x 10^3	NO. HOUSEHOLDS (URBAN) x 10^3
SP	Greater Sao Paulo	12 588	10 696	2 915.6
	Campinas	664	567	133.4
	Santos	417	411	106.1
	Ribeirao Preto	318	301	70.5
	Sao Jose dos Campos	288	268	59.1
	Sorocaba	270	255	59.0
	Jundiai	259	210	50.2
PR	Curitiba	1 442	844	187.6 *
	Londrina	302	258	57.3 *
SC	Joinville	236	(217)	47.6
	Florianopolis	-	(153)	-
	Blumeanau	-	(120)	-
RS	Greater Porto Alegre	2 232	2 014	588

* Estimated from urban population

TABLE 11-20

NUMBER OF HOUSEHOLDS, PUBLIC SERVICES - 1978

	Greater Sao Paulo	Greater Curitiba	Greater Porto Alegre
Population county - $x10^3$ inhabitants	11 645	1 104	2 051
Number of households, x 10^3	2 778	245	516
Households with water from public grid, $x10^3$	2 207	156	425
%	79%	64%	82%
Number with sewer from public grid, x 10^3	1 443	90	229
%	52%	58%	44%
Number of inhabitants per household	4.2	4.5	4.0

11.6.3 Total, Nonindustrial Demand

Business demand, estimated as 45 percent of household demand, and total demand figures are also shown in Table 11-21. Forecast of demand in 1985 and 1990 was obtained using actual population growth figures for the past decade for the metropolitan areas.

11.7 TOTAL SNG DEMAND

Table 11-22 presents a summary of SNG demand in the years 1985 and 1990.

TABLE 11-21

NONINDUSTRIAL DEMAND

STATE	CITY	NO. URBAN HOUSEHOLDS (10^3)	HOUSEHOLD DEMAND (10^3TOE/YR)	BUSINESS DEMAND. (10^3TOE/YR)	TOTAL NONINDUSTRIAL DEMAND - 1980 (10^3TOE/YR)	FORECAST NONINDUSTRIAL DEMAND (10^3TOE/YR) 1985	1990
SP	Greater Sao Paulo	2 302	506	228	734	914	1 138
	Campinas	85	19	8	27	33	42
	Santos	68	15	7	22	27	34
	Ribeirao Preto	45	10	5	15	19	23
	Sao Jose dos Campos	38	8	4	12	15	19
	Sorocaba	38	8	4	12	15	19
	Jundiai	32	7	3	10	12	15
	Total SP	2 608	574	258	832	1 035	1 290
PA	Curitiba	120	26	12	38	50	67
SC	Joinville	30	7	3	10	12	15
RS	Greater Porto Alegre	458	101	45	146	176	213
TOTAL, SOUTHERN STATES		3 216	708	319	1 027	1 273	1 585

TABLE 11-22

SNG DEMAND

		DEMAND 1985 - 10^3 TOE/YR					DEMAND 1990 - 10^3 TOE/YR				
STATE	CITY	INDUSTRIAL	REFINERIES	NON-INDUSTRIAL	PRIORITY DEMAND	TOTAL DEMAND	INDUSTRIAL	REFINERIES	NON-INDUSTRIAL	PRIORITY DEMAND	TOTAL DEMAND
SP	Greater Sao Paulo	2 256	55	914	2 256	3 225	2 667	55	1 138	2 667	3 860
SP	Campinas	412	450	33	412	895	486	450	42	486	978
SP	Cubatao/Santos	392	300	27	392	719	465	300	34	465	799
SP	Sorocaba	192	-	15	192	207	227	-	19	227	246
SP	Sao Jose dos Campos	168	340	15	168	523	198	340	19	198	557
SP	Limeira	152	-	-	152	152	180	-	-	180	180
SP	Mogi Guacu	150	-	-	150	150	177	-	-	177	177
SP	Pindamonhangaba	102	-	-	102	102	121	-	-	121	121
SP	Jundiai	95	-	12	95	107	113	-	15	113	128
SP	Salto	96	-	-	96	96	114	-	-	114	114
	TOTAL, SAO PAULO	4 015	1 145	1 016	4 015	6 176	4 748	1 145	1 267	4 748	7 160
PA	Greater Curitiba	124	225	50	124	399	145	225	67	145	437
PA	Ponta Grossa	87	-	-	87	87	103	-	-	103	103
	TOTAL, PARANA	211	225	50	211	486	248	225	67	248	540
SC	Criciuna	76	-	-	76	76	90	-	-	90	90
SC	Blumenau	75	-	-	75	75	87	-	-	87	87
SC	Joinville	(13)	-	(12)	(31)	(43)	(37)	-	(15)	(37)	(52)
	TOTAL, SANTA CATARINA	151	-	-	151	151	177	-	-	177	177
RS	Greater Porto Alegre	185	225	176	185	586	219	225	213	219	657
RS	Triunfo	94	-	-	94	94	99	-	-	99	99
	TOTAL, RIO GRANDE DO SUL	279	225	176	279	680	318	225	213	318	756
TOTAL		4 656	1 595	1 242	4 656	7 493	5 491	1 595	1 547	5 491	8 633

11.8 CONSIDERATION OF SNG AS FEEDSTOCK

SNG could be considered as suitable feedstock for production of methanol and ammonia and thus a brief review on market for these products in Brazil is included here.

11.8.1 Methanol Market

At present, major Brazilian feedstocks for methanol production are petrochemical naphtha, fuel oil, refinery gas, and natural gas.

The major methanol producers are shown in Table 11-23.

TABLE 11-23

METHANOL PRODUCERS

Producer	State	Capacity, Metric Tons Per Year	Feedstock
Prosint	Rio de Janeiro	50 000	Nahptha and refinery gas
Metanor	Bahia	60 000	Natural gas
Alba Adria	Sao Paulo	24 000	Fuel oil
Petrofertil	Parana	8 000	Fuel oil
Various producers (seven)	Sao Paulo and Bahia	21 000	Polyester by-product
TOTAL PRODUCTION CAPACITY		168 000	

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Demand figures are presented in Table 11-24.

TABLE 11-24

METHANOL DEMAND

YEAR	Source, metric tons per year: Domestic Production	Source, metric tons per year: Imports	Demand Total metric tons per year
1970	14 000	12 600	26 600
1972	35 200	4 600	39 800
1974	53 700	13 500	67 200
1976	74 500	15 300	89 800
1978	101 300	3 000	104 300
1980	160 000	-	160 000
1985	160 000	(180 000)	(300 000)

While forecast of methanol demand is high, some additional 140 000 metric tons per year are expected to be needed by 1985; there is no firm committed methanol plant scheduled for the near future.

Methanol demand will be high enough to justify a new plant, eventually having SNG as feedstock.

11.8.2 Ammonia Market

Ammonia in Brazil is primarily produced from four major sources: natural gas, naphtha, refinery gas, and heavy oil.

Major producers are listed in Table 11-25.

TABLE 11-25

PRESENT CAPACITY, AMMONIA PRODUCTION

Producer	State	Capacity, Metric tons per year
Nitrofertil I and II	Bahia (Camacari)	366 100
Petrofertil I	Sergipe (Laranjeiras)	300 000
Petrofertil II	Paran (Araucaria)	400 000
Ultrafertil S/A (2)	Sao Paulo (Piacaguera and Cubatao)	180 000
Other small producers(3)	Various states	37 100
TOTAL BRAZIL		1 283 200

Two new plants are planned in the near future, the Petrofertil III unit, using natural gas, in Rio de Janeiro with 300 000 metric tons per year capacity, and the Petrobras unit, planned to use SNG, in Rio Grande do Sul (Sao Jeronimo), with 300 000 to 400 000 metric tons per year capacity and with a tentative date for start-up by 1986.

Table 11-26 presents figures for evolution of ammonia demand.

TABLE 11-26

AMMONIA DEMAND

YEAR	Source, metric tons per year: Domestic Production	Imported	Demand total, metric tons per year
1970	25 800	22 500	48 300
1972	149 600	30 700	180 300
1974	208 000	85 000	293 000
1976	170 000	160 300	330 900
1978	234 200	221 200	455 400
1981	706 000	124 000	830 000
1985	1 284 000	108 000	1 382 000

From Table 11-25, it can be seen that Brazilian demand is satisfied up to 1985 basically through natural gas. Petrobras has plans to use coal gas to produce ammonia in Sao Jeronimo in the state of Rio Grande do Sul.

Ammonia demand after 1985 might grow at very high yearly rates, as per capita utilization of fertilizers in Brazilian agriculture has been very low and is expected to increase in the long term.

APPENDIX A

ABBREVIATIONS

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APPENDIX A

ABBREVIATIONS

CAEEB	Companhia Auxiliar de Empresas Eletricas Brasileiras Brazilian Power Stations Auxiliary Company (Government company for control and execution of coal programs)
CET	Carvao Energetico para Termoeletricidade Thermoelectricity Steam Coal
CM	Carvao Metalurgico Coking Coal
CNP	Conselho Nacional do Petroleo National Petroleum Council
COPELMI	Companhia de Pesquisas de Lavras Minerais Company of Research of Mineral Deposits (One of the mining coal companies in Rio Grande do Sul)
CPL	Carvao Pre-lavado Pre-washed Coal
CPRM	Companhia de Pesquisas de Recursos Minerais Company of Research in Mineral Resources (Government Survey Company)
CRM	Companhia Riograndense de Mineracao Riograndense Mining Company (The other coal company in Rio Grande do Sul)
CV	Carvao Vapor Steam Coal
CVF	Carvao Vapor Fino Best Steam Coal
CVS	Carvao Vapor Secundario Secondary Steam Coal
Cz	Cinzas Ash
DNPM	Departamento Nacional de Producao Mineral National Department of Mineral Production (Controls CPRM and decides on mineral research policy)
FSI	Indice de Inchamento Free Swelling Index

HGI	Indice de Moabilidade Hardgrove Grindability Index
ROM	Carvao Bruto Run of Mine
TECH	Termoeletrica de Charqueadas Power Station of Charqueadas

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APPENDIX B

COAL PRODUCTION AND ANALYSIS

Tables B-1 through B-9 show coal production and analysis discussed in Section 8.

Table B-1
"IN SITU" COAL RESERVES IN PARANA BASIN – SITUATION OF 31/12/81

STATE	REGION/SEAM	TYPE OF MINE	RESERVES (x 10^6 t) BLOCKED	INDICATED	ESTIMATED	TOTAL
RIO GRANDE DO SUL	GRANDE CANDIOTA	OP	407,85	431,29	373,66	1.212,80
		UG	64,83	334,70	6.387.67	6.787,20
	SÃO SEPÉ/DURASNAL	OP	-	25,42	150,00	175,42
	IRUÍ/CAPANÊ	OP	54,34	21,50	90,00	165,84
		UG	122,23	379,75	2.517,18	3.019,16
	FAXINAL/ÁGUA BOA	OP	13,00	-	-	13,00
	LEÃO	OP	20,73	12,37	-	33,10
		UG	559,40	272,32	2.903,18	3.734,90
	CHARQUEADAS/TRIUNFO	UG	465,00	512,15	582,65	1.560,70
	SANTA RITA	UG	72,78	185,06	342,16	600,00
	MORUNGAVA - BLOCO SUL	UG	-	300,00	300,00	600,00
	MORUNGAVA - BLOCO NORTE	UG	-	180,00	320,00	500,00
	GRAVATAÍ	OP	-	27,00	-	27,00
	CHICO LOMÃ	UG	-	824,15	-	824,15
	ROLANTE	UG	3,10	21,50	117,30	141,90
	SANTA TEREZINHA	UG	-	-	1.038,43	1.038,00
	SUL DE TORRES	UG	2,30	16,80	315,30	334,40
	SUBTOTAL		1.786,46	3.544,01	15.437,53	20.768,00
SANTA CATARINA	BARRO BRANCO	OP/UG	239,17	387,03	226,16	852,36
	BONITO SUPERIOR	OP/UG	13,80	55,30	31,50	100,60
	BONITO INFERIOR	UG	116,34	416,74	395,20	928,28
	IRAPUÃ	UG	10,00	-	-	10,00
	PRÉ-BONITO SUPERIOR	UG	-	-	40,00	40,00
	PONTE ALTA	UG	-	-	10,00	10,00
	SUBTOTAL		379,31	859,07	702,86	1.941,24
PARANÁ	BARBOSAS	UG	0,40	-	-	0,40
	IBAITI	UG	0,30	-	-	0,30
	CARVÃOZINHO	UG	0,26	-	-	0,26
	EUZÉBIO DE OLIVEIRA	UG	-	0,14	-	0,14
	CAMBUÍ	UG	25,90	19,10	-	45,00
	PÉLAME	UG	0,28	-	-	0,28
	SALTO APARADO	UG	3,50	3,50	3,00	10,00
	RIBEIRÃO DAS ANTAS	UG	-	-	2,00	2,00
	CAMPINA DOS PUPOS	UG	1,40	5,00	-	6,40
	SAPOPEMBA	UG	-	30,00	-	30,00
	SUBTOTAL		32,04	57,74	5,00	94,78
SÃO PAULO	MONTE MOR	UG	-	-	0,01	0,01
	BURI	UG	-	-	0,01	0,01
	CERQUILHO	UG	2,00	1,00	7,00	10,00
	SUBTOTAL		2,00	1,00	7,02	10,02
	TOTAL		2.199,81	4.461,82	16.152,41	22.814,04

OP = Open Pit Mine; UG = Underground Mine

TABLE B-2

ROM COAL PRODUCTION - 1980

STATE/COMPANY/MINE	Tons/Year	
Rio Grande do Sul		
C.R.M.		
Leao I	612 460	
Candiota	472 040	
Copelmi		
Recreio	1 077 090	
Charqueadas	367 444	
Subtotal		2 529 034
Santa Catarina		
Grupo A (State Companies)		
Carbonifera Prospera	3 210 446	
Carbonifera Barao do Rio Branco	284 590	
Grupo B (Private Companies)		
Cia. Brasil. Carbonifera Aranrangua	1 085 510	
Carbonifera Criciuma S.A.	2 250 821	
Cia. Carbonifera Catarinense S.A.	429 914	
Cia. Carbonifera Urussanga	2 385 329	
Carbonifera Metropolitana S.A.	2 459 519	
Cia. Nac. de Miner. Carvao Barro Branco	432 837	
Carbonifera Palermo Ltda.	182 307	
Carbonifera Treviso S.A.	441 628	
Subtotal		13 161 931
Parana		
Cambui	291 604	
Klabin	17 662	
Subtotal		309 266
TOTAL		16 000 231

TABLE B-3

COAL PRODUCTION PER TYPE - 1980

TYPE	Tons/Year	
Rio Grande do Sul		
Coal/(Mine)		
Tech (Charqueadas)	320 941	
Tech (Recreio)	334 446	
CV40 (Recreio)	115 295	
CV35 (Recreio)	167 961	
CV52/54 (Candiota)	471 979	
CV20 (Leao I)	60 662	
CV35 (Leao I)	89 899	
CV40 (Leao I)	92 718	
Subtotal		1 653 901
Santa Catarina		
Capivari Washer		
CPL (Beneficiado)	3 268 492	
Carvao Metalurgico (CM)	1 287 604	
Carvao Vapor Secundario (CVS 42%)	1 264 049	
Carvao Vapor Locomotiva	75 908	
Carvao Vapor Fino (CVF)	444 868	
Subtotal		3 072 426
CV35% Directly From the Mines		
Carbonifera Prospera	41 533	
Carbonifera Criciuma	13 457	
Subtotal		54 990
Parana		
Cambui 20%Cz	191 085	
Klabin 20%Cz	11 820	
Subtotal		202 905
TOTAL		4 984 222

TABLE B-4

FORECASTED DEMAND (1980/1985) - GOVERNMENT PLANS

TYPE	PARTICIPATION IN 1980		PARTICIPATION IN 1985	
	10^3 ton	%	10^3 ton	%
THERMOELECTRICITY	1 831	51.80	8 050	47.8
TRANSPORT	44	1.2	50	0.3
STEEL WORK	136	3.8	1 210	7.2
CEMENT	1 056	30.0	5 560	33.0
PULP AND PAPER	134	3.8	540	3.2
OTHERS	334	9.4	1 400	8.5
TOTAL	3 535	100.0	16 810	100.0

STEAM COAL PRODUCTION FORECAST

YEAR	FORECAST PRODUCTION (10^6 ton)	% INCREASE OVER BASE 1980
1981	5.2	1.42
1982	6.9	1.89
1983	9.5	2.61
1984	12.7	3.48
1985	17.0	4.67

Table B-5
PROJECTS APPROVED/ANALYSED IN PRODUCTION PLANNED UP TO 1985

STATE	PROJECT	TYPE OF MINE	Predicted Production 10^3 ton/year		START UP	Available Steam Coal 10^3 ton/year			STATUS
			ROM	SALE		CV35	CV40	CV52	
RS	CANDIOTA II	O.P.	4 000	3 200	84	1 000		2 200	Approved. Executive and detail engineering phase
	IRUI - CRM	O.P.	1 560	720	81	720			In production
	FAXINAL	O.P.	900	480	82	480			Final Implantation
	LEÃO II	U.G.	2 400	1 200	84	1 200			In Implantation
	4		8 860	5 600		3 400		2 200	
SC	S. GERALDO	U.G.	1 900	470	82	150	188		App'd In Implantation
	R. AMERICA	U.G.	2 200	510	85	163	204		App'd In Implantation
	ESPERANÇA	U.G.	2 350	550	83	176	220		App'd In Implantation
	FONTANELLA	U.G.	2 900	720	85	720	-		Analysed and forwarded for financing.
	BONITO	O.P.	1 200	300	84	300	-		Final engineering
	UM 2	U.G.	1 536	720	84	390	190		In Implantation
	UM 4	U.G.	384	180	84	60	72		In Implantation
	UM 6	U.G.	154	72	84	20	30		In Implantation
	M. ALBINO	U.G.	2 400	620	82	200	250		Analysed and forwarded for Financing.
	9		15 024	4 142		2 179	1 154		
	TOTAL		23 884	9 742		5 579	1 154	2 200	

O.P. - OPEN PIT MINE U.G. - UNDERGROUND MINE

Table B-6
COAL ANALYSIS OF RIO GRANDE DO SUL MINES

Table B-6a — Proximate Analysis, HHV and Sulfur Content in Coal Samples of Candiota Mine

ANALYSIS \ SAMPLE		CANDIOTA - Upper Seam						CANDIOTA - Lower Seam						Banco Louco - BC
		1 - OP	2 - OP	3 - OP	4 - OP	5 - OP	6 - OP	1 - OP	2 - OP	3 - OP	4 - OP	5 - OP	6 - OP	
Proximate Analysis	Total moisture	11.0	10.2	13.4	12.8	11.3	10.4	18.4	16.6	16.6	6.0	13.5	12.8	17.2
	Free moisture	5.3	5.2	6.3	6.4	6.3	7.0	6.5	8.1	8.3	3.3	5.2	5.0	9.5
	Higroscopic mois.	5.7	5.0	7.1	6.2	5.0	3.4	11.9	8.5	8.5	2.7	8.3	7.8	7.7
	Ash, d.b. %	52.1	51.9	51.6	52.0	53.5	51.4	49.1	49.7	52.4	49.9	50.6	51.1	50.9
	V.Matter d.b. %	23.4	22.3	22.8	22.2	21.5	21.5	23.5	23.1	21.5	22.0	22.7	22.7	21.1
	F.Carbon d.b. %	24.5	25.8	25.6	25.8	25.0	27.1	27.4	27.2	26.0	28.1	26.7	26.2	28.0
HHV, d.b., cal/g		3200	3204	3253	3213	3027	3263	3572	3473	3256	3421	3363	3326	3345
Sulfhur, d.b, %		3.1	1.7	1.0	1.5	2.0	1.1	1.4	0.9	1.5	1.4	1.7	2.2	0.9

Table B-6b — Proximate Analysis, HHV and Sulphur Content in Coal Samples of Charqueadas and Recreio Mines

ANALYSIS \ SAMPLES		CHARQUEADAS - Seam I_1F					RECREIO-Upper Seam				RECREIO-L.S.		
		10 - L	8 - N	14 - N	1 - NL	CV	I - R1	II - Canal I	II - Canal II	II - Canal III	II - Canal I	II Canal II	II - Canal III
Proximate Analysis	Total moisture	7.9	6.5	8.8	10.7	9.2	11.7	11.0	12.8	12.1	13.0	12.9	14.3
	Free moisture	2.3	1.7	3.3	5.9	2.6	3.3	3.3	3.3	3.3	6.0	6.0	6.0
	Higroscopic moisture	5.6	4.8	5.5	4.8	6.6	8.4	7.7	9.5	8.8	7.0	6.9	8.3
	Ash, d.b. %	57.3	67.3	67.1	66.8	51.7	54.9	44.0	52.0	47.2	55.0	64.2	51.0
	V.Matter, d.b. %	20.0	16.4	16.7	17.0	21.4	22.1	26.0	23.0	24.7	21.4	17.4	22.8
	F.Carbon, d.b. %	22.7	16.3	16.2	16.2	26.9	23.0	30.0	25.0	28.1	23.6	18.4	26.2
HV, d.b., cal/g		2891	1766	1806	1839	3346	3009	3935	3266	3641	3068	2306	3408
Sulphur, d.b., %		0.4	0.2	0.5	0.3	0.3	1.5	2.9	3.3	1.6	1.6	1.6	1.4

Table B-6c — Proximate Analysis, HV and Sulphur Content in Coal Samples of Leao I Mine

ANALYSIS \ SAMPLE	LEÃO - Lower seam											
	1 – NS	2 – WB	3 – O_1	4 – O_2	5 – O_3	6 – O_3	7 – WB_2	8 – O_4	9 – O_5	10 – WB	11 – WB	12 – WB
Total moisture	5,6	6,4	7,9	6,9	8,9	11,7	5,0	8,1	10,5	10,7	10,4	11,1
Free moisture	1,3	2,8	3,1	2,8	3,1	5,0	2,4	3,4	1,9	3,9	3,2	1,4
Higroscopic moisture	4,3	3,6	4,8	4,1	5,8	6,7	2,6	4,7	8,6	6,8	7,2	9,7
Ash, d.b. %	38,6	40,2	51,8	51,7	35,4	37,8	50,9	38,5	44,8	51,5	51,7	48,2
V.Matter, d.b. %	27,7	26,3	23,4	23,0	28,9	27,6	23,3	28,2	25,6	23,3	23,5	24,8
F.Carbon, d.b. %	33,7	33,5	24,8	25,3	35,7	34,6	25,8	33,3	29,6	25,2	24,8	27,0
HV, d.b. cal/g	4415	4245	3256	3224	4785	4523	3349	4517	3800	3280	3258	3546
Suphur, d.b. %	1,7	1,2	1,1	1,5	0,7	1,5	1,2	1,2	2,2	1,2	0,7	2,4

Table B-6d — Equilibrium Moisture, Proximate Analysis, Ultimate Analysis and HV in Coal Samples of Candiota, Charqueadas, Leao and Recreio Mines

MINE-SEAMS \ ANALYSIS	EQUIL. MOISTURE %	Prox. Analysis			Ultimate Analysis						HV	
		Higrosc. Moisture, %	V. Matter d.b., %	F. Carbon d.b., %	Ash d.b., %	Carbon d.b., %	Hydrogen d.b., %	Nitrogen d.b., %	Sulphur d.b., %	Oxygen + Halogen d.b., %	High, d.b., cal/g	Low, d.b., cal/g
CANDIOTA - Upper Seam	16,8	3,1	22,5	25,8	51,7	34,3	2,7	0,5	1,6	9,2	3208	3068
CANDIOTA - Lower Seam	18,8	4,7	22,1	27,8	50,1	34,9	2,8	0,7	2,0	9,5	3416	3272
CHARQUEADAS - Seam I_1F	9,3	6,5	19,3	21,5	59,2	29,3	2,2	0,5	0,4	8,4	2677	2564
LEÃO - Lower Seam	13,6	10,7	24,6	29,4	46,0	38,8	2,7	0,6	1,7	10,2	3826	3687
RECREIO - Upper Seam	11,5	9,8	24,9	28,4	46,7	38,7	2,9	0,6	2,6	8,5	3719	3570
RECREIO - Lower Seam	13,1	8,4	22,2	25,0	52,8	34,3	2,7	0,6	2,0	7,6	3245	3106

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Table B-6e — Carbonates, Chlorine, Sulphur, Weight Density, Bulk Density and Grindability in Coal Samples of Candiota, Charqueadas, Leao and Recreio Mines

MINES - SEAM / ANALYSIS	Carbonates, d.b., % (CO_2)	Chlorine, d.b., %	Sulfhur Forms: Piritic, d.b., %	Sulphatic, d.b., %	Organic, d.b., %	Total, d.b., %	W.Density, g/cm³	Bulk Density, kg/m³(1"x0)	HGI
CANDIOTA - Upper Seam	1,58	0,12	0,99	0,12	0,44	1,53	1,9	1108	107
CANDIOTA - Lower Seam	3,11	0,09	1,41	0,04	0,55	2,00	1,9	1094	100
CHARQUEADAS - Lower Seam	1,35	0,03	0,23	nihil	0,17	0,40	2,1	1057	67
LEÃO - Lower Seam	1,25	nihil	1,30	0,07	0,43	1,80	2,0	1004	62
RECREIO - Upper Seam	1,30	0,01	1,73	0,42	0,48	2,63	1,9	1192	73
RECREIO - Lower Seam	1,40	0,04	1,28	0,31	0,43	2,02	2,0	1053	79

Table B-6f — FSI, Dilatometry, Reactivity and Pirolysis in Coal Samples of Candiota, Charqueadas, Leao and Recreio Mines

MINES - SEAMS / ANALYSIS	Free Swelling Index (F.S.I.)		Audibert-Arnu Dilatometry: Initial Temp. plastic phase ºC	Max. Temp. Concentr. ºC	Max. Temp. Expansion ºC	Max. Contr. %	Max. Expan. %	Reactivity to CO_2 (Koppers-Jenkner)	Pirolysis: Coke Residue d.b., %	Tar d.b., %	Decomp. water d.b., %	Gases d.b., %
CANDIOTA - Upper Seam	0	0*	Coal did not present contraction nor expansion					→	84,6	5,2	9,2	1,0
CANDIOTA - Lower Seam	0	0*	Idem					easily reactive	84,0	4,6	10,4	1,0
CHARQUEADAS - Seam I_1F	0	0*	Idem						92,6	1,4	3,0	3,0
LEÃO - Lower Seam	0	0*	Idem						85,2	5,2	5,7	3,9
RECREIO - Upper Seam	0	1/2*	340	430	490	8,3	-		90,3	3,8	3,0	2,9
RECREIO - Lower Seam	0	0*	Coal did not present contraction nor expansion					↓	90,9	3,2	3,5	2,4

* Float in 1,5

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Table B-6g — Spectrografic Analysis Reflectance Power and Melting Characteristic of the Ashes in Coal Samples of Candiota, Charqueadas and Recreio Mines

ANALYSIS / MINES - SEAM	SPECTROSCOPIC ANALYSIS				Reflectance Power	Fusibility of Ash (oxidizing atm.)		
	Vitrinite, %	Exinite, %	Inertinite, %	Minerals, %		Initial Deformation °C	Hemispherical °C	Fluid °C
CANDIOTA – Upper Seam	69*	5*	18*	8*	0.51 ± 0.05*	1440	1560	1580
CANDIOTA – Lower Seam	69*	4*	13*	14*	0.46 ± 0.04*	1390	1490	1510
CHARQUEADAS – Lower Seam	37*	15*	36*	12*	0.72 ± 0.06*	1460	1580	1600
LEÃO – Lower Seam	63*	8*	22*	7*	0.53 ± 0.05*	1480	1565	1600
RECREIO – Lower Seam	50*	8*	36*	6*	0.59 ± 0.06*	1430	1540	1560
RECREIO – Lower Seam	52*	5*	32*	11*	0.76 ± 0.06*	1490	>1600	>1600

* Float in 1,5

Table B-6h — Chemical Analysis of Ash in Coal Samples of Candiota, Charqueadas, Leao and Recreio Mines

ANALYSIS / MINES - SEAMS	CHEMICAL ANALYSIS OF ASH											
	Dióxido de Silício (SiO_2), %	Óxido de Alumínio (Al_2O_3), %	Óxido de Cálcio (CaO), %	Óxido de Magnésio (MgO), %	Óxido Férrico (Fe_2O_3), %	Dióxido de Titânio (TiO_2), %	Dióxido de Manganês (MnO), %	Óxido de Potássio (K_2O), %	Óxido de Sódio (Na_2O), %	Pentóxido de Fósforo (P_2O_5), %	Trióxido de Enxofre (SO_3), acima de 950°C, %	Perda ao fogo (LOI) °C, %
CANDIOTA – Upper Seam	71.2	19.6	0.7	0.4	6.2	0.7	0.07	0.9	0.2	0.01	n d	0.02
CANDIOTA – Lower Seam	71.2	21.4	0.5	0.5	4.4	0.7	0.05	0.9	0.2	0.02	0.01	0.02
CHARQUEADAS – I_1F Seam	63.9	25.2	1.3	0.8	3.1	1.1	0.04	1.3	0.8	0.07	0.5	2.0
LEÃO – Lower Seam	58.2	26.8	1.4	0.4	5.4	1.2	<0.01	1.1	1.4	0.08	0.2	3.3
RECREIO – Upper Seam	60.4	25.6	2.2	0.4	5.2	1.0	0.05	0.7	0.4	0.1	0.9	3.4
RECREIO – Lower Seam	64.3	25.6	1.2	0.3	2.8	1.0	0.02	0.7	0.5	0.07	0.4	3.3

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TABLE B-6 (Continued)

B-6i Leao I Mine Proximate Analysis

	ROM		20% Ash	35% Ash	40% Ash
	UG	OP			
% Ash	55.6	53.2	20.1	35.4	40.2
V. Matter	20.1	23.4	34.4	29.6	27.4
F. Carbon	24.3	23.4	45.5	35	32.4
S	2.3	1.5	0.6	0.9	1.3
HV kcal/kg	3199	3391	6047	4887	4516

B-6j Candiota Mine Proximate Analysis of ROM Coal

Ash	V. Matter	F. Carbon	S%	HV kcal/kg
54.5	22.1	23.4	1.5	3060

o Proximate Analysis of CV35 Coal (future)

Ash	V. Matter	F. Carbon	S	HHV kcal/kg	H.G.I.
35	28	37	1	4600	110

Hygroscopic moisture	12%
Surface moisture	8%
Total	20%

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TABLE B-6 (Continued)

B-6j (Continued)

o Size Analysis of CV35 (future)

1 1/4" x 1/2"	1/2" x 1/4"	1/4" x 0.04"	-0.04"
35	22	30	13

B-6k Irui Mine Proximate Analysis of ROM Coal

Ash	V. Matter	F. Carbon	S	Moisture	HV kcal/kg
38.6	24.9	36.5	0.4	10	4 408

B-61 Charqueadas Mine Proximate Analysis of ROM Coal

Ash	V. Matter	F. Carbon	S	HV kcal/kg
57.3	20	22.7	0.4	2 891

B-6m Recreio Mine Proximate Analysis of CV35

Ash	V. Matter	F. Carbon	S	Moisture	HV kcal/kg
35	29.6	35.4	0.9	7.5	4 780

o Ultimate Analysis of CV35

C%	H%	N%	S%	O%
52	1.7	0.8	0.9	9.6

TABLE B-6 (Continued)

B-6m (Continued)

o Chemical Analysis of Ash (CV35)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	Na_2O	K_2O	P_2O_5	SO_3(950°C)	SO_3(450°C)
60.30	26.50	3.90	1.02	0.46	0.75	1.32	0.07	4.00	0.83	0.95

Loss after incineration (950°C)
4.00

o Size Analysis of CV35

+1"	1" x 5/8"	5/8" x 1/2"	1/2" x 1/4"	1/4" x 0.04"	0.04"
8.6	28.7	16.0	10.8	31.70	4.2

o Fusibility of Ash (Oxidizing Atmosphere)

Initial deformation	1 400 °C
Hemispherical	1 602 °C
Fluid	1 617 °C

Table B-7

AVERAGE COAL CHARACTERISTICS OF BARRO BRANCO SEAM IN STA. CATARINA DEPOSITS

DESCRIPTION	UNIT	ROM COAL TOTAL SEAM	PRÉ-WASHING COAL C P L	COKING COAL CM	CV-35 35% ASH	CV-40 40% ASH
Ash	%	57 à 65	27 à 32	16	32 à 35	39 à 44
Size	mm	500mm x 0	60mm x 0	25mm x 0	25mm x 0	25mm x 0
Moisture	%	5 - 6	5 - 6	5 - 6	5 - 6	5 - 6
Sulphur	%	5 - 8	2 - 3	1,5 - 1,8	2 - 3	2,8 - 3,5
V.Matter	%	-	28 - 30	32 - 34	26 - 28	23 - 26
F.Carbon	%	-	38 - 45	50	34 - 40	30 - 38
HHV	Kcal/Kg	-	5.800/6.000	6.900	5.000/5.500	4.500/5.000
LHV	Kcal/Kg	-	-	-	-	-
Weight Density	t/m^3	1,65	1,50	1,40	1,50	1,60
Bulk Density	t/m^3	1,50	1,00	0,85	1,00	1,10
Free Swelling Index	FSI	-	2.0	4.0 à 5.0	1.0 à 1.5	0.5 à 1.5
Hidrogen	%	-	-	5,2	-	-
Nitrogen	%	-	-	0,64	-	-

TABLE B-8

PROXIMATE ANALYSIS OF SANTA CATARINA MINES

B-8a Prospera Coal Company

Mine		Ash	V. Matter	C	S	FSI
A. Sangao ROM	65.7	8.0	27.0	3.0		
	CPL	31.5	28	42	1.65	2.5
Sideropolis	ROM UG	60.3	8.0	-	6.1	-
	ROM OP	38.5	18.1	-	3.9	-
	CPL	31.0	-	40.0	1.64	4.0

B-8b Metropolitana Coal Company

Mine		H_2O	Ash	V. Matter	C	S	FSI	HV kcal/kg
UNIAO	ROM	3	62.5	21.7	12.8	4.1	-	2 700
	CPL	8	32	32.0	28	2.5	4	5 500

B-8c Criciuma Coal Company

Mine		Ash	V. Matter	C	S	FSI
Sao Roque	ROM	63	17.7	-	4.6	-
	CPL	32	24.3	-	2.0	2

TABLE B-8 (Continued)

B-8d Urussanga Coal Company

Mines		Ash	V. Matter	C	S	FSI	HV kcal/kg
S. Augusta	ROM	68	18.0	10.0	2.8	-	
	CPL	30	32.0	34.0	1.9	4.5	
	Fines	15	34.0	47.0	1.6	5.5	
S. Geraldo	ROM	63.9	18.5	-	4.26		
Rio Deserto	ROM	57.9	10.6	31.5	5.8		
	Anthracitic Coal	36.0	11.4	52.60	3.21		
Santana	ROM	62.9	16.6	21.7	5.8		
	CPL	27.4	30.1	44.7	2.1	2.5	6100
	Fines	13.0	32.0	52.2	1.5	8.0	6350

TABLE B-9

CV-40 STEAM COAL ANALYSIS OF CAPIVARI WASHER PLANT

o Ultimate Analysis

C	H_2	N_2	S	O_2	Ash	HGI
46.68	3	0.98	2.65	3.09	41.6	57

o Ash Characteristics

SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	SO_3	T_1O_2	P_2O_5
49.2	25.5	9	2.5	2.2	0.2	2.6	-	2.5	0.1

M_nO_2	Undeterminated
4.5	1.7

o Fusibility of Ash (Oxidizing Atmosphere)

Initial deformation 1 460°C
Hemispherical 1 545°C
Fluid 1 560°C

o Proximate Analysis

Ash	V. Matter	F. Carbon	Moisture	HV kcal/kg
41.6	23.0	35.4	1.6	4 351

o Coal Size Analysis

+1 1/2"	1 1/2"x1	1"x3/4"	3/4"x1/2"	1/2"x1/4"	1/4"x1/8"	1/8"x28 Mesh	-28
1.29	9.61	10.37	18.59	21.53	15.75	13.84	9.02

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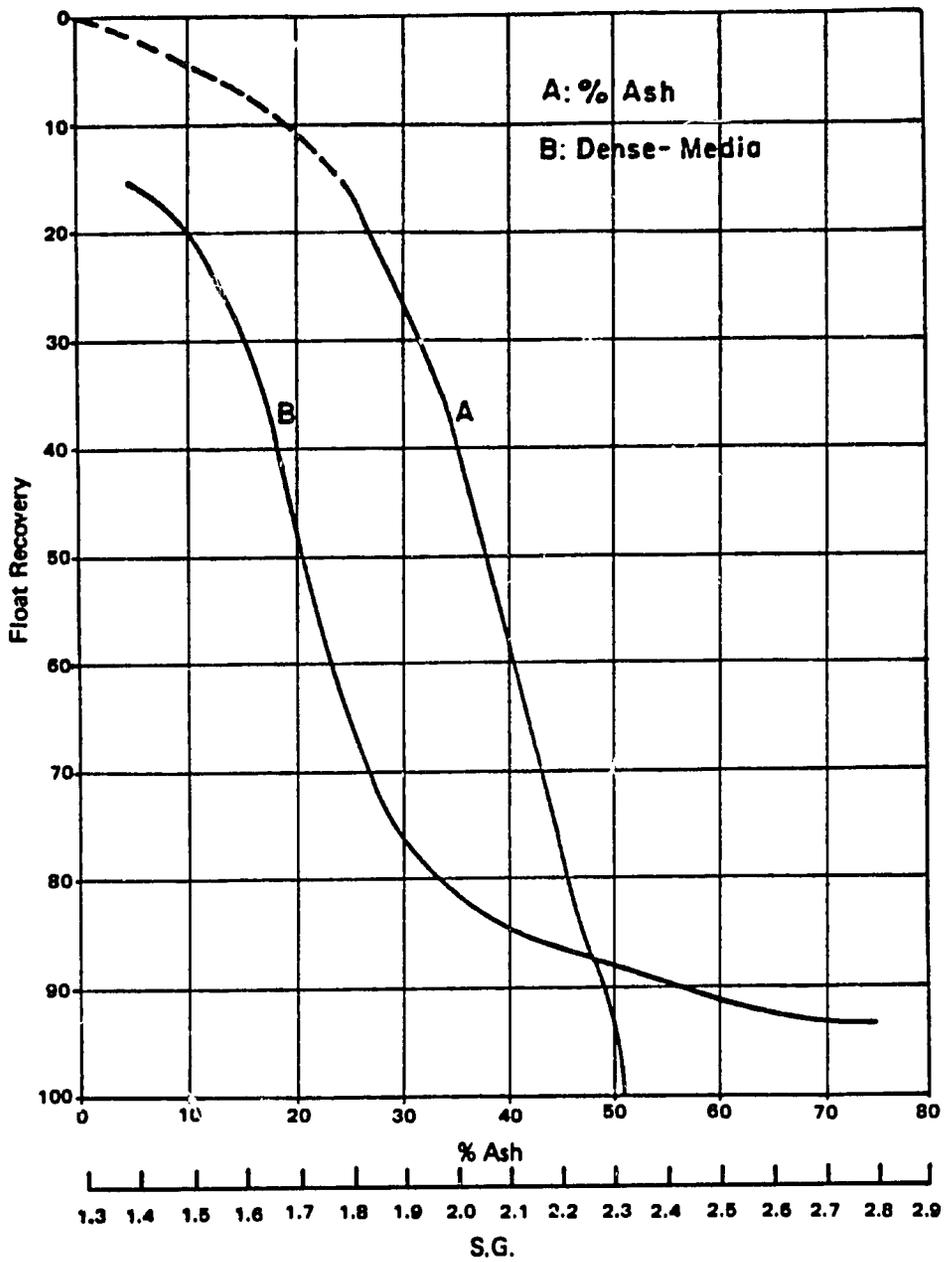
APPENDIX C

WASHABILITY CURVES

The washability curves discussed in Section 8 are presented here as Figures C-1 through C-9.

Figure C-1
WASHABILITY CURVES OF COAL SAMPLES
CANDIOTA MINE – UPPER SEAM



Characteristics of the sample:

Size	1" x 28 Mesh
Moisture	6.4%
Ash, d.b.	52.1%
V. Matter, d.b.	21.5%
F. Carbon, d.b.	26.4%
S, d.b.	1.7%
HV	3 264 (kcal/kg)

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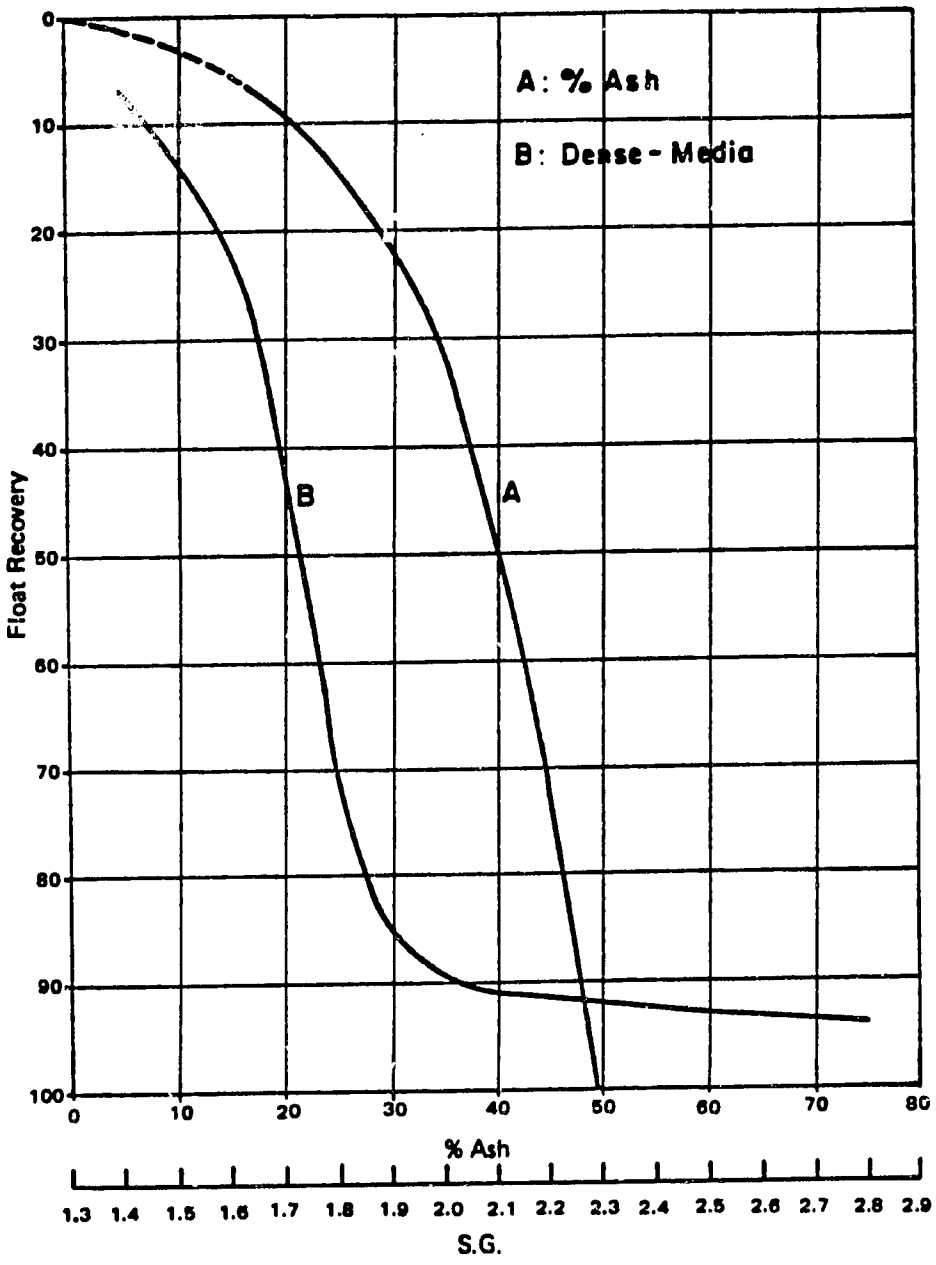
Figure C-2
WASHABILITY CURVES OF COAL SAMPLES
CANDIOTA MINE – LOWER SEAM



Characteristics of the sample:

Size	1" x 28 Mesh
Moisture	10.3%
Ash, d.b.	50.8%
V. Matter, d.b.	22.6%
F. Carbon, d.b.	26.2%
S, d.b.	1.2%
HV	3 363 (kcal/kg)

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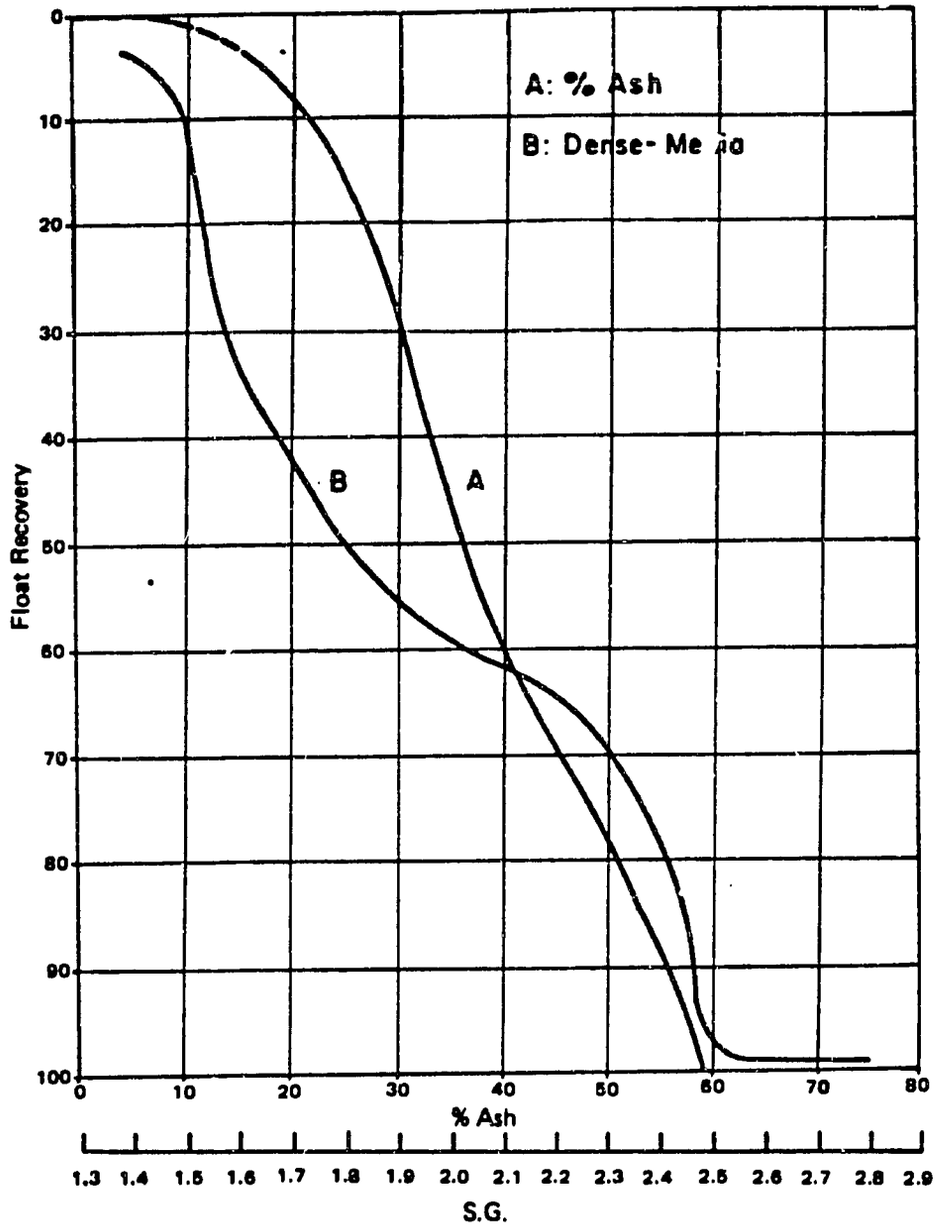
Figure C-3
WASHABILITY CURVES OF COAL SAMPLES
CHARQUEDAS MINE – 1, F SEAM



Characteristics of the sample:

Size	1" x 28 Mesh
Moisture	7.4%
Ash, d.b.	60.8%
V. Matter, d.b.	18.5%
F. Carbon, d.b.	20.7%
S, d.b.	0.6%
HV	1 985 (kcal/kg)

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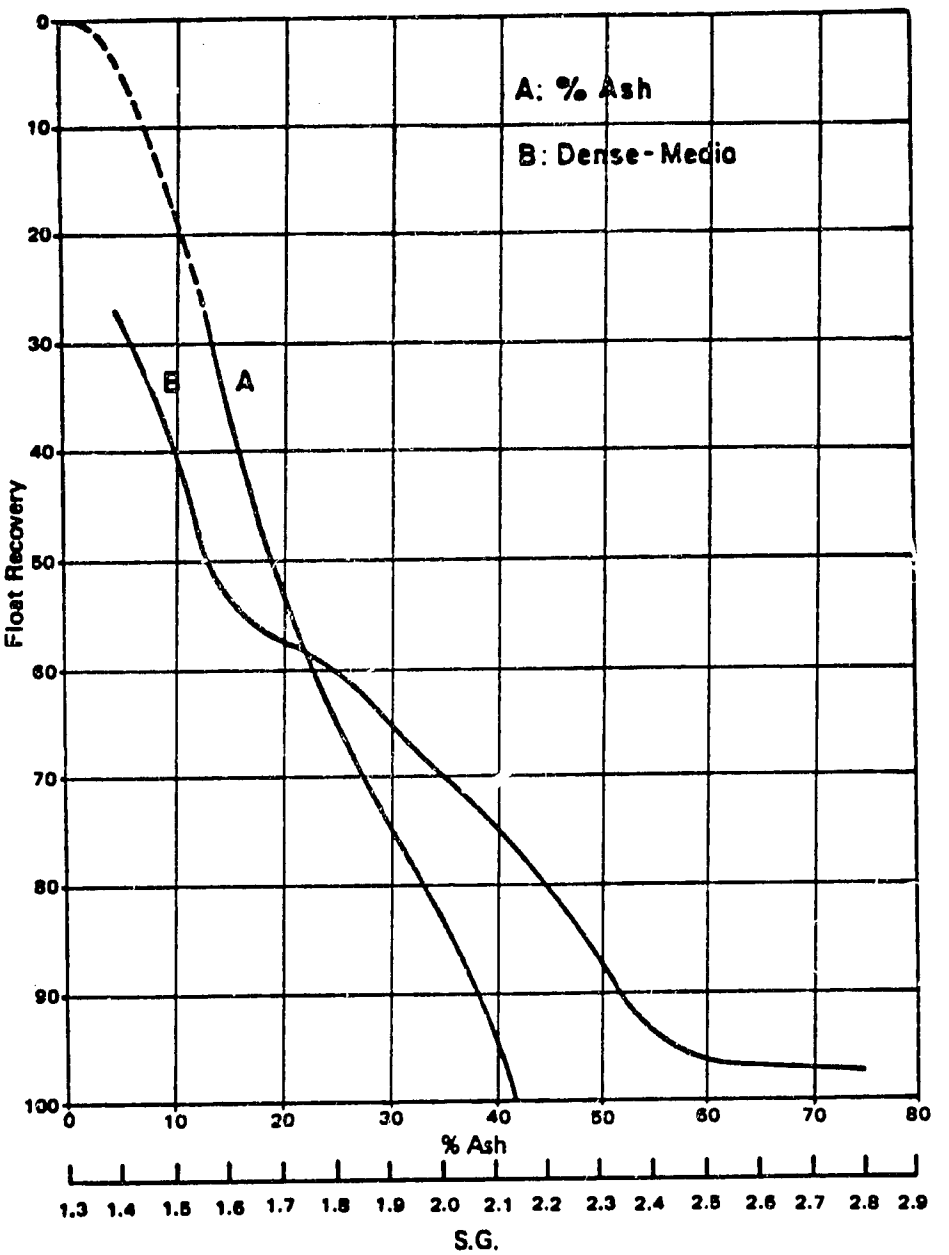
Figure C-4
WASHABILITY CURVES OF COAL SAMPLES
LEAO MINE – LOWER SEAM



Characteristics of the sample:

Size	1" x 28 Mesh
Moisture	7.9%
Ash, d.b.	48.5%
V. Matter, d.b.	24.2%
F. Carbon, d.b.	27.3%
S, d.b.	1.8%
HV	3 597 (kcal/kg)

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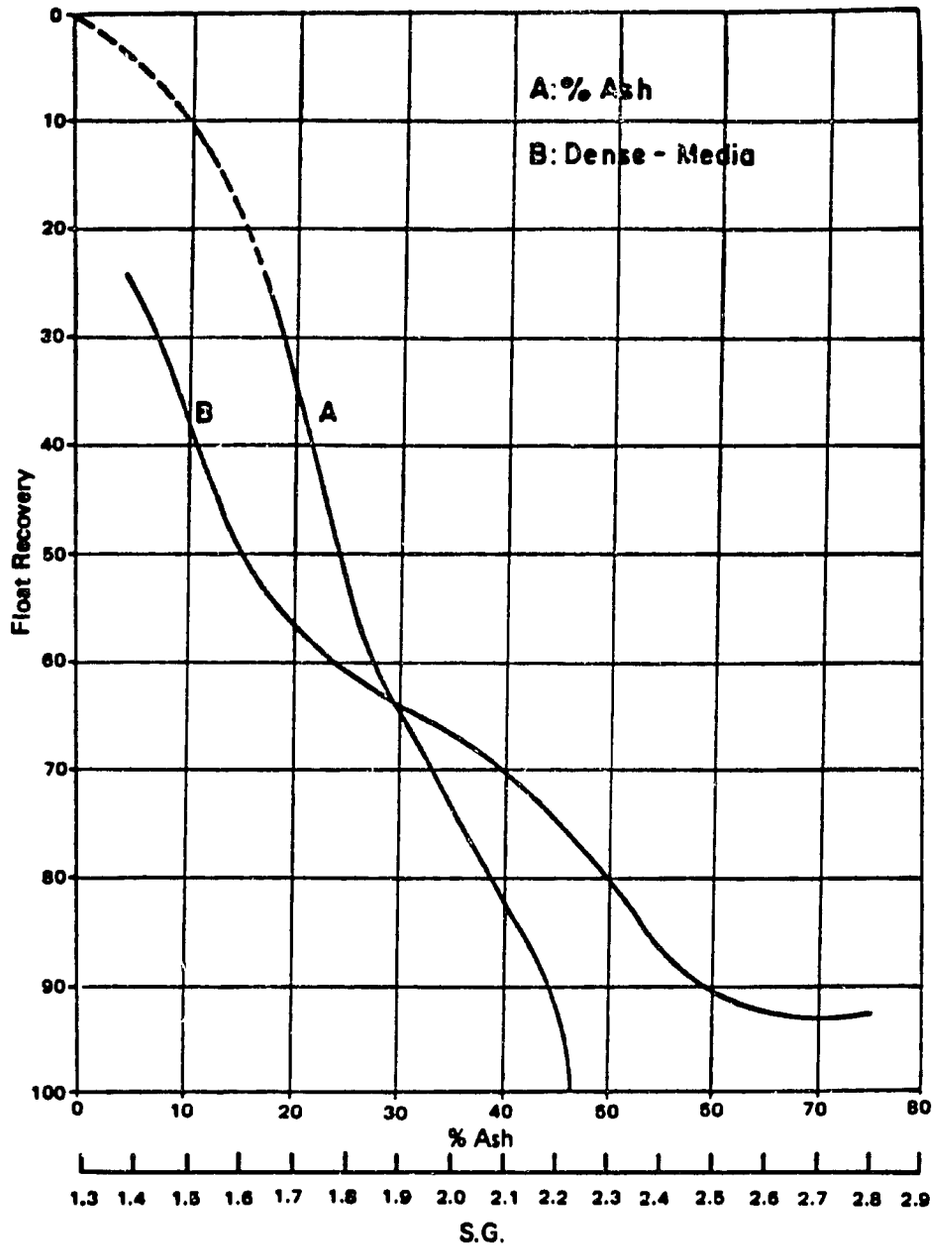
Figure C-5
WASHABILITY CURVES OF COAL SAMPLES
RECREIO MINE – UPPER SEAM



Characteristics of the sample:

Size	1" x 28 Mesh
Moisture	7.7%
Ash, d.b.	47.3%
V. Matter, d.b.	24.2%
F. Carbon, d.b.	28.5%
S, d.b.	1.7%
HV	3 695 (kcal/kg)

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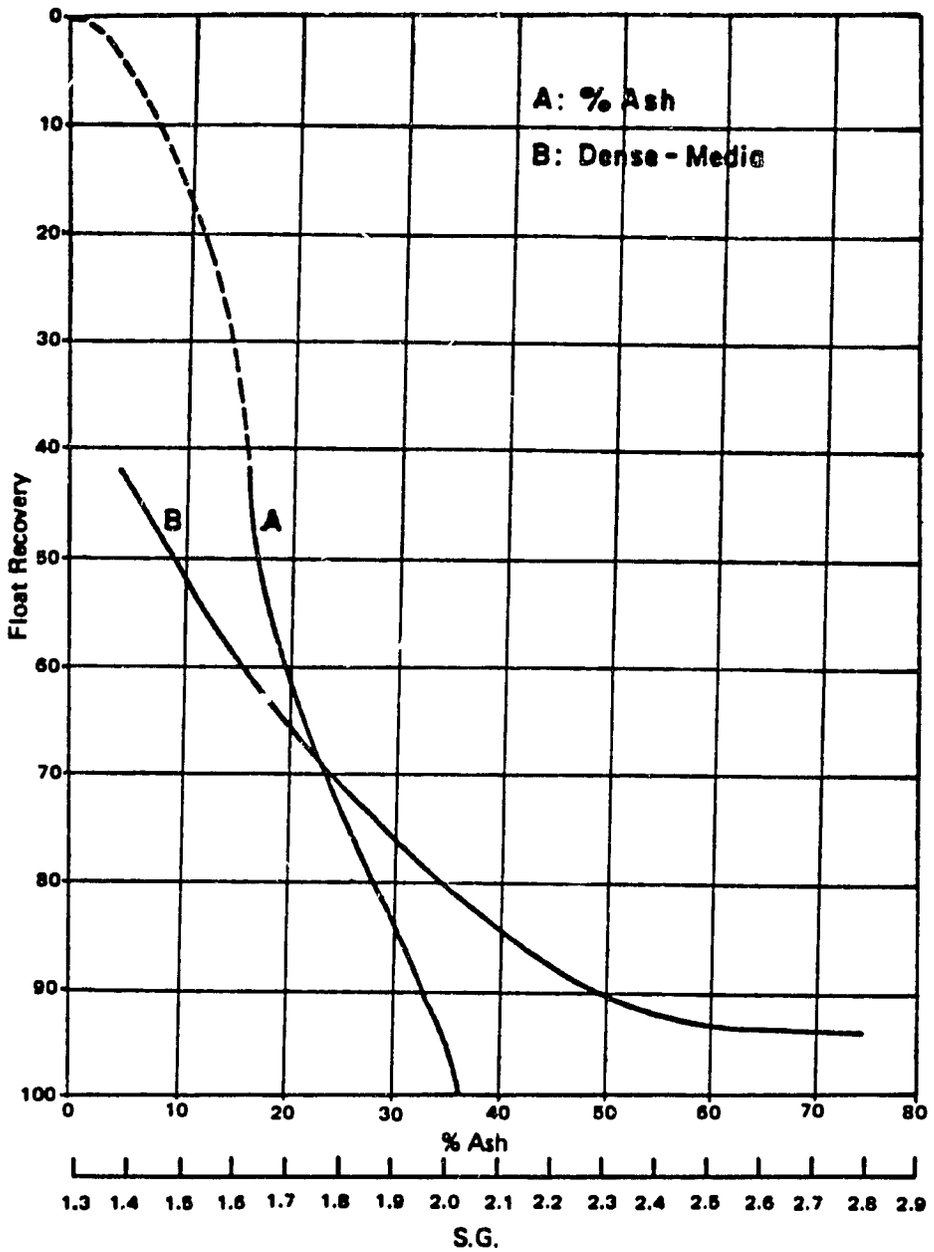
Figure C-6
WASHABILITY CURVES OF COAL SAMPLES
RECREIO MINE – LOWER SEAM



Characteristics of the sample:

Size	1" x 28 Mesh
Moisture	8.7%
Ash, d.b.	37.3%
V. Matter, d.b.	29.2%
F. Carbon, d.b.	33.5%
S, d.b.	2.6%
HV	4 498 (kcal/kg)

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Figure C-7
WASHABILITY CURVES OF A. SANGAO MINE
BARRO BRANCO SEAM – STA. CATARINA

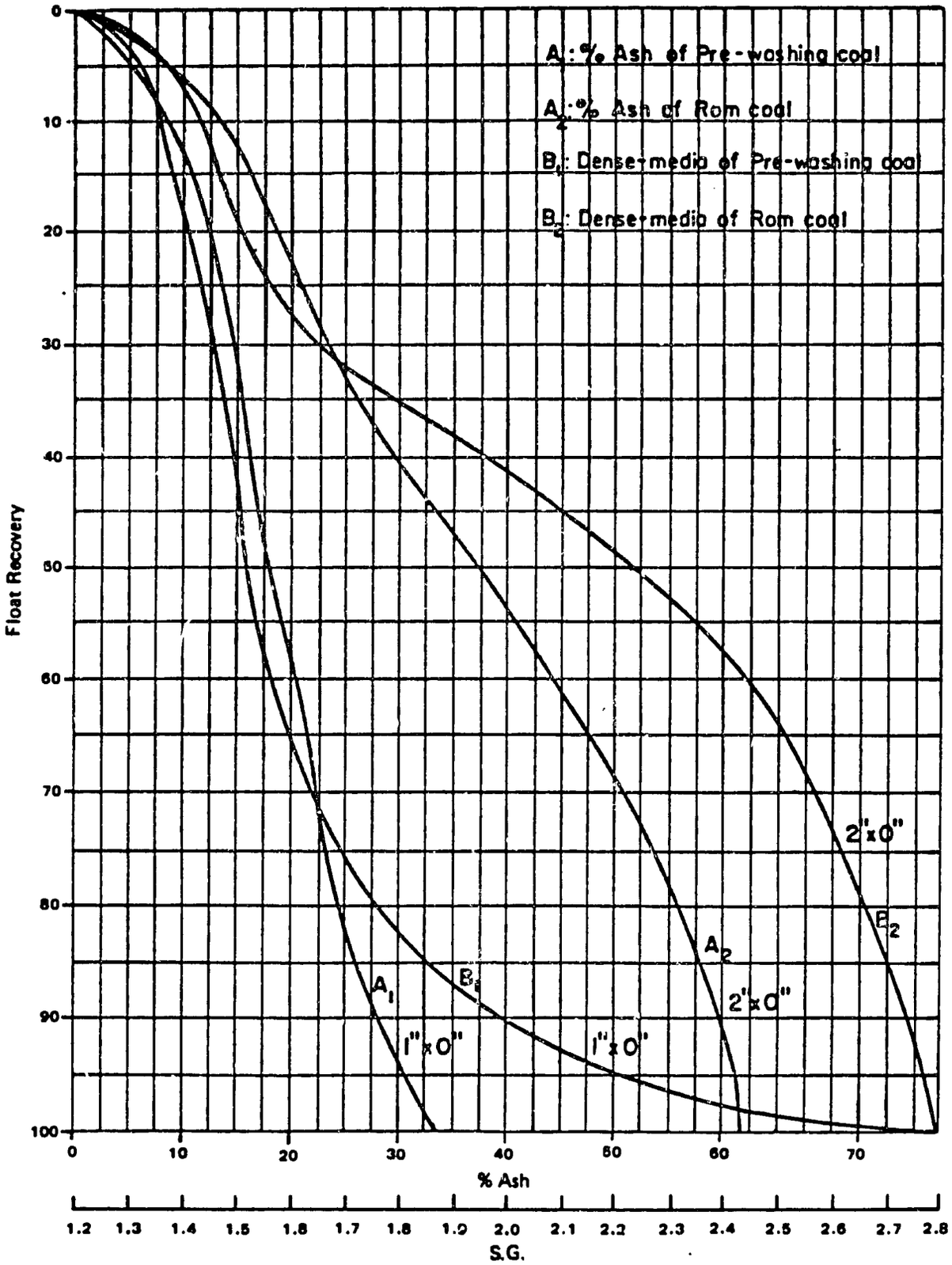

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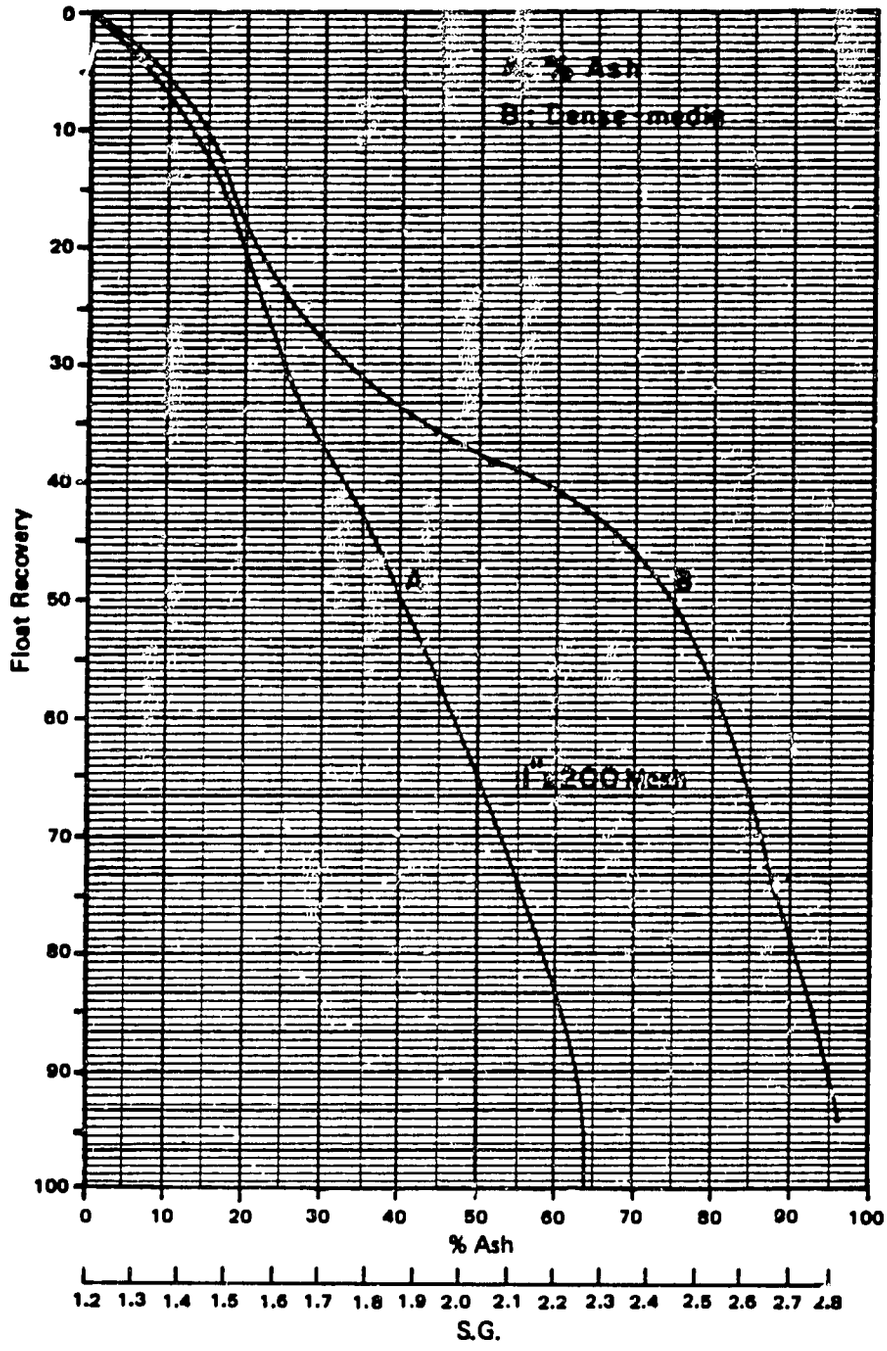
Figure C-8
WASHABILITY CURVES OF COAL SAMPLES
STA. CATARINA RESERVES -- BARRO BRANCO SEAM



Characteristics of the sample:

Proximate analysis:	V. Matter	17.7%
	Ash	64.3%
	F. Carbon	18.0%
	S	4.01%
	Size	1 1/2" x 0"

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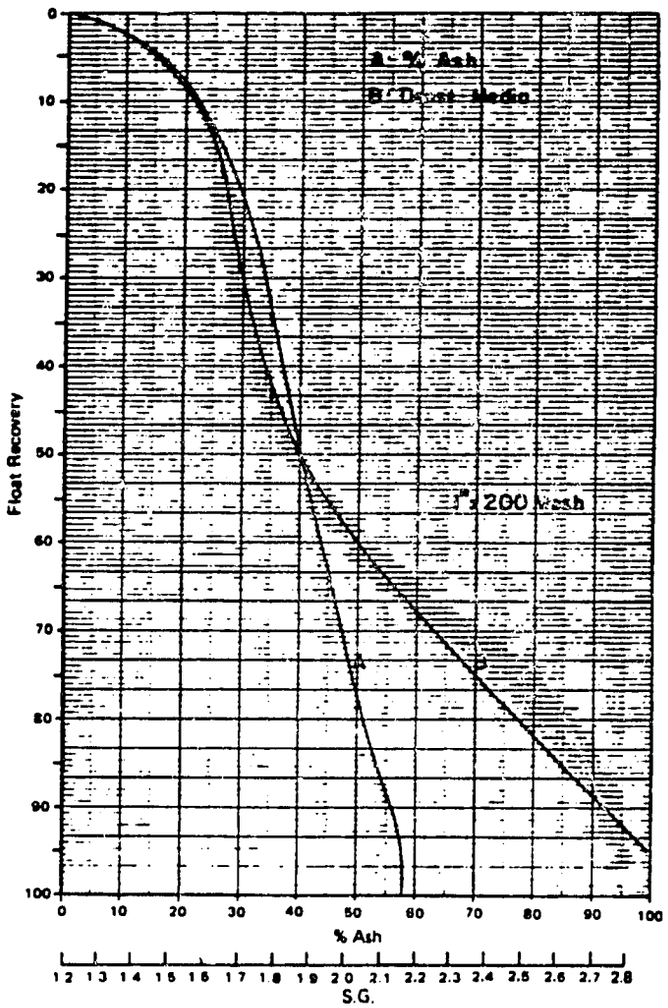
Figure C-9
WASHABILITY CURVES OF COAL SAMPLE
STA. CATARINA RESERVES – BONITO SEAM



Characteristics of the sample:

SG	Weight	Ash	S	V.Matter	F.S.I.
Size 1x2000 Mesh					
- 1.50	6.76	18.1	2.24	33.7	5.5
1.50 x 1.85	40.99	43.7	2.12	-	-
+ 1.85	40.18	74.7	5.51	-	-
200 Mesh x 0	3.07	67.7	2.21	-	-
TOTAL	100.00	57.9	3.80	-	-

Sample Analysis:	Ash	58.1%
	S	3.89%
	V. Matter	18.4%
	S.G. Seam	1.93%

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APPENDIX D

COAL RESERVE MAPS

Location of coal reserves discussed in Section 8 are presented here as Figures D-1 and D-2.

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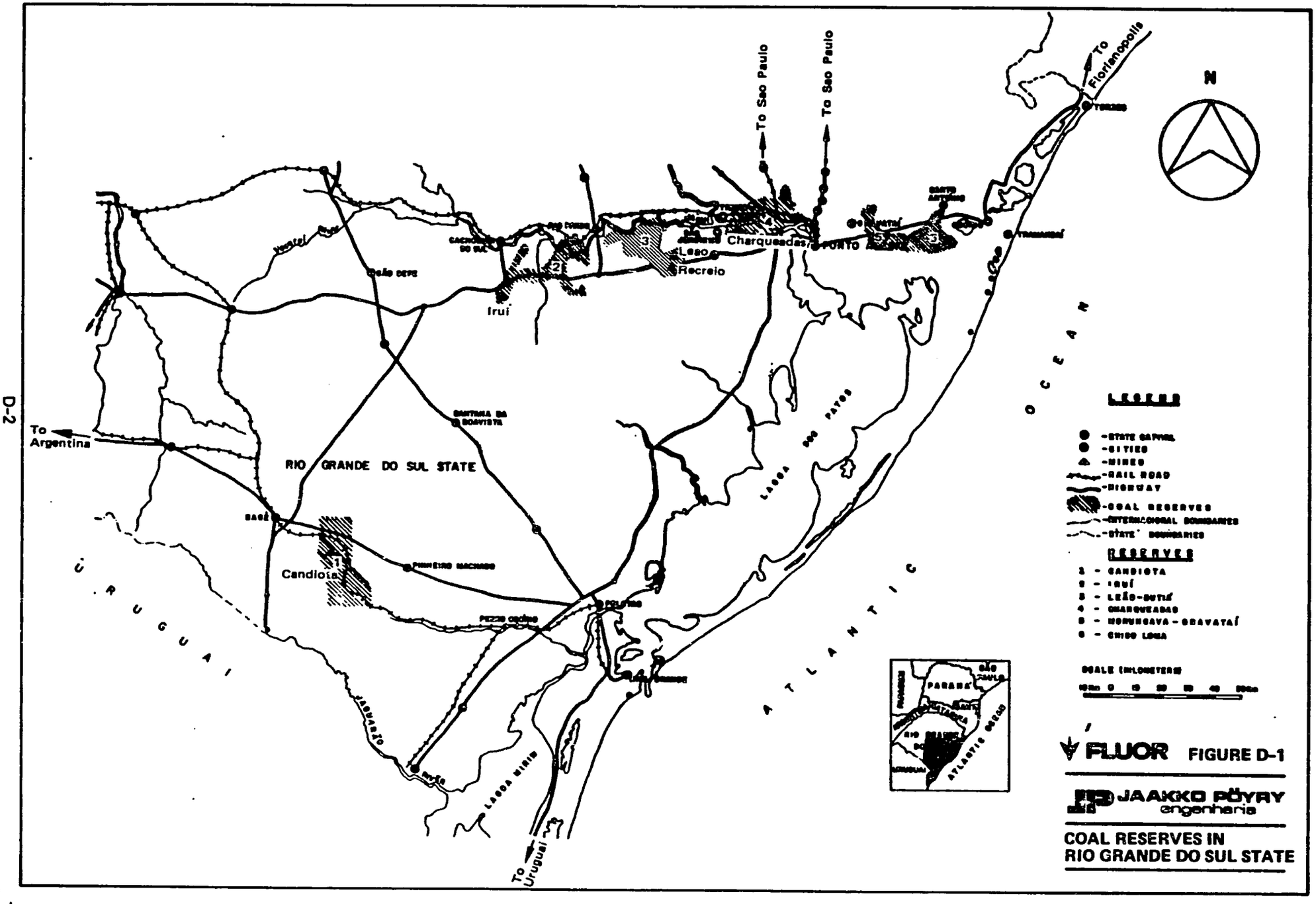
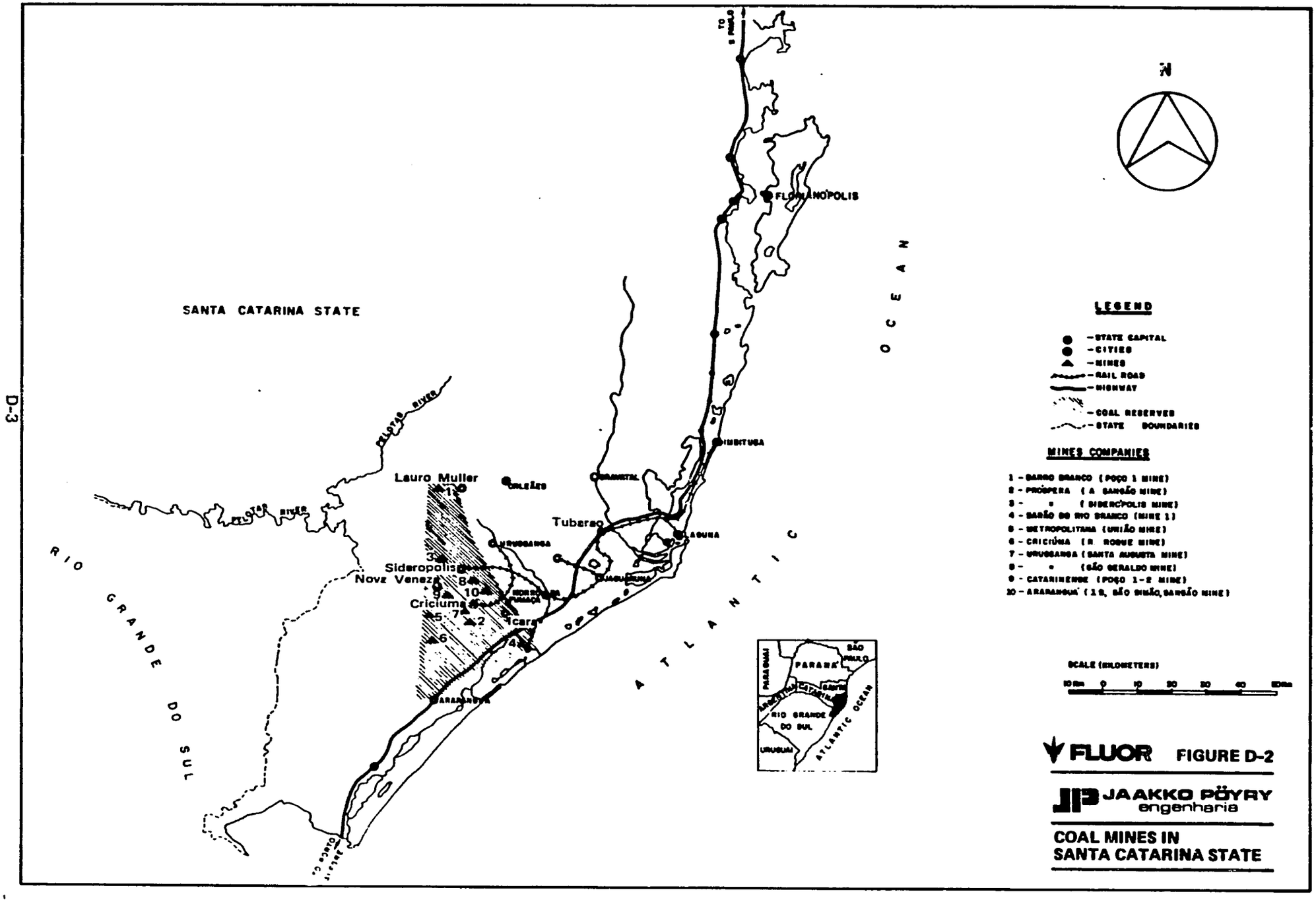

To Florianopolis
To Sao Paulo
To Sao Paulo
To Argentina
To Uruguai
RIO GRANDE DO SUL STATE
Irui
Leao
Recreio
Charqueadas
Candiota
BAGÉ
SANTANA DA BOAVISTA
PINHEIRO MACHADO
PELOTAS
LAGOA DOS PATOS
LAGOA MIRIM
URUGUAI
ATLANTIC
OCEAN
N
LEGEND
-STATE CAPITAL
-CITIES
-MINES
-RAIL ROAD
-HIGHWAY
-COAL RESERVES
-INTERNACIONAL BOUNDARIES
-STATE BOUNDARIES
RESERVES
1 - CANDIOTA
2 - IRUÍ
3 - LEÃO-BUTIÁ
4 - CHARQUEADAS
5 - MONUMGAVA - GRAVATAÍ
6 - CHIBO LOMA
SCALE (KILOMETERS)
PARANÁ
SÃO PAULO
SANTA CATARINA
RIO GRANDE DO SUL
URUGUAI
ATLANTIC OCEAN
FLUOR
FIGURE D-1
JAAKKO PÖYRY engenharia
COAL RESERVES IN RIO GRANDE DO SUL STATE



FLUOR FIGURE D-2

JAAKKO PÖYRY engenharia

COAL MINES IN SANTA CATARINA STATE

APPENDIX E

ANALYSIS OF RAW WATER FROM THE JACUI RIVER

Raw water analyses as discussed in Section 7 are presented here as Tables E-1 through E-4.

APPENDIX E

ANALYSIS OF RAW WATER FROM JACUI RIVER

TABLE E-1

PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS

PERIOD: FROM FEB. 15, 1971 to FEB. 10, 1972

River Jacui - Station 57	Min.	(≤25%) Lower Quartile	Median	Mean	(≤75%) Upper Quartile	Max.
Water temperature	11.5	17	20	21	27	28.5
Air temperature	-	-	-	-	-	-
Color	20	41	60	60	78	100
Turbidity	10	18	22.5	30.7	39	88
Dissolved O_2	4.6	6.5	8.3	7.7	8.8	9.4
pH	6.5	6.6	6.7	6.7	6.8	7.1
Oxygen cons. in acid ambient	2.5	4.7	6.2	7.4	8.7	10.5
BOD	0.2	0.4	0.85	1.2	1.6	3.6
COD	3.0	7.2	20.6	23.1	46.4	57.6
Total residues at 105°C	51.4	85.3	99.6	101 5	120.9	157.6
Silica	-	-	-	-	-	-
Sulfate	-	-	-	-	-	-
Total PO_4	0.4	-	-	2.0	-	4.8
Ortho PO_4	zero	zero	0.05	0.35	0.87	1.35
Ammonia	0.02	0.088	0.14	0.157	0.2	0.4
Organic N	zero	0.12	0.23	0.328	0.3	1.756
Nitrate	zero	0.005	0.011	0.024	0.047	0.07
Nitrate	zero	0.15	0.53	0.71	1.29	2.2
*Total Coliform MPN	$1.41\ 10^2$	$4.2\ 10^2$	$2.3\ 10^3$	$3.3\ 10^3$	$8.0\ 10^3$	$2.2\ 10^6$
*Fecal Coliform MPN	zero	5.6 10	$2.8\ 10^2$	$1.87\ 10^2$	$1.2\ 10^3$	$2.2\ 10^6$
Total bacterial count	32	55	86	86	124	132
*Streptococco fecal MPN	-	-	-	-	-	-
Strept. fecal count (plate)	-	-	-	-	-	-
*Total no. of plankton org.	$3.6\ 10^3$	$1.2\ 10^4$	$1.5\ 10^4$	$1.58\ 10^4$	$2.9\ 10^4$	$5.4\ 10^4$
*Total no. of bentic org.	zero	zero	zero	$1.67\ 10^0$	zero	$4.62\ 10^2$
**Odor level	zero	-	-	-	1	zero
Conductivity	-	-	-	-	-	-

*Geometric mean
**Occurrence of odor - E

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APPENDIX E

TABLE E-2

PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS

PERIOD: FROM APRIL 6, 1972 to APRIL 17, 1973

River Jacui - Station 57	Min.	(≤25%) Lower Quartile	Median	Mean	(≤75%) Upper Quartile	Max.
Water temperature	13.5	17	20	20.5	25	28
Air temperature	23	-	-	27	-	30
Color	50	70	85	82	90	120
Turbidity	17	24	34.5	42.4	65	86
Dissolved O_2	5.6	6.6	7.0	7.2	8.2	9.0
pH	6.2	6.6	6.9	6.8	7.1	7.6
Oxygen cons. in acid ambient	3.4	4.1	6.8	6.6	8.7	9.5
BOD	0.4	0.6	0.8	0.9	1.2	1.8
COD	3.3	5	12.6	19.2	32	40
Total residues at 105°C	67.6	81	90.6	97.7	117	139.6
Silica	-	-	-	-	-	-
Sulfate	-	-	-	-	-	-
Total PO_4	zero	0.3	0.49	0.47	0.8	1.3
Ortho PO_4	zero	zero	0.125	0.18	0.22	0.9
Ammonia N	0.025	0.075	0.095	0.117	0.19	0.25
Organic N	zero	zero	0.06	0.14	0.27	0.54
Nitrate	zero	0.006	0.026	0.036	0.063	0.098
Nitrate	zero	0.02	0.42	0.58	0.87	1.5
*Total Coliform MPN	4.9 10	$3.3\ 10^2$	$7.9\ 10^2$	$1.14\ 10^3$	$7.9\ 10^3$	$1.3\ 10^4$
*Fecal Coliform MPN	3.1 10	$1.4\ 10^2$	$4.9\ 10^2$	$4.84\ 10^2$	$3.0\ 10^3$	$7.9\ 10^3$
Total bacterial count	16	46	60	75	110	165
*Streptococco fecal MPN	-	-	-	-	-	-
Strept. fecal count (plate)	-	-	-	-	-	-
*Total no. of plankton org.	$2.1\ 10^4$	$2.8\ 10^4$	$4.0\ 10^4$	$3.85\ 10^4$	$5.2\ 10^4$	$6.1\ 10^4$
*Total no. of benthic org.	zero	-	-	-	-	zero
**Odor level	zero	zero	zero	-	1	2
Conductivity	-		-	-	-	-

*Geometric mean
**Occurrence of odor - E

APPENDIX E

TABLE E-3

PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS

PERIOD: FROM MAY 20, 1973 to APRIL 29, 1973

River Jacui - Station 57	Min.	(≤25%) Lower Quartile	Median	Mean	(≤75%) Upper Quartile	Max.
Water temperature	14	15	20.5	20.5	25.5	26.5
Air temperature	14.5	17	19	20.5	24.5	29
Color	45	55	80	69	80	85
Turbidity	27	32	38	43.2	57.5	72
Dissolved O_2	6.8	7.1	8.2	8.1	9.0	9.6
pH	6.6	7.0	7.3	7.2	7.4	7.7
Oxygen cons. in acid ambient	2.9	3.3	4.2	4.5	5.5	7.5
BOD	0.2	0.6	0.8	0.8	1.1	1.6
COD	4	7	16	26.8	44	76
Total residues at 105°C	63	79.9	84.6	91.5	102.3	121
Silica	-	-	-	-	-	-
Sulfate	-	-	-	-	-	-
Total PO_4	0.175	0.28	0.42	0.5	0.74	1.1
Ortho PO_4	0.08	0.10	0.15	0.17	0.18	0.46
Ammonia N	0.024	0.03	0.75	0.077	0.1	0.18
Organic N	zero	0.075	0.4	0.46	0.95	1.0
Nitrate	zero	0.14	0.03	0.033	0.05	0.06
Nitrate	0.08	0.11	0.37	0.33	0.53	0.62
*Total Coliform MPN	$1.3\ 10^2$	$1.8\ 10^2$	$3.3\ 10^2$	$4.2\ 10^2$	$9.4\ 10^2$	$3.3\ 10^3$
*Fecal Coliform MPN	7.9 10	$1.19\ 10^2$	$2.3\ 10^2$	$3.14\ 10^2$	$7.45\ 10^2$	$3.3\ 10^3$
Total bacterial count	33	46	80	80	99	160
*Streptococco fecal MPN	8.10^0	2.3 10	2.3 10	4.4 10	$2.24\ 10^2$	$7.9\ 10^2$
Strept. fecal count (plate)	zero	1	4	8	6	52
*Total no. of plankton org.	$1.6\ 10^4$	$2.3\ 10^4$	$4.1\ 10^4$	$4.18\ 10^4$	$8.5\ 10^4$	$1.14\ 10^5$
*Total no. of benthic org.	zero	zero	zero	$1.92\ 10^0$	6.1 10	$1.3\ 10^2$
**Odor level	zero	1	1	-	1	1
Conductivity	41	43.4	46.2	46.6	50	52.2

*Geometric mean
**Occurrence of odor - E

TABLE E-4

FOR THE JACUI RIVER, STATION 57

				MOLUSCS			ANELIDS			LARVAE				
DATE	COLOR	ODOR	COMPOSITION	G	P	C	T	H	Ch	Ca	Ce	Cm	O	Hm
24.06.71	LIGHT BROWN	WET EARTH	SAND											
19.07.71	LIGHT BROWN	NONE	SAND											
16.08.71	SAND	NONE	SAND											
16.09.71	SAND	NONE	SAND											
14.10.71	SAND	NONE	SAND											
02.12.71	MID BROWN	WET EARTH	SAND											
17.01.72	LIGHT BROWN	NONE	SAND											
10.02.72	LIGHT BROWN	WET EARTH	SAND	462										
06.04.72	MID BROWN	WET EARTH	SAND											
10.05.72	MID BROWN	NONE	SAND											
12.06.72	VOID SAMPLE													
10.07.72	VOID SAMPLE													
07.08.72	LIGHT BROWN	NONE	SAND											
14.09.72	VOID SAMPLE													
16.10.72	LIGHT BROWN	NONE	SAND											
06.11.72	VOID SAMPLE													
20.12.72	VOID SAMPLE													
08.02.73	MID BROWN	NONE	SAND											
12.03.73	MID BROWN	NONE	SILTY-SAND											
17.04.73	LIGHT BROWN	NONE	SILTY-SAND											
20.06.73	VOID SAMPLE													
02.07.73	SAND	NONE	SAND											
13.08.73	MID BROWN	NONE	SAND											
08.10.73	SAND	NONE	SAND											
12.11.73	LIGHT BROWN	SEWAGE	SILTY-SAND				130							
05.12.73	SAND	SEWAGE	SILTY-SAND									29		
02.01.74	LIGHT BROWN	SEWAGE	SILTY-SAND											
04.03.74	VOID SAMPLE													
03.04.74	LIGHT BROWN	NONE	SAND											
29.04.74	MID BROWN	NONE	SAND OIL FILM											
29.05.74	MID BROWN	NONE	SILTY-SAND											

APPENDIX F

APPLICABLE BRAZILIAN ENVIRONMENTAL REGULATIONS

The following pages represent extractions from Brazilian environmental regulations by Jaakko Poyry Engerharia for this report.

APPENDIX F

APPLICABLE BRAZILIAN ENVIRONMENTAL REGULATIONS

REGULATION OF LAW NO. 997, OF MAY 31 1976, WHICH GOVERNS THE PREVENTION AND CONTROL OF POLLUTION OF THE ENVIRONMENT

HEADING I - PROTECTION OF THE ENVIRONMENT

CHAPTER 1 - PRELIMINARY

Art. 3 All and every form of material or energy discharged or liberated on waters, air, or ground will be considered polluting:

I With intensity, quantity, or concentration in disagreement with the emission standards in this regulation and its current norms.

II With characteristics and conditions of discharge or liberation in disagreement with the treatment and design standards in these instructions.

III From sources of pollution with peculiarities of location and utilization in disagreement with the above referenced standards of treatment and design.

IV With intensity, quantity, or concentration or with characteristics that directly or indirectly exceed or can exceed the environment quality standards in this regulation and its current norms.

V Which, independent of being covered in previous clauses, turn or can turn waters, air, or ground, unsuitable, harmful or offensive to health, detrimental to the public well being; damaging to materials, the fauna and flora; prejudicial to safety, to the use and enjoyment of property, as well as normal activities of the community.

PART 2 - WATER POLLUTION

CHAPTER 1 - CLASSIFICATION OF WATERS

Art. 7 For the purpose of this regulation, the waters situated in the interior of the State (of Sao Paulo) will be classified according to the following predominant usages:

I Class 1: waters destined for domestic supply, without prior treatment or with disinfection only.

II Class 2: waters destined for domestic supply after conventional treatment, and for irrigation of vegetables or fruits, and for recreation involving primary contact (swimming, water skiing, and diving).

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III Class 3: waters destined for domestic supply after conventional treatment, and for the preservation of fish in general, and other elements of fauna and flora, and for the watering of animals.

IV Class 4: waters destined for domestic supply after advanced treatment, or for navigation, or for landscaping purposes, industrial supply, irrigation and less demanding uses.

There is nothing to prevent waters of better quality being used for less demanding uses, since these uses do not prejudice the quality established for these waters.

Art. 8 The inclusion of a body of water in any class will not take into consideration future conditions beyond the forecast limits of the class which result from natural causes.

Art. 9 The bodies of water projected for the treatment and transport of wastewaters will not be considered for inclusion in the classes of this regulation.

Projects in areas covered by this article must be submitted to CETESB for approval, who will also define the effluent quality.

CHAPTER 2 - STANDARDS

SECTION 1 - QUALITY STANDARDS

Art. 10 In the waters of class 1, discharges of effluent will not be tolerated even though treated.

Art. 11 In the waters of class 2, effluents cannot be discharged, even though treated, which prejudice the water quality by altering the following parameters or values:

I Virtually absent:

a. Floating materials, including foam (except natural foam)

b. Substances soluble in hexane

c. Substances which have taste or odor

d. In the case of substances potentially detrimental, up to the limits listed below:

1.	Ammonia	0.5 mg/l as nitrogen
2.	Arsenic	0.1 mg/l

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3.	Barium	1.0 mg/l
4.	Cadmium	0.01 mg/l
5.	Chromium (total)	0.05 mg/l
6.	Cyanide	0.2 mg/l
7.	Copper	1.0 mg/l
8.	Lead	0.1 mg/l
9.	Tin	2.0 mg/l
10.	Phenols	0.001 mg/l
11.	Fluorine	1.4 mg/l
12.	Mercury	0.002 mg/l
13.	Nitrates	10.0 mg/l
14.	Nitrites	1.0 mg/l
15.	Selenium	0.01 mg/l
16.	Zinc	5.0 mg/l

II Prohibition of the presence of artificial colors which may not be removed by conventional processes of coagulation, sedimentation, and filtration.

III Coliforms MPN 5 000, fecal coliforms MPN 1 000, in 100 ml for 80 percent of at least 5 samples taken within a 5 week period.

IV 5 day BOD at 20°C up to 5 mg/l in each sample.

V DO in each sample not less than 5 mg/l.

Art. 14 The limits of BOD established for classes 2 and 3 can be raised in cases where a study of the self purification of the receiving body shows that minimum limits of DO foreseen will not be violated at any point under critical discharge conditions.

Art. 15 For the purpose of this regulation, in the case of unforeseen pollutants, CETESB have the authority to determine the concentration described as "Virtually Absent," case by case.

Art. 16 The methods of analysis must be internationally acceptable and specified in the ultimate edition of "Standard Methods," except for the constants of the standards already approved by ABNT (Associacao Brasileira de Normas Tecnicas).

SECTION II - EMISSION STANDARDS

Art. 17 Effluents from whatever source can only be discharged into surface or underground, interior or coastal waters situated within the territory of the State, provided that the effluents are not considered pollutant, in the form established in Article 3 of this regulation.

The disposal in question is applied to discharges made directly by the source of pollution, or indirectly through public or private sewers, as well as through other means of transport whether owned by the party making the discharge or by third parties.

Art. 18 Effluents from whatever pollution source can only be discharged, directly or indirectly, into water catchments provided that they comply with the following conditions:

I pH between 5.0 and 9.0

II Temperature below 40°C

III Settleable solids less than 1.0 ml/l in 60 minutes an Inhoff Cone tests.

IV Substances soluble in hexane less than 100 mg/l.

V 20°C 5 day BOD at a maximum of 60 mg/l.

This limit can only be exceeded in the case of effluent from a wastewater treatment system which reduces the pollution load in terms of 20°C 5-day BOD at the outfall by at least 80 percent.

VI Maximum concentration of the following parameters:

a.	Arsenic	0.2 mg/l
b.	Barium	5.0 mg/l
c.	Boron	5.0 mg/l
d.	Cadmium	0.2 mg/l
e.	Lead	0.5 mg/l
f.	Cyanide	0.2 mg/l
g.	Copper	1.0 mg/l

h.	Hexavalent Chromium	0.1 mg/l
i.	Total Chromium	5.0 mg/l
j.	Tin	4.0 mg/l
k.	Phenols	0.5 mg/l
l.	Soluble iron (Fe2+)	15.0 mg/l
m.	Fluorides	10.0 mg/l
n.	Soluble Manganese (Mn2+)	1.0 mg/l
o.	Mercury	0.1 mg/l
p.	Nickel	2.0 mg/l
q.	Silver	0.02 mg/l
r.	Selenium	0.02 mg/l
s.	Zinc	5.0 mg/l

VII Other substances potentially detrimental in concentration to be fixed, case by case, by the rules of CETESB.

VIII Discharge regime continuous 24 hours a day with a maximum variation of 50 percent of the average flow.

§1. Further to complying with the limits of this article, the effluents cannot bestow on the receiving body characteristics in disagreement with those defined in the classification of waters.

§2. In the case where the source which originated the pollution has different outfalls or individual emissions, the governing limits of this regulation may be applied to each one of the outlets or the combination of them after mixing at the discretion of CETESB.

§3. When the effluent has more then one potentially detrimental substance, CETESB may reduce the respective individual limits in proportion to the numbers of substances present.

HEADING III - AIR POLLUTION

CHAPTER I - NORMS FOR THE USE AND PRESERVATION OF AIR

SECTION II - PROHIBITIONS AND GENERAL DEMANDS

Art. 26 The burning of solid wastes, liquid wastes, or whatever other combustible material in free air is prohibited except through previous authorization of CETESB for:

I Fire fighting training.

II To avoid the development of undesirable species, of animals or plants, for the protection of agriculture and cattle raising.

Art. 27 The installation and operation of domestic or commercial incinerators of whatever type is prohibited.

Art. 28 In cases in which it becomes necessary CETESB can demand:

I The installation and operation of automatic measuring equipment with recorders at the air pollution sources to monitor the quantities of pollutants emitted. The inspection of the respective recorders for supervising their operation to be admissable to this organization (CETESB).

II That those responsible for the sources of pollution prove the quantity and quality of the atmospheric pollutants emitted through taking samples in the chimney, using methods approved by this organization.

III That those responsible for the pollution sources construct platforms and supply all the requisites necessary for taking samples in chimneys.

CHAPTER II - STANDARDS

SECTION I - QUALITY STANDARDS

Art. 29 The following air quality standards are established throughout the territory of Sao Paulo State:

I For particulate in suspension:

a. Average annual geometric concentration of 80 $\mu g/m^3$ or lesser value;

or

b. Average cocentration in 24 consecutive hours of 240 $\mu g/m^3$ or lesser value, not to be exceeded more than once per year.

II For sulfur dioxide:

a. Average annual arithmetic concentration of 80 $\mu g/m^3$ or lesser value;

or

b. Average concentration in 24 consecutive hours of 365 $\mu g/m^3$ or lesser value, which may not be exceeded more than once per year.

III For carbon monoxide:

a. Maximum average concentration of 10 000 $\mu g/m^3$ or lesser value in 8 consecutive hours, which cannot be exceeded more than once per year,

or

b. Maximum average concentration of 40 000 $\mu g/m^3$ or lesser value in one hour, which cannot be exceeded more than once per year.

IV For photochemical oxidants:

Maximum average concentration of 160 $\mu g/m^3$ or lesser value in one hour, which cannot be exceeded more than once per year.

§1. All the measurements must be corrected to 25°C and 760 mm Hg.

§2. For determining concentrations of different forms of material, for the purpose of comparing them with the air quality standards, the methods of analysis and sampling defined in these regulations, or current norms must be used as well as adequately located measuring stations in accordance with the requirements of CETESB.

§3. The frequency of sampling must be effected for at least one 24 hour period every 6 days for sulfur dioxide and suspended particulate, and continuously for carbon monoxide and photochemical oxidants.

§4. The air quality standards for other forms of material will be fixed by degree.

Art. 30 For the purpose of §2 of the previous article, the following methods are established:

I For suspended particulate: the method of sampling large volumes, or equivalent, conforming to Annex I of this regulation.

II For sulfur dioxide: the pararosanaline method or equivalent, conforming to Annex 2 for this regulation.

III For carbon monoxide: the method of absorption of now dispersive infrared radiation, or equivalent, conforming to Annex 3 of this regulation.

IV For photochemical oxidants (like ozone): method of chemical high emission, or equivalent, conforming to Annex 4 of this regulation.

All the methods of sampling and analysis are considered equivalent which, when tested by CETESB, give results equivalent to the methods specified in the annexes of this regulation, which touch on the characteristics of reliability, specificness, accuracy, exactness sensitivity, response time, zero error, calibration error, and other important or convenient characteristics required by CETESB.

SECTION II - EMISSION STANDARDS

Art. 31 It is prohibited to emit smoke from stationary sources with a colormetric density greater than standard I on the Ringlemann scale except for:

I A single period of 15 minutes per day for the operation of heating up the fire box.

II A period of 3 minutes, consecutive or not, in any 1 hour period.

Smoke with a density greater than that established in this article cannot be emitted for a longer period than 15 minutes in any one hour period.

Art. 32 No diesel powered vehicle shall be able to circulate or operate in the State of Sao Paulo emitting through its exhaust smoke with a colormetric density greater than standard 2 on the Ringlemann scale, or equivalent, for more than 5 consecutive seconds except from a cold start.

§1. The specification of the method of measurement referred to in the outside will be set out in the norm to be issued by CETESB.

§2. It is the responsibility of the State organizations in charge of traffic, with the technical assistance of CETESB, to enforce compliance with this article.

Art. 33 It is prohibited to emit odorous substances to the atmosphere in quantities which can be perceptible outside the limits of the area of the property of the source of emission.

On the decision of CETESB the verification of the emission referred to in this article will be carried out by:

1. a qualified technician of CETESB

2. by comparing its concentration in air with the threshold odor limit for the substances enumerated below:

Substances	Threshold odor limit ppm by volume
1. Acetaldehyde	0.21
2. Acetone	100.00
3. Acetic acid	1.00
4. Butyric acid	0.001
5. Gaseous hydrochloric acid	10.00
6. Ethyl acrylate	0.00017
7. Acroleine	0.21

Substance	Threshold odor limit ppm by volume
8. Acronitril	21.4
9. Ammonia	46.8
10. Aniline	1.0
11. Benzene	4.68
12. Bromine	0.047
13. Alkyl chlorate	0.47
14. Benzyl chlorate	0.047
15. Methyl chlorate	10.0
16. Methylene chlorate	214.00
17. Chlorine	0.314
18. Sulfur dichlorate	0.001
19. Dimethyl amine	0.047
20. Dimethylacetamide	46.8
21. Dimethyl formamide	100.00
22. Dimethyl sulfide	0.001
23. Carbon disulfide	0.21
24. Styrene	0.1
25. Synthetic ethanol	10.0
26. Diphenyl ether	0.1
27. Ethyl mercaptar	0.001
28. Phenol	0.047
29. Formaldehide	1.0
30. Phosphene	0.021
31. Phosgene ($COCl_2$)	1.0
32. Methyl metacrylate	0.21
33. Methanol	100.00
34. Methyl ethyl ketone	10.0
35. Methyl mercaptan	0.0021
36. Methylisobutyl ketone	0.47
37. Monochlorobenzene	0.21
38. Monomethyl amine	0.021
39. Nitrobenezene	0.0047
40. Paracresol	0.001
41. Para-xylene	0.47
42. Perchloroethylene	4.68
43. Pyridine	0.021
44. Benzyl sulfide	0.0021
45. Diphenyl sulfide	0.0047
46. Hydrogen sulfide (coming from sodium bisulfide)	0.0047
47. Hydrogen sulfide (gaseous)	0.00047
48. Carbon tetrachloride (coming from the chlorination of carbon disulfide)	21.4
49. Carbon tetrachloride (coming from the chlorination of methane)	100.0
50. Toluene di-isocyanate	2.14
51. Toluene (from coke)	4.68
52. Toluene (from petroleum)	2.14

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Substances	Threshold odor limit ppm by volume
53. Trichloroacetaldehyde	0.047
54. Trichloroethylene	21.4
55. Trimethyl amine	0.00021

SECTION III - THE DESCRIBED STANDARDS AND THE DESIGN OF STATIONARY SOURCES

Art. 34 The discharge of effluents coming from the burning of combustible solids, liquids, or gases must be made through a chimney.

Art. 35 Every source of air pollution must be provided with a local exhaust ventilation system, and the discharge of effluents into the atmosphere can only be made through a chimney except when otherwise specified in this regulation or in its current norms.

The operations, processes, or functioning of equipment for crushing, grinding, transport, handling, loading and unloading of granular or particulate material can be exempted from this exigencies referred to in this article, provided that they are kept wet, by means of a permanent wetting process.

Art. 36 The storage of granular or particulate material must be made in bins adequately sealed, or in another air pollution control system better or equal of a form to impede the scatter of the respective material by wind action.

Art. 37 In areas whose dominant use will be residential or commercial, it will remain the right of CETESB to specify the type of fuel to be utilized by new equipment or combustion contrivances.

Ovens of bakeries, restaurants, and boilers for any purpose whatsoever are included in the provisions of this article.

Art. 38 Odorous substances resulting from the sources enumerated below must be incinerated in after-burners, operating at a temperature of at least 750°C with a residence time of at least 0.5 seconds, or by another system of pollution control, with an efficiency better or equal.

I Toasting and cooling of coffee, peanuts, cashew nuts and barley.

II Autoclaves and digesters utilized in making use of animal material.

III Houses for the drying and hardening of painted or varnished items, or lithographs.

IV Oxidation of asphalt.

V Smoking meats or similar items.

VI Sources of hydrogen sulfide and mercaptans.

VII Regeneration of rubber.

§1. When the sources enumerated in the clauses of this article are located in areas whose use in predominately residential or commercial, the after-burner must use gas as an auxiliary fuel. In other areas, it remains at the discretion of CETESB to define this fuel.

§2. For this purpose of control, the after-burner must be provided with a temperature indicator in the combustion chamber, in a place easy to see.

Art. 39 The emissions coming from the incinerator of septic wastes and hospital surgeries must be oxidized in after-burners which use gaseous fuel, operating at a temperature of at least 850°C and with a residence time of at least 0.8 seconds, or by another pollution control system with an efficiency better or equal.

For the purpose of control, the after-burner referred to in this article must display a temperature gauge on the combustion chamber, in a place easily seen.

Art. 40 The operations of covering surfaces using sprays, like paint or applying varnish with a spray gun, must be carried out in special compartments provided with an exhaust ventilation system and equipment efficient in retaining particulate material.

Art. 41 For the sources of pollution for which emission standards have not been established, systems of air pollution control will be adopted based on the best technical practices available, for each case.

In this article, the adoption of known technology will be made through the analysis and approval by CETESB of a plan of control, presented by the party responsible for the source of pollution. CETESB will specify the measures to be adopted and the desirable reduction for the emission.

Art. 42 New sources of air pollution which it is proposed to install and operate, with regard to the location shall be:

I Obliged to prove that the emissions coming from the installation or its operation will not cause, for the region or subregion considered to be saturated, an increase in the pollution levels that cause the saturation.

II Prohibited from installing or operating when, at the decision of CETESB these would be a potential risk that alludes to clause V of article 3 of this regulation, even though the emissions coming from its process may be covered by clauses I, II, III, and IV of the same article.

§1. For the type of risk mentioned in clause II, the nature of this source, as well as the construction, buildings or properties may be considered subject to sustaining the effects foreseen in clause V of article 3.

§3. It will be the task of the proprietor of the new source to prove, inasmuch as CETESB may demand, the performance of the requisite foreseen in clause I.

HEADING IV - GROUND POLLUTION

Art. 51 It is not permitted to deposit, dispose of, unload, bury, infiltrate, or accumulate wastes such as pollutants on the ground, in whatever physical state, in the manner established in article 3 of this regulation.

Art. 52 The ground can only be utilized for the final disposal of wastes of whatever kind, provided that their disposal is made in an adequate manner, established in specific projects of transport and final disposal, the unrestricted discharge or deposit being prohibited, whether it may be on public or private property.

When the final disposal mentioned in this article demands the carrying out of sanitary fills, adequate measures for the protection of surface and underground waters must be taken, complying with norms to be given out by CETESB.

Art. 53 Wastes of whatever kind, carriers of pathogens or of high toxicity, as well as flammable, explosive, radioactive, and other harmful wastes, at the discretion of CETESB, must undergo, before their final disposal on the ground, adequate treatment and/or conditioning and stated in specific projects, which meet the requirements of environmental protection.

Art. 54 The projects mentioned in articles 52 and 53, as well as the control of their siting, operation and maintenance, are subject to the approval of CETESB.

Art. 55 Only the temporary accumulation of wastes of whatever nature will be tolerated at the source of pollution or at other locations, provided that it does not incur the risk of polluting the ambient.

Art. 56 The treatment, and, when may be the case, the transport and disposal of wastes of whatever nature, from industrial, commercial, and service establishments, when not the responsibility of the Municipality, must be done by the establishment causing the pollution.

§1. In the event that the applicable norms of this regulation are infringed, the establishment causing the pollution is not relieved of the responsibility, even though the above mentioned services are carried out by the Municipality.

§2. The precept of this article is also applied to sludges, whether digested or not, from waste treatment systems and other materials.

APPENDIX G

OIL REFINING STRUCTURE IN BRAZIL

APPENDIX G

OIL REFINING STRUCTURE IN BRAZIL

The following is a review of the Brazilian oil refining industry prepared by Jaakko Poyry:

G-1 INTRODUCTION

Brazilian refining installed capacity is in the range of 1 400 thousand BPSD, and in 1980-81 the refineries were running at 70 percent of overall installed capacity.

Table G-1 below shows the breakdown of refinery processing capacity.

TABLE G-1

REFINERIES IN BRAZIL

Nominal Refinery	State	Capacity BSPD
Manaus Refinery - REMAN	Amazonas	10 000
Landulpho Alves Refinery - RLAM	Bahia	140 000
Gabriel Passos Refinery - REGAP	Minas Gerais	126 000
Duque de Caxias Refinery - REDUC	Rio de Janeiro	210 000
Manguinhos Refinery	Rio de Janeiro	10 000
Paulinea Refinery - REPLAN	Sao Paulo	252 000
Presidente Bernardes Refinery - RPBC	Sao Paulo	170 000
Leopoldo Migues Refinery - REVAP	Sao Paulo	190 000
Capuava Refinery - RECAP	Sao Paulo	30 000
Parana Refinery - REPAR	Parana	126 000
Alberto Pasqualini Refinery - REFAP	Rio Grande do Sul	126 000
Ipiranga Refinery	Rio Grande do Sul	10 000
Total Brazil - 12 Refineries		1 400 000

G-2 REFINING STRUCTURE

G-2.1 Product Groups

To facilitate the evaluation of Brazilian refining structure, products can be combined in three groups as identified below:

Light - Under this heading are included the following products: LGP, ethylene, propylene, propane, butane, gasolines, naphtha, hexane, benzene, toluene, xylene, thinner, and rubber solvents.

Medium - Includes kerosene and diesel oil.

Heavy - Includes fuel oils, gasoil, asphalts, basic lube oils, paraffines, sulfur, and petroleum coke.

G-2.3 Evolution of Brazilian Refining Structure

Petroleum refining in Brazil started early in 1932. During the first 20 years the increases in refining capacity were very small. By 1950 Brazilian refineries supplied only 10 percent of the domestic demand.

During the fifties, the Brazilian refining capacity increased from 10 percent to 69 percent (in 1960). Brazil became self-sufficient between 1969 and 1970.

During the period of 1960 through 1965, Brazilian refining structure was oriented toward the production of more heavy products due to the high demand for fuel oil.

During the period of 1966 through 1974, due to a substantial increase in motor car use, the refining structure was shifted to produce increasing amounts of light products, especially automotive gasoline.

From 1975 on, the market demand for medium products increased, and demand of heavy products decreased as shown on Table G-2 below.

TABLE G-2

EVOLUTION OF REFINING STRUCTURE

		Year						
		75	76	77	78	79	80	81(*)
Crude Process 10^3 m/day		139	147	152	169	175	173	161
Production Structure	Lights, %	40.8	39.3	36.6	37.5	26.3	34.0	35.9
	Medium, %	28.6	30.4	32.1	31.8	32.8	36.6	36.0
	Heavy, %	30.6	30.3	31.3	30.7	30.9	29.3	28.1

(*) - forecast

The demand of crude oil is expected to stay steady around 160 000 m^3/day until 1985, and the demand of heavy products is forecast to be around 18.8 percent of total processed crude by 1985.

The decrease in heavy products demand is mainly due to the energy conservation programs and fuel oil substitution programs now under way in Brazil.

To accommodate the expected change in demand of medium and heavy products, the refineries are already planning to install new refining units to convert the residues into petroleum coke and additional destillate.

The new refining units and the partial shift of diesel truck transportation into electric driven railroad transportation will reestablish the desired equilibrium between production and demand of refined products.

APPENDIX H

PRO FORMA FINANCIAL AND CASH FLOW REPORTS
(See Section 5)

Summary
Income Statement
Balance Sheet (Inflation Adjusted)
Balance Sheet (Historical Cost)
Sources and Uses of Funds
Cash Flows and Ratios
Income Tax Worksheet
Loan Funding and Repayment Schedule
Cash Flow Detail Report (ROI)
Cash Flow Detail Report (ROE)

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

2 JUN 1982

SUMMARY REPORT

	NOMINAL DOLLARS	REAL DOLLARS
PRETAX RETURN ON INVESTMENT (1)	21.14%	10.13%
POST-TAX RETURN ON INVESTMENT (2)	18.80%	8.00%
RETURN ON EQUITY (3)	23.70%	12.45%
(1982 US$ MILLIONS)		
POST-TAX NPV @ 5%		$475.33
POST-TAX NPV @ 10%		$-187.20
SNG PRICE (JANUARY 1982)		
PER GIGACAL		$31.22
PER MILLION BTU		$7.87
PER 1000 NM3		$285.30
PER 1000 SCF		$7.64
COAL PRICE PER TON (JANUARY 1982)		$32.90

NOTES

(1) ROI (PRETAX) = OPERATING INCOME, LESS INCREASES IN WORKING CAPITAL, PLUS RECOVERED WORKING CAPITAL, DISCOUNTED AGAINST CAPITAL INVESTMENT.

(2) ROI (POST-TAX) = OPERATING INCOME, LESS TAXES ON OPERATING INCOME LESS DEPRECIATION, LESS INCREASES IN WORKING CAPITAL, PLUS RECOVERED WORKING CAPITAL, DISCOUNTED AGAINST CAPITAL INVESTMENT.

(3) ROE = NET CASH FLOW AVAILABLE TO EQUITY HOLDERS, DISCOUNTED AGAINST EQUITY INVESTMENT.

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

INCOME STATEMENT

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8
REVENUES								
SNG	637.3	952.9	1079.6	1223.2	1385.9	1570.2	1779.0	2015.7
SULFUR	19.6	29.3	33.2	37.6	42.6	48.3	54.7	62.0
AMMONIA	4.9	7.4	8.4	9.5	10.8	12.2	13.8	15.7
NAPHTHA	10.9	16.4	18.5	21.0	23.8	26.9	30.5	34.6
TOTAL REVENUES	672.8	1005.9	1139.7	1291.3	1463.0	1657.6	1878.1	2127.9
OPERATING EXPENSES								
COAL	290.7	434.6	492.5	558.0	632.2	716.2	811.5	919.4
CATALYST & CHEMICALS	18.3	27.3	31.0	35.1	39.8	45.1	51.0	57.8
OPERATING LABOR	1[illegible].6	20.3	23.5	27.1	31.3	36.1	41.7	48.2
MAINTENANCE LABOR	6.2	7.2	8.3	9.6	11.0	12.7	14.7	17.0
MAINTENANCE MATERIAL	48.5	55.0	62.3	70.6	80.0	90.6	102.6	116.3
OVERHEAD	3.6	4.1	4.7	5.4	6.1	7.0	8.0	9.1
TOTAL OPERATING EXPENSES	384.9	548.6	622.1	705.6	800.3	907.7	1029.6	1167.8
OPERATING INCOME	287.9	457.4	517.6	585.7	662.7	749.9	848.5	960.0
OTHER EXPENSES								
DEPRECIATION	356.8	392.5	431.7	474.9	522.4	574.6	632.1	695.3
INTEREST	234.1	210.1	186.1	162.1	138.1	114.0	90.0	66.0
TOTAL OTHER EXPENSES	590.9	602.6	617.8	637.0	660.4	688.7	722.1	761.3
INCOME BEFORE TAXES	-303.0	-145.2	-100.2	-51.3	2.3	61.2	126.4	198.7
INCOME TAX	-	-	-	-	-	-	24.2	69.5
NET INCOME	-303.0	-145.2	-100.2	-51.3	2.3	61.2	102.1	129.2
SNG PRICE PER GIGACALORIE	79.64	90.23	102.23	115.83	131.23	148.69	168.46	190.87
CPI INDEX (JAN 1982 = 100)	204.4	224.8	247.3	272.0	299.2	329.2	362.1	398.3

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FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

INCOME STATEMENT

	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16
REVENUES								
SNG	2283.7	2587.5	2931.6	3321.5	3763.3	4263.8	4830.9	5473.4
SULFUR	70.2	79.5	90.1	102.1	115.7	131.1	148.5	168.3
AMMONIA	17.7	20.1	22.8	25.8	29.2	33.1	37.5	42.5
NAPHTHA	39.2	44.4	50.3	57.0	64.6	73.2	82.9	93.9
TOTAL REVENUES	2410.9	2731.5	3094.8	3506.4	3972.8	4501.2	5099.8	5778.1
OPERATING EXPENSES								
COAL	1041.7	1180.3	1337.2	1515.1	1716.6	1944.9	2203.6	2496.6
CATALYST & CHEMICALS	65.5	74.2	84.1	95.3	108.0	122.3	138.6	157.1
OPERATING LABOR	55.7	64.3	74.3	85.8	99.1	114.5	132.2	152.7
MAINTENANCE LABOR	19.6	22.7	26.2	30.2	34.9	40.3	46.6	53.8
MAINTENANCE MATERIAL	131.8	149.3	169.1	191.6	217.1	246.0	278.7	315.8
OVERHEAD	10.4	11.8	13.5	15.4	17.6	20.0	22.9	26.1
TOTAL OPERATING EXPENSES	1324.7	1502.6	1704.4	1933.5	2193.3	2488.1	2822.6	3202.1
OPERATING INCOME	1086.2	1228.9	1390.4	1573.0	1779.5	2013.1	2277.2	2576.0
OTHER EXPENSES								
DEPRECIATION	764.8	841.3	-	-	-	-	-	-
INTEREST	42.0	18.0	-	-	-	-	-	-
TOTAL OTHER EXPENSES	806.8	859.3	-	-	-	-	-	-
INCOME BEFORE TAXES	279.4	369.6	1390.4	1573.0	1779.5	2013.1	2277.2	2576.0
INCOME TAX	97.8	129.4	486.6	550.5	622.8	704.6	797.0	901.6
NET INCOME	181.6	240.3	903.7	1022.4	1156.7	1308.5	1480.2	1674.4
SNG PRICE PER GIGACALORIE	216.25	245.02	277.60	314.53	356.36	403.75	457.45	518.29
CPI INDEX (JAN 1982 = 100)	438.1	481.9	530.1	583.1	641.4	705.6	776.1	853.8

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

INCOME STATEMENT

	YEAR 17	YEAR 18	YEAR 19	YEAR 20
REVENUES				
SNG	6201.4	7026.1	7960.6	9019.4
SULFUR	190.6	216.0	244.7	277.3
AMMONIA	48.2	54.6	61.8	70.0
NAPHTHA	106.4	120.6	136.6	154.8
TOTAL REVENUES	6546.6	7417.3	8403.8	9521.5
OPERATING EXPENSES				
COAL	2828.7	3204.9	3631.2	4114.1
CATALYST & CHEMICALS	177.9	201.6	228.4	258.8
OPERATING LABOR	176.4	203.7	235.3	271.8
MAINTENANCE LABOR	62.2	71.8	82.9	95.8
MAINTENANCE MATERIAL	357.8	405.4	459.3	520.3
OVERHEAD	29.8	34.0	38.9	44.4
TOTAL OPERATING EXPENSES	3632.8	4121.4	4676.0	5305.2
OPERATING INCOME	2913.8	3295.8	3727.8	4216.2
OTHER EXPENSES				
DEPRECIATION	-	-	-	-
INTEREST	-	-	-	-
TOTAL OTHER EXPENSES	-	-	-	-
INCOME BEFORE TAXES	2913.8	3295.8	3727.8	4216.2
INCOME TAX	1019.8	1153.5	1304.7	1475.7
NET INCOME	1894.0	2142.3	2423.1	2740.6
SNG PRICE PER GIGACALORIE	587.23	665.33	753.82	854.07
CPI INDEX (JAN 1982 = 100)	939.1	1033.0	1136.4	1250.0

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

BALANCE SHEET (INFLATION ADJUSTED)

	YEAR -6 2ND HALF	YEAR -5 1ST HALF	YEAR -5 2ND HALF	YEAR -4 1ST HALF	YEAR -4 2ND HALF	YEAR -3 1ST HALF	YEAR -3 2ND HALF	YEAR -2 1ST HALF
LONG-TERM LIABILITIES								
LONG-TERM DEBT	6.7	19.8	34.4	84.6	254.2	554.6	950.6	1327.2
EQUITY	2.9	9.0	16.6	40.6	119.4	266.4	476.2	707.2
TOTAL	9.5	28.8	51.0	125.2	373.6	821.0	1426.7	2034.4
ASSETS								
WORKING CAPITAL	-	-	-	-	-	-	-	-
DEPRECIABLE ASSETS								
PLANT & EQUIPMENT	8.9	26.7	46.4	114.0	342.5	748.1	1284.7	1799.3
OWNER'S COSTS	.4	1.1	2.0	4.9	14.6	31.9	54.7	76.6
PRE-OPERATIONAL COSTS	-	-	-	-	-	-	-	-
CAPITALIZED IDC	.2	1.0	2.6	6.2	16.5	41.1	87.3	158.5
TOTAL DEPRECIABLE ASSETS	9.5	28.8	51.0	125.2	373.6	821.0	1426.7	2034.4
LESS: ACCUM. DEPRECIATION	-	-	-	-	-	-	-	-
NET FIXED ASSETS	9.5	28.8	51.0	125.2	373.6	821.0	1426.7	2034.4
TOTAL	9.5	28.8	51.0	125.2	373.6	821.0	1426.7	2034.4
CPI INDEX (JAN 1982 = 100)	115.4	121.0	126.9	133.1	139.6	146.4	153.6	161.1

NOTE: EQUITY DOES NOT INCLUDE RETAINED EARNINGS.

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

BALANCE SHEET (INFLATION ADJUSTED)

	YEAR -2 2ND HALF	YEAR -1 1ST HALF	YEAR -1 2ND HALF	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
LONG-TERM LIABILITIES								
LONG-TERM DEBT	1602.6	1755.5	2000.8	1800.7	1600.0	1400.5	1200.5	1000.4
EQUITY	924.5	1113.4	1358.6	1525.4	1668.8	1755.7	1787.3	1753.8
TOTAL	2527.1	2868.9	3359.3	3326.1	3269.4	3156.2	2987.8	2754.2
ASSETS								
WORKING CAPITAL	-	-	38.5	38.5	54.9	62.2	70.6	80.0
DEPRECIABLE ASSETS								
PLANT & EQUIPMENT	2181.8	2403.2	2541.7	2795.8	3075.4	3382.9	3721.2	4093.4
OWNER'S COSTS	92.9	102.4	108.3	119.1	131.0	144.1	158.5	174.4
PRE-OPERATIONAL COSTS	-	-	179.5	197.5	217.2	238.9	262.8	289.1
CAPITALIZED IDC	252.3	363.3	491.4	540.5	594.6	654.1	719.5	791.4
TOTAL DEPRECIABLE ASSETS	2527.1	2868.9	3320.8	3652.9	4018.2	4420.0	4862.0	5348.2
LESS: ACCUM. DEPRECIATION	-	-	-	365.3	803.6	1326.0	1944.8	2674.1
NET FIXED ASSETS	2527.1	2868.9	3320.8	3287.6	3214.6	3094.0	2917.2	2674.1
TOTAL	2527.1	2868.9	3359.3	3326.1	3269.4	3156.2	2987.8	2754.2
CPI INDEX (JAN 1982 = 100)	168.9	177.2	185.8	204.4	224.8	247.3	272.0	299.2

NOTE: EQUITY DOES NOT INCLUDE RETAINED EARNINGS.

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FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

BALANCE SHEET (INFLATION ADJUSTED)

	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13
LONG-TERM LIABILITIES								
LONG-TERM DEBT	800.3	600.2	400.2	200.1	-	-	-	-
EQUITY	1643.7	1444.1	1140.3	715.4	150.3	170.4	193.3	219.3
TOTAL	2444.0	2044.4	1540.5	915.5	150.3	170.4	193.3	219.3
ASSETS								
WORKING CAPITAL	90.8	103.0	116.8	132.5	150.3	170.4	193.3	219.3
DEPRECIABLE ASSETS								
PLANT & EQUIPMENT	4502.7	4953.0	5448.3	5993.1	6592.4	7251.6	7976.8	8774.5
OWNER'S COSTS	191.8	211.0	232.1	255.3	280.8	308.9	339.8	373.7
PRE-OPERATIONAL COSTS	318.0	349.8	384.8	423.3	465.6	512.2	563.4	619.8
CAPITALIZED IDC	870.5	957.6	1053.4	1158.7	1274.6	1402.0	1542.2	1696.5
TOTAL DEPRECIABLE ASSETS	5883.1	6471.4	7118.5	7830.4	8613.4	9474.7	10422.2	11464.4
LESS: ACCUM. DEPRECIATION	3529.8	4530.0	5694.8	7047.3	8613.4	9474.7	10422.2	11464.4
NET FIXED ASSETS	2353.2	1941.4	1423.7	783.0	-	-	-	-
TOTAL	2444.0	2044.4	1540.5	915.5	150.3	170.4	193.3	219.3
CPI INDEX (JAN 1982 = 100)	329.2	362.1	398.3	438.1	481.9	530.1	583.1	641.4

NOTE: EQUITY DOES NOT INCLUDE RETAINED EARNINGS.

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

BALANCE SHEET (INFLATION ADJUSTED)

	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
LONG-TERM LIABILITIES							
LONG-TERM DEBT	-	-	-	-	-	-	-
EQUITY	248.8	282.3	320.2	363.3	412.1	467.6	-
TOTAL	248.8	282.3	320.2	363.3	412.1	467.6	-
ASSETS							
WORKING CAPITAL	248.8	282.3	320.2	363.3	412.1	467.6	-
DEPRECIABLE ASSETS							
PLANT & EQUIPMENT	9651.9	10617.1	11678.8	12845.7	14131.4	15544.5	17099.0
OWNER'S COSTS	411.1	452.2	497.5	547.2	601.9	662.1	728.3
PRE-OPERATIONAL COSTS	681.7	749.9	824.9	907.4	998.1	1097.9	1207.7
CAPITALIZED IDC	1866.1	2052.7	2258.0	2483.8	2732.2	3005.4	3305.9
TOTAL DEPRECIABLE ASSETS	12610.9	13872.0	15259.2	16785.1	18463.6	20310.0	22341.0
LESS: ACCUM. DEPRECIATION	12610.9	13872.0	15259.2	16785.1	18463.6	20310.0	22341.0
NET FIXED ASSETS	-	-	-	-	-	-	-
TOTAL	248.8	282.3	320.2	363.3	412.1	467.6	-
CPI INDEX (JAN 1982 = 100)	705.6	776.1	853.8	939.1	1033.0	1136.4	1250.0

NOTE: EQUITY DOES NOT INCLUDE RETAINED EARNINGS.

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FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

SOURCES AND USES OF FUNDS

	YEAR -6 2ND HALF	YEAR -5 1ST HALF	YEAR -5 2ND HALF	YEAR -4 1ST HALF	YEAR -4 2ND HALF	YEAR -3 1ST HALF	YEAR -3 2ND HALF	YEAR -2 1ST HALF
SOURCES OF FUNDS								
DEBT	6.7	13.2	14.5	50.2	169.6	300.4	396.0	376.6
EQUITY	2.9	5.7	6.2	21.5	72.7	128.8	169.7	161.4
NET INCOME AFTER TAXES	-	-	-	-	-	-	-	-
DEPRECIATION	-	-	-	-	-	-	-	-
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL SOURCES	9.5	18.9	20.7	71.7	242.3	429.2	565.7	538.0
USES OF FUNDS								
PLANT AND EQUIPMENT	8.9	17.3	18.4	65.4	222.9	388.8	500.1	451.9
PRE-OPERATIONAL COSTS	-	-	-	-	-	-	-	-
OWNER'S COSTS	.4	.7	.8	2.8	5	16.6	21.3	19.2
INTEREST DURING CONSTRUCTION (IDC)	.2	.8	1.6	3.5	10.0	23.8	44.2	66.9
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-	-
INCREASES IN WORKING CAPITAL	-	-	-	-	-	-	-	-
DEBT REPAYMENT	-	-	-	-	-	-	-	-
AVAILABLE FUNDS	-	-	-	-	-	-	-	-
TOTAL USES	9.5	18.9	20.7	71.7	242.3	429.2	565.7	538.0
CPI INDEX (JAN 1982 = 100)	115.4	121.0	126.9	133.1	139.6	146.4	153.6	161.1

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

SOURCES AND USES OF FUNDS

	YEAR -2 2ND HALF	YEAR -1 1ST HALF	YEAR -1 2ND HALF	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
SOURCES OF FUNDS								
DEBT	275.4	152.9	245.3	-	-	-	-	-
EQUITY	118.0	65.5	105.1	-	-	-	-	-
NET INCOME AFTER TAXES	-	-	-	-303.0	-145.2	-100.2	-51.3	2.3
DEPRECIATION	-	-	-	356.8	392.5	431.7	474.9	522.4
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL SOURCES	393.4	218.4	350.4	53.8	247.3	331.5	423.6	524.7
USES OF FUNDS								
PLANT AND EQUIPMENT	294.7	114.9	21.2	-	-	-	-	-
PRE-OPERATIONAL COSTS	-	-	179.5	-	-	-	-	-
OWNER'S COSTS	12.6	4.9	.9	-	-	-	-	-
INTEREST DURING CONSTRUCTION (IDC)	86.1	98.7	110.4	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	38.5	-	-	-	-	-
INCREASES IN WORKING CAPITAL	-	-	-	-	16.4	7.4	8.3	9.5
DEBT REPAYMENT	-	-	-	200.1	200.1	200.1	200.1	200.1
AVAILABLE FUNDS	-	-	-	-146.3	30.8	124.1	215.2	315.1
TOTAL USES	393.4	218.4	350.4	53.8	247.3	331.5	423.6	524.7
CPI INDEX (JAN 1982 = 100)	168.9	177.2	185.8	204.4	224.8	247.3	272.0	299.2

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

SOURCES AND USES OF FUNDS

	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13
SOURCES OF FUNDS								
DEBT	-	-	-	-	-	-	-	-
EQUITY	-	-	-	-	-	-	-	-
NET INCOME AFTER TAXES	61.2	102.1	129.2	181.6	240.3	903.7	1022.4	1156.7
DEPRECIATION	574.6	632.1	695.3	764.8	841.3	-	-	-
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL SOURCES	635.8	734.2	824.5	946.4	1081.6	903.7	1022.4	1156.7
USES OF FUNDS								
PLANT AND EQUIPMENT	-	-	-	-	-	-	-	-
PRE-OPERATIONAL COSTS	-	-	-	-	-	-	-	-
OWNER'S COSTS	-	-	-	-	-	-	-	-
INTEREST DURING CONSTRUCTION (IDC)	-	-	-	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-	-
INCREASES IN WORKING CAPITAL	10.7	12.2	13.8	15.7	17.8	20.2	22.9	26.0
DEBT REPAYMENT	200.1	200.1	200.1	200.1	200.1	-	-	-
AVAILABLE FUNDS	425.0	522.0	610.5	730.6	863.7	883.6	999.5	1130.7
TOTAL USES	635.8	734.2	824.5	946.4	1081.6	903.7	1022.4	1156.7
CPI INDEX (JAN 1982 = 100)	329.2	362.1	398.3	438.1	481.9	530.1	583.1	641.4

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

SOURCES AND USES OF FUNDS

	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
SOURCES OF FUNDS							
DEBT	-	-	-	-	-	-	-
EQUITY	-	-	-	-	-	-	-
NET INCOME AFTER TAXES	1308.5	1480.2	1674.4	1894.0	2142.3	2423.1	2740.6
DEPRECIATION	-	-	-	-	-	-	-
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	530.5
TOTAL SOURCES	1308.5	1480.2	1674.4	1894.0	2142.3	2423.1	3271.1
USES OF FUNDS							
PLANT AND EQUIPMENT	-	-	-	-	-	-	-
PRE-OPERATIONAL COSTS	-	-	-	-	-	-	-
OWNER'S COSTS	-	-	-	-	-	-	-
INTEREST DURING CONSTRUCTION (IDC)	-	-	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-
INCREASES IN WORKING CAPITAL	29.5	33.4	38.0	43.1	48.9	55.5	62.9
DEBT REPAYMENT	-	-	-	-	-	-	-
AVAILABLE FUNDS	1279.0	1446.7	1636.4	1850.9	2093.4	2367.6	3208.2
TOTAL USES	1308.5	1480.2	1674.4	1894.0	2142.3	2423.1	3271.1
CPI INDEX (JAN 1982 = 100)	705.6	776.1	853.8	939.1	1033.0	1136.4	1250.0

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FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

CASH FLOWS AND RATIOS

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8
NET INCOME AFTER TAXES	-303.0	-145.2	-100.2	-51.3	2.3	61.2	102.1	129.2
DEPRECIATION	282.0	282.0	282.0	282.0	282.0	282.0	282.0	282.0
INCREASES IN WORKING CAPITAL	-	-16.4	-7.4	-8.3	-9.5	-10.7	-12.2	-13.8
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
CASH FLOW FROM OPERATIONS	53.8	230.9	324.1	415.3	515.2	625.1	722.0	810.6
DEBT PRINCIPAL REPAYMENT	200.1	200.1	200.1	200.1	200.1	200.1	200.1	200.1
NET CASH FLOW	-146.3	30.8	124.1	215.2	315.1	425.0	522.0	610.5
INTEREST	234.1	210.1	186.1	162.1	138.1	114.0	90.0	66.0
CPI INDEX (JAN 1982 = 100)	204.4	224.8	247.3	272.0	299.2	329.2	362.1	398.3
INTEREST COVER (1)	-.29	.31	.46	.68	1.02	1.54	2.40	4.01
DEBT SERVICE COVER (2)	.66	1.08	1.32	1.59	1.93	2.35	2.80	3.29

NOTES

$$(1)\ \text{INTEREST COVER} = \frac{\text{EARNINGS BEFORE INTEREST AND TAXES}}{\text{INTEREST}}$$

$$(2)\ \text{DEBT SERVICE COVER} = \frac{\text{CASH FLOW FROM OPERATIONS + INTEREST}}{\text{PRINCIPAL REPAYMENT + INTEREST}}$$

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

CASH FLOWS AND RATIOS

	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16
NET INCOME AFTER TAXES	181.6	240.3	903.7	1022.4	1156.7	1308.5	1480.2	1674.4
DEPRECIATION	282.0	282.0	-	-	-	-	-	-
INCREASES IN WORKING CAPITAL	-15.7	-17.8	-20.2	-22.9	-26.0	-29.5	-33.4	-38.0
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
CASH FLOW FROM OPERATIONS	930.7	1063.8	883.6	999.5	1130.7	1279.0	1446.7	1636.4
DEBT PRINCIPAL REPAYMENT	200.1	200.1	-	-	-	-	-	-
NET CASH FLOW	730.6	863.7	883.6	999.5	1130.7	1279.0	1446.7	1636.4
INTEREST	42.0	18.0	-	-	-	-	-	-
CPI INDEX (JAN 1982 = 100)	438.1	481.9	530.1	583.1	641.4	705.6	776.1	853.8
INTEREST COVER (1)	7.65	21.53	-	-	-	-	-	-
DEBT SERVICE COVER (2)	4.02	4.96	-	-	-	-	-	-

NOTES

$$(1)\ \text{INTEREST COVER} = \frac{\text{EARNINGS BEFORE INTEREST AND TAXES}}{\text{INTEREST}}$$

$$(2)\ \text{DEBT SERVICE COVER} = \frac{\text{CASH FLOW FROM OPERATIONS + INTEREST}}{\text{PRINCIPAL REPAYMENT + INTEREST}}$$

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

CASH FLOWS AND RATIOS

	YEAR 17	YEAR 18	YEAR 19	YEAR 20
NET INCOME AFTER TAXES	1894.0	2142.3	2423.1	2740.6
DEPRECIATION	-	-	-	-
INCREASES IN WORKING CAPITAL	-43.1	-48.9	-55.5	-62.9
RECOVERY OF WORKING CAPITAL	-	-	-	530.5
CASH FLOW FROM OPERATIONS	1850.9	2093.4	2367.6	3208.2
DEBT PRINCIPAL REPAYMENT	-	-	-	-
NET CASH FLOW	1850.9	2093.4	2367.6	3208.2
INTEREST	-	-	-	-
CPI INDEX (JAN 1982 = 100)	939.1	1033.0	1136.4	1250.0
INTEREST COVER (1)	-	-	-	-
DEBT SERVICE COVER (2)	-	-	-	-

NOTES

$$(1)\ \text{INTEREST COVER} = \frac{\text{EARNINGS BEFORE INTEREST AND TAXES}}{\text{INTEREST}}$$

$$(2)\ \text{DEBT SERVICE COVER} = \frac{\text{CASH FLOW FROM OPERATIONS + INTEREST}}{\text{PRINCIPAL REPAYMENT + INTEREST}}$$

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

INCOME TAX WORKSHEET

	YEAR 1 1ST HALF	YEAR 1 2ND HALF	YEAR 2 1ST HALF	YEAR 2 2ND HALF	YEAR 3 1ST HALF	YEAR 3 2ND HALF	YEAR 4 1ST HALF	YEAR 4 2ND HALF
INCOME BEFORE TAX	-214.6	-88.4	-78.0	-67.2	-56.0	-44.3	-32.0	-19.3
PLUS: COMPULSORY ELECTRIC LOAN	-	-	-	-	-	-	-	-
TAX BASE	-214.6	-88.4	-78.0	-67.2	-56.0	-44.3	-32.0	-19.3
LESS: 3.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-214.6	-88.4
	-214.6	-88.4	-78.0	-67.2	-56.0	-44.3	-32.0	-19.3
LESS: 2.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-214.6	-88.4	-78.0
	-214.6	-88.4	-78.0	-67.2	-56.0	-258.9	-120.4	97.2
LESS: 2.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-214.6	-88.4	-78.0	-67.2
	-214.6	-88.4	-78.0	-67.2	-270.6	-347.3	-198.4	-164.4
LESS: 1.5 YEAR LOSS CARRY FORWARD	-	-	-	-214.6	-88.4	-78.0	-67.2	-56.0
	-214.6	-88.4	-78.0	-281.8	-359.0	-425.2	-265.6	-220.4
LESS: 1.0 YEAR LOSS CARRY FORWARD	-	-	-214.6	-88.4	-78.0	-67.2	-56.0	-44.3
	-214.6	-88.4	-292.6	-370.2	-436.9	-492.4	-321.5	-264.7
LESS: 0.5 YEAR LOSS CARRY FORWARD	-	-214.6	-88.4	-78.0	-67.2	-56.0	-44.3	-32.0
TAXABLE INCOME	-214.6	-303.0	-381.0	-448.2	-504.1	-548.4	-365.8	-296.7
TAX LIABILITY @ 35%	-	-	-	-	-	-	-	-
CPI INDEX (JAN 1982 = 100)	194.9	204.4	214.4	224.8	235.8	247.3	259.4	272.0

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

INCOME TAX WORKSHEET

	YEAR 5 1ST HALF	YEAR 5 2ND HALF	YEAR 6 1ST HALF	YEAR 6 2ND HALF	YEAR 7 1ST HALF	YEAR 7 2ND HALF	YEAR 8 1ST HALF	YEAR 8 2ND HALF
INCOME BEFORE TAX	-5.9	8.2	22.9	38.3	54.6	71.8	89.8	108.9
PLUS: COMPULSORY ELECTRIC LOAN	-	-	-	-	-	-	-	-
TAX BASE	-5.9	8.2	22.9	38.3	54.6	71.8	89.8	108.9
LESS: 3.0 YEAR LOSS CARRY FORWARD	-78.0	-67.2	-56.0	-44.3	-32.0	-	-	-
	-5.9	-	-	-	22.6	71.8	89.8	108.9
LESS: 2.5 YEAR LOSS CARRY FORWARD	-67.2	-56.0	-44.3	-32.0	-19.3	-2.5	-	-
	-73.1	-56.0	-44.3	-32.0	3.3	69.2	89.8	108.9
LESS: 2.0 YEAR LOSS CARRY FORWARD	-56.0	-44.3	-32.0	-19.3	-5.9	-	-	-
	-129.0	-100.2	-76.3	-51.3	-2.5	69.2	89.8	108.9
LESS: 1.5 YEAR LOSS CARRY FORWARD	-44.3	-32.0	-19.3	-5.9	-	-	-	-
	-173.3	-132.3	-95.5	-57.2	-2.5	69.2	89.8	108.9
LESS: 1.0 YEAR LOSS CARRY FORWARD	-32.0	-19.3	-5.9	-	-	-	-	-
	-205.3	-151.5	-101.4	-57.2	-2.5	69.2	89.8	108.9
LESS: 0.5 YEAR LOSS CARRY FORWARD	-19.3	-5.9	-	-	-	-	-	-
TAXABLE INCOME	-224.6	-157.4	-101.4	-57.2	-2.5	69.2	89.8	108.9
TAX LIABILITY @ 35%	-	-	-	-	-	24.2	31.4	38.1
CPI INDEX (JAN 1982 = 100)	285.3	299.2	313.8	329.2	345.2	362.1	379.7	398.3

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

INCOME TAX WORKSHEET

	YEAR 9 1ST HALF	YEAR 9 2ND HALF	YEAR 10 1ST HALF	YEAR 10 2ND HALF	YEAR 11 1ST HALF	YEAR 11 2ND HALF	YEAR 12 1ST HALF	YEAR 12 2ND HALF
INCOME BEFORE TAX	129.0	150.3	172.9	196.7	673.7	716.6	762.2	810.7
PLUS: COMPULSORY ELECTRIC LOAN	-	-	-	-	-	-	-	-
TAX BASE	129.0	150.3	172.9	196.7	673.7	716.6	762.2	810.7
LESS: 3.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	129.0	150.3	172.9	196.7	673.7	716.6	762.2	810.7
LESS: 2.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	129.0	150.3	172.9	196.7	673.7	716.6	762.2	810.7
LESS: 2.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	129.0	150.3	172.9	196.7	673.7	716.6	762.2	810.7
LESS: 1.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	129.0	150.3	172.9	196.7	673.7	716.6	762.2	810.7
LESS: 1.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	129.0	150.3	172.9	196.7	673.7	716.6	762.2	810.7
LESS: 0.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
TAXABLE INCOME	129.0	150.3	172.9	196.7	673.7	716.6	762.2	810.7
TAX LIABILITY @ 35%	45.2	52.6	60.5	68.9	235.8	250.8	266.8	283.8
CPI INDEX (JAN 1982 = 100)	417.7	438.1	459.5	481.9	505.4	530.1	556.0	583.1

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

INCOME TAX WORKSHEET

	YEAR 13 1ST HALF	YEAR 13 2ND HALF	YEAR 14 1ST HALF	YEAR 14 2ND HALF	YEAR 15 1ST HALF	YEAR 15 2ND HALF	YEAR 16 1ST HALF	YEAR 16 2ND HALF
INCOME BEFORE TAX	862.3	917.2	975.5	1037.6	1103.5	1173.7	1248.3	1327.7
PLUS: COMPULSORY ELECTRIC LOAN	-	-	-	-	-	-	-	-
TAX BASE	862.3	917.2	975.5	1037.6	1103.5	1173.7	1248.3	1327.7
LESS: 3.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	862.3	917.2	975.5	1037.6	1103.5	1173.7	1248.3	1327.7
LESS: 2.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	862.3	917.2	975.5	1037.6	1103.5	1173.7	1248.3	1327.7
LESS: 2.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	862.3	917.2	975.5	1037.6	1103.5	1173.7	1248.3	1327.7
LESS: 1.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	862.3	917.2	975.5	1037.6	1103.5	1173.7	1248.3	1327.7
LESS: 1.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	862.3	917.2	975.5	1037.6	1103.5	1173.7	1248.3	1327.7
LESS: 0.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
TAXABLE INCOME	862.3	917.2	975.5	1037.6	1103.5	1173.7	1248.3	1327.7
TAX LIABILITY @ 35%	301.8	321.0	341.4	363.1	386.2	410.8	436.9	464.7
CPI INDEX (JAN 1982 = 100)	611.6	641.4	672.7	705.6	740.0	776.1	814.0	853.8

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

INCOME TAX WORKSHEET

	YEAR 17 1ST HALF	YEAR 17 2ND HALF	YEAR 18 1ST HALF	YEAR 18 2ND HALF	YEAR 19 1ST HALF	YEAR 19 2ND HALF	YEAR 20 1ST HALF	YEAR 20 2ND HALF
INCOME BEFORE TAX	1412.0	1501.8	1597.2	1698.6	1806.5	1921.3	2043.3	2173.0
PLUS: COMPULSORY ELECTRIC LOAN	-	-	-	-	-	-	-	-
TAX BASE	1412.0	1501.8	1597.2	1698.6	1806.5	1921.3	2043.3	2173.0
LESS: 3.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	1412.0	1501.8	1597.2	1698.6	1806.5	1921.3	2043.3	2173.0
LESS: 2.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	1412.0	1501.8	1597.2	1698.6	1806.5	1921.3	2043.3	2173.0
LESS: 2.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	1412.0	1501.8	1597.2	1698.6	1806.5	1921.3	2043.3	2173.0
LESS: 1.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	1412.0	1501.8	1597.2	1698.6	1806.5	1921.3	2043.3	2173.0
LESS: 1.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	1412.0	1501.8	1597.2	1698.6	1806.5	1921.3	2043.3	2173.0
LESS: 0.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
TAXABLE INCOME	1412.0	1501.8	1597.2	1698.6	1806.5	1921.3	2043.3	2173.0
TAX LIABILITY @ 35%	494.2	525.6	559.0	594.5	632.3	672.4	715.1	760.5
CPI INDEX (JAN 1982 = 100)	895.4	939.1	985.0	1033.0	1083.5	1136.4	1191.8	1250.0

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR -6 2ND HALF	YEAR -5 1ST HALF	YEAR -5 2ND HALF	YEAR -4 1ST HALF	YEAR -4 2ND HALF	YEAR -3 1ST HALF	YEAR -3 2ND HALF	YEAR -2 1ST HALF
PROJECT LOANS								
BORROWINGS THIS PERIOD	6.5	12.7	13.4	47.7	162.7	283.8	365.0	329.8
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	6.5	19.2	32.6	80.3	243.0	526.8	891.8	1221.5
INTEREST THIS PERIOD	.2	.8	1.6	3.4	9.7	23.1	42.6	63.4
INTEREST DURING CONSTRUCTION LOAN								
BORROWINGS THIS PERIOD	.1	.5	1.1	2.4	7.0	16.6	31.0	46.8
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	.1	.7	1.8	4.2	11.2	27.8	58.8	105.7
INTEREST THIS PERIOD	-	-	-	.1	.3	.7	1.7	3.5
TOTAL OF ALL LOANS								
BORROWINGS THIS PERIOD	6.7	13.2	14.5	50.2	169.6	300.4	396.0	376.6
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	6.7	19.8	34.4	84.6	254.2	554.6	950.6	1327.2
INTEREST THIS PERIOD	.2	.8	1.6	3.5	10.0	23.8	44.2	66.9
CPI INDEX (JAN 1982 = 100)	115.4	121.0	126.9	133.1	139.6	146.4	153.6	161.1

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BRAZIL SOUTHERN CONE ENERGY NETWORK
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ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR -2 2ND HALF	YEAR -1 1ST HALF	YEAR -1 2ND HALF	YEAR 1 1ST HALF	YEAR 1 2ND HALF	YEAR 2 1ST HALF	YEAR 2 2ND HALF	YEAR 3 1ST HALF
PROJECT LOANS								
BORROWINGS THIS PERIOD	215.1	83.8	168.1	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	84.4	84.4	84.4	84.4	84.4
PRINCIPAL OUTSTANDING AT CLOSE	1436.6	1520.5	1688.5	1604.1	1519.7	1435.3	1350.8	1266.4
INTEREST THIS PERIOD	79.7	88.7	96.3	101.3	96.2	91.2	86.1	81.0
INTEREST DURING CONSTRUCTION LOAN								
BORROWINGS THIS PERIOD	60.3	69.1	77.3	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	15.6	15.6	15.6	15.6	15.6
PRINCIPAL OUTSTANDING AT CLOSE	165.9	235.0	312.2	296.6	281.0	265.4	249.8	234.2
INTEREST THIS PERIOD	6.3	10.0	14.1	18.7	17.8	16.9	15.9	15.0
TOTAL OF ALL LOANS								
BORROWINGS THIS PERIOD	275.4	152.9	245.3	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	100.0	100.0	100.0	100.0	100.0
PRINCIPAL OUTSTANDING AT CLOSE	1602.6	1755.5	2000.8	1900.7	1800.7	1700.7	1600.6	1500.6
INTEREST THIS PERIOD	86.1	98.7	110.4	120.0	114.0	108.0	102.0	96.0
CPI INDEX (JAN 1982 = 100)	168.9	177.2	185.8	194.9	204.4	214.4	224.8	235.8

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BRAZIL SOUTHERN CONE ENERGY NETWORK
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ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR 3 2ND HALF	YEAR 4 1ST HALF	YEAR 4 2ND HALF	YEAR 5 1ST HALF	YEAR 5 2ND HALF	YEAR 6 1ST HALF	YEAR 6 2ND HALF	YEAR 7 1ST HALF
PROJECT LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	84.4	84.4	84.4	84.4	84.4	84.4	84.4	84.4
PRINCIPAL OUTSTANDING AT CLOSE	1182.0	1097.6	1013.1	928.7	844.3	759.8	675.4	591.0
INTEREST THIS PERIOD	76.0	70.9	65.9	60.9	55.7	50.7	45.6	40.5
INTEREST DURING CONSTRUCTION LOAN								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6
PRINCIPAL OUTSTANDING AT CLOSE	218.6	203.0	187.3	171.7	156.1	140.5	124.9	109.3
INTEREST THIS PERIOD	14.1	13.1	12.2	11.2	10.3	9.4	8.4	7.5
TOTAL OF ALL LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
PRINCIPAL OUTSTANDING AT CLOSE	1400.5	1300.5	1200.5	1100.4	1000.4	900.4	800.3	700.3
INTEREST THIS PERIOD	90.0	84.0	78.0	72.0	66.0	60.0	54.0	48.0
CPI INDEX (JAN 1982 = 100)	247.3	259.4	272.0	285.3	299.2	313.8	329.2	345.2

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR 7 2ND HALF	YEAR 8 1ST HALF	YEAR 8 2ND HALF	YEAR 9 1ST HALF	YEAR 9 2ND HALF	YEAR 10 1ST HALF	YEAR 10 2ND HALF	YEAR 11 1ST HALF
PROJECT LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	84.4	84.4	84.4	84.4	84.4	84.4	84.4	-
PRINCIPAL OUTSTANDING AT CLOSE	506.6	422.1	337.7	253.3	168.9	84.4	-	-
INTEREST THIS PERIOD	35.5	30.4	25.3	20.3	15.2	10.1	5.1	-
INTEREST DURING CONSTRUCTION LOAN								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	15.6	15.6	15.6	15.6	15.6	15.6	15.6	-
PRINCIPAL OUTSTANDING AT CLOSE	93.7	78.1	62.4	46.8	31.2	15.6	-	-
INTEREST THIS PERIOD	6.6	5.6	4.7	3.7	2.6	1.9	.9	-
TOTAL OF ALL LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	100.0	100.0	100.0	100.0	100.0	100.0	100.0	-
PRINCIPAL OUTSTANDING AT CLOSE	600.2	500.2	400.2	300.1	200.1	100.0	-	-
INTEREST THIS PERIOD	42.0	36.0	30.0	24.0	18.0	12.0	6.0	-
CPI INDEX (JAN 1982 = 100)	362.1	379.7	398.3	417.7	438.1	459.5	481.9	505.4

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BRAZIL SOUTHERN CONE ENERGY NETWORK
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(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR 11 2ND HALF	YEAR 12 1ST HALF	YEAR 12 2ND HALF	YEAR 13 1ST HALF	YEAR 13 2ND HALF	YEAR 14 1ST HALF	YEAR 14 2ND HALF	YEAR 15 1ST HALF
PROJECT LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-	-	-	-	-	-
INTEREST THIS PERIOD	-	-	-	-	-	-	-	-
INTEREST DURING CONSTRUCTION LOAN								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-	-	-	-	-	-
INTEREST THIS PERIOD	-	-	-	-	-	-	-	-
TOTAL OF ALL LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-	-	-	-	-	-
INTEREST THIS PERIOD	-	-	-	-	-	-	-	-
CPI INDEX (JAN 1982 = 100)	530.1	556.0	583.1	611.6	641.4	672.7	705.6	740.0

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BRAZIL SOUTHERN CONE ENERGY NETWORK
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ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR 15 2ND HALF	YEAR 16 1ST HALF	YEAR 16 2ND HALF	YEAR 17 1ST HALF	YEAR 17 2ND HALF	YEAR 18 1ST HALF	YEAR 18 2ND HALF	YEAR 19 1ST HALF
PROJECT LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-	-	-	-	-	-
INTEREST THIS PERIOD	-	-	-	-	-	-	-	-
INTEREST DURING CONSTRUCTION LOAN								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-	-	-	-	-	-
INTEREST THIS PERIOD	-	-	-	-	-	-	-	-
TOTAL OF ALL LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-	-	-	-	-	-
INTEREST THIS PERIOD	-	-	-	-	-	-	-	-
CPI INDEX (JAN 1982 = 100)	776.1	814.0	853.8	895.4	939.1	985.0	1033.0	1083.5

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ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR 19 2ND HALF	YEAR 20 1ST HALF	YEAR 20 2ND HALF
PROJECT LOANS			
BORROWINGS THIS PERIOD	-	-	-
REPAYMENT THIS PERIOD	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-
INTEREST THIS PERIOD	-	-	-
INTEREST DURING CONSTRUCTION LOAN			
BORROWINGS THIS PERIOD	-	-	-
REPAYMENT THIS PERIOD	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-
INTEREST THIS PERIOD	-	-	-
TOTAL OF ALL LOANS			
BORROWINGS THIS PERIOD	-	-	-
REPAYMENT THIS PERIOD	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-
INTEREST THIS PERIOD	-	-	-
CPI INDEX (JAN 1982 = 100)	1136.4	1191.8	1250.0

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROI)

	YEAR -6	YEAR -5	YEAR -4	YEAR -3	YEAR -2	YEAR -1	YEAR 1	YEAR 2
PRETAX CASH FLOWS								
CASH OUT								
DEPRECIABLE INVESTMENT	9.3	37.2	300.6	926.8	778.4	321.4	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	38.5	-	-
TOTAL CASH OUT	9.3	37.2	300.6	926.8	778.4	359.9	-	-
CASH IN								
OPERATING INCOME	-	-	-	-	-	-	287.9	457.4
INCREASES IN WORKING CAPITAL	-	-	-	-	-	-	-	-16.4
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	-	-	-	-	-	-	287.9	441.0
POST-TAX CASH FLOWS								
CASH OUT								
DEPRECIABLE INVESTMENT	9.3	37.2	300.6	926.8	778.4	321.4	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	38.5	-	-
TOTAL CASH OUT	9.3	37.2	300.6	926.8	778.4	359.9	-	-
CASH IN								
OPERATING INCOME	-	-	-	-	-	-	287.9	457.4
INCREASES IN WORKING CAPITAL	-	-	-	-	-	-	-	-16.4
ADJUSTED TAXES	-	-	-	-	-	-	-	-
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	-	-	-	-	-	-	287.9	441.0
REAL POST-TAX NPV @ 5%	-8.1	-37.0	-235.4	-773.2	-1169.0	-1324.4	-1224.6	-1090.5
REAL POST-TAX NPV @ 10%	-7.7	-34.3	-207.9	-659.2	-977.4	-1095.9	-1025.1	-[illegible]3.7
REAL PRETAX ROI %	-	-	-	-	-	-	-	-
NOMINAL PRETAX ROI %	-	-	-	-	-	-	-	-
REAL POST-TAX ROI %	-	-	-	-	-	-	-	-
NOMINAL POST-TAX ROI %	-	-	-	-	-	-	-	-
CPI INDEX (JAN 1982 = 100)	115.4	126.9	139.6	153.6	168.9	185.8	204.4	224.8

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROI)

	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
P R E T A X C A S H F L O W S								
CASH OUT								
DEPRECIABLE INVESTMENT	-	-	-	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH OUT	-	-	-	-	-	-	-	-
CASH IN								
OPERATING INCOME	517.6	585.7	662.7	749.9	848.5	960.0	1086.2	1228.9
INCREASES IN WORKING CAPITAL	-7.4	-8.3	-9.5	-10.7	-12.2	-13.8	-15.7	-17.8
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	510.2	577.3	653.2	739.1	836.3	946.2	1070.5	1211.1
P O S T - T A X C A S H F L O W S								
CASH OUT								
DEPRECIABLE INVESTMENT	-	-	-	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH OUT	-	-	-	-	-	-	-	-
CASH IN								
OPERATING INCOME	517.6	585.7	662.7	749.9	848.5	960.0	1086.2	1228.9
INCREASES IN WORKING CAPITAL	-7.4	-8.3	-9.5	-10.7	-12.2	-13.8	-15.7	-17.8
ADJUSTED TAXES	-27.5	-63.4	-76.2	-91.1	-108.5	-128.7	-152.1	-179.2
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	482.7	514.0	577.1	648.0	727.8	817.5	918.4	1031.9
REAL POST-TAX NPV @ 5%	-963.0	-845.7	-731.7	-620.8	-513.0	-408.2	-306.2	-207.0
REAL POST-TAX NPV @ 10%	-850.7	-777.9	-710.3	-647.6	-589.4	-535.4	-485.2	-438.6
REAL PRETAX ROI %	-	-	-	-	-	.75	2.59	4.06
NOMINAL PRETAX ROI %	-	-	.44	4.91	8.25	10.83	12.85	14.47
REAL POST-TAX ROI %	-	-	-	-	-	-	1.21	2.67
NOMINAL POST-TAX ROI %	-	-	-	3.48	6.77	9.32	11.33	12.94
CPI INDEX (JAN 1982 = 100)	247.3	272.0	299.2	329.2	362.1	398.3	438.1	481.9

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FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROI)

	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18
P R E T A X C A S H F L O W S								
CASH OUT								
DEPRECIABLE INVESTMENT	-	-	-	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH OUT	-	-	-	-	-	-	-	-
CASH IN								
OPERATING INCOME	1390.4	1573.0	1779.5	2013.1	2277.2	2576.0	2913.8	3295.8
INCREASES IN WORKING CAPITAL	-20.2	-22.9	-26.0	-29.5	-33.4	-38.0	-43.1	-48.9
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	1370.2	1550.1	1753.5	1983.6	2243.8	2538.0	2870.7	3247.0
P O S T - T A X C A S H F L O W S								
CASH OUT								
DEPRECIABLE INVESTMENT	-	-	-	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH OUT	-	-	-	-	-	-	-	-
CASH IN								
OPERATING INCOME	1390.4	1573.0	1779.5	2013.1	2277.2	2576.0	2913.8	3295.8
INCREASES IN WORKING CAPITAL	-20.2	-22.9	-26.0	-29.5	-33.4	-38.0	-43.1	-48.9
ADJUSTED TAXES	-486.6	-550.5	-622.8	-704.6	-797.0	-901.6	-1019.8	-1153.5
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	883.6	999.5	1130.7	1279.0	1446.7	1636.4	1850.9	2093.4
REAL POST-TAX NPV @ 5%	-133.5	-61.4	9.1	78.2	145.9	212.1	277.0	340.5
REAL POST-TAX NPV @ 10%	-405.6	-374.8	-346.0	-319.1	-293.9	-270.4	-248.4	-227.8
REAL PRETAX ROI %	5.25	6.23	7.03	7.71	8.28	8.76	9.17	9.53
NOMINAL PRETAX ROI %	15.77	16.85	17.74	18.48	19.11	19.64	20.09	20.48
REAL POST-TAX ROI %	3.60	4.40	5.08	5.68	6.19	6.64	7.04	7.38
NOMINAL POST-TAX ROI %	13.96	14.84	15.59	16.25	16.81	17.31	17.74	18.12
CPI INDEX (JAN 1982 = 100)	530.1	583.1	641.4	705.6	776.1	853.8	939.1	1033.0

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROI)

	YEAR 19	YEAR 20
P R E T A X C A S H F L O W S		
CASH OUT		
DEPRECIABLE INVESTMENT	-	-
INITIAL WORKING CAPITAL	-	-
TOTAL CASH OUT	-	-
CASH IN		
OPERATING INCOME	3727.8	4216.2
INCREASES IN WORKING CAPITAL	-55.5	-62.9
RECOVERY OF WORKING CAPITAL	-	530.5
TOTAL CASH IN	3672.4	4683.8
P O S T - T A X C A S H F L O W S		
CASH OUT		
DEPRECIABLE INVESTMENT	-	-
INITIAL WORKING CAPITAL	-	-
TOTAL CASH OUT	-	-
CASH IN		
OPERATING INCOME	3727.8	4216.2
INCREASES IN WORKING CAPITAL	-55.5	-62.9
ADJUSTED TAXES	-1304.7	-1475.7
RECOVERY OF WORKING CAPITAL	-	530.5
TOTAL CASH IN	2367.6	3208.2
REAL POST-TAX NPV @ 5%	402.8	475.3
REAL POST-TAX NPV @ 10%	-208.6	-187.2
REAL PRETAX ROI %	9.83	10.13
NOMINAL PRETAX ROI %	20.82	21.14
REAL POST-TAX ROI %	7.68	8.00
NOMINAL POST-TAX ROI %	18.45	18.80
CPI INDEX (JAN 1982 = 100)	1136.4	1250.0

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROE)

R O E C A S H F L O W S	YEAR -6	YEAR -5	YEAR -4	YEAR -3	YEAR -2	YEAR -1	YEAR 1	YEAR 2
CASH OUT								
EQUITY INVESTMENT	2.9	11.9	94.2	298.5	279.4	170.7	-	-
TOTAL CASH OUT	2.9	11.9	94.2	298.5	279.4	170.7	-	-
CASH IN								
OPERATING INCOME	-	-	-	-	-	-	287.9	457.4
INCREASES IN WORKING CAPITAL	-	-	-	-	-	-	-	-16.4
TAXES	-	-	-	-	-	-	-	-
INTEREST	-	-	-	-	-	-	-234.1	-210.1
DEBT REPAYMENT	-	-	-	-	-	-	-200.1	-200.1
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	-	-	-	-	-	-	-146.3	30.8
REAL ROE %	-	-	-	-	-	-	-	-
NOMINAL ROE %	-	-	-	-	-	-	-	-
CPI INDEX (JAN 1982 = 100)	115.4	126.9	139.6	153.6	168.9	185.8	204.4	224.8

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FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROE)

R O E C A S H F L O W S	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
CASH OUT								
EQUITY INVESTMENT	-	-	-	-	-	-	-	-
TOTAL CASH OUT	-	-	-	-	-	-	-	-
CASH IN								
OPERATING INCOME	517.6	585.7	662.7	749.9	848.5	960.0	1086.2	1228.9
INCREASES IN WORKING CAPITAL	-7.4	-8.3	-9.5	-10.7	-12.2	-13.8	-15.7	-17.8
TAXES	-	-	-	-	-24.2	-69.5	-97.8	-129.4
INTEREST	-186.1	-162.1	-138.1	-114.0	-90.0	-66.0	-42.0	-18.0
DEBT REPAYMENT	-200.1	-200.1	-200.1	-200.1	-200.1	-200.1	-200.1	-200.1
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	124.1	215.2	315.1	425.0	522.0	610.5	730.6	863.7
REAL ROE %	-	-	-	-	-	.91	3.59	5.66
NOMINAL ROE %	-	-	-	1 8	7.10	11.00	13.95	16.23
CPI INDEX (JAN 1982 = 100)	247.3	272.0	299.2	329.2	362.1	398.3	438.1	481.9

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FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROE)

R O E C A S H F L O W S	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18
CASH OUT								
EQUITY INVESTMENT	-	-	-	-	-	-	-	-
TOTAL CASH OUT	-	-	-	-	-	-	-	-
CASH IN								
OPERATING INCOME	1390.4	1573.0	1779.5	2013.1	2277.2	2576.0	2913.8	3295.8
INCREASES IN WORKING CAPITAL	-20.2	-22.9	-26.0	-29.5	-33.4	-38.0	-43.1	-48.9
TAXES	-486.6	-550.5	-622.8	-704.6	-797.0	-901.6	-1019.8	-1153.5
INTEREST	-	-	-	-	-	-	-	-
DEBT REPAYMENT	-	-	-	-	-	-	-	-
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	883.6	999.5	1130.7	1279.0	1446.7	1636.4	1850.9	2093.4
REAL ROE %	7.10	8.24	9.16	9.91	10.53	11.04	11.47	11.84
NOMINAL ROE %	17.81	19.07	20.08	20.91	21.58	22.15	22.62	23.02
CPI INDEX (JAN 1982 = 100)	530.1	583.1	641.4	705.6	776.1	853.8	939.1	1033.0

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: COAL GASIFICATION PLANT

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROE)

R O E C A S H F L O W S	YEAR 19	YEAR 20
CASH OUT		
EQUITY INVESTMENT	-	-
TOTAL CASH OUT	-	-
CASH IN		
OPERATING INCOME	3727.8	4216.2
INCREASES IN WORKING CAPITAL	-55.5	-62.9
TAXES	-1304.7	-1475.7
INTEREST	-	-
DEBT REPAYMENT	-	-
RECOVERY OF WORKING CAPITAL	-	530.5
TOTAL CASH IN	2367.6	3208.2
REAL ROE %	12.14	12.45
NOMINAL ROE %	23.36	23.70
CPI INDEX (JAN 1982 = 100)	1136.4	1250.0

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FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK

COAL GASIFICATION FOR SNG PRODUCTION

AND PIPELINE SYSTEM

FEASIBILITY STUDY

PART II

GAS PIPELINE AND DISTRIBUTION SYSTEM

UNITED STATES

TRADE AND DEVELOPMENT PROGRAM

AND

AGENCY FOR INTERNATIONAL DEVELOPMENT

CONTRACT PDC-0000-C-00-1106-00

ACKNOWLEDGEMENTS

Part II of this report has been prepared by Fluor Engineers and Constructors, Inc. - Advanced Technology Division - with the technological support of Fluor Ocean Services. Acknowledgement is made to Jaakko Poyry Engenharia for relevant data specific to Brazil and to local conditions.

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12.0 INTRODUCTION

Coal gasification for SNG production is the subject of Part I of Volume II of this feasibility report. Part II addresses the pipeline, which includes the operations and management infrastructure to operate and maintain a main transmission pipeline, distribution systems, and lateral branches.

12.1 EXECUTIVE SUMMARY

A composite Executive Summary of the Coal Gasification Plant and Pipeline is bound in Volume I of this report.

12.2 SUMMARY AND CONCLUSIONS

This pipeline is a technically and commercially viable project which could serve as the base system for providing gas to known and projected users. Furthermore, it would stimulate utilization of abundant subbituminous coal reserves that are commercially mineable in the States of Rio Grande do Sul and Santa Catarina. Because of the coal's friable nature and high ash content, these reserves would be difficult to ship and process in the other parts of the country where the energy is needed, and where air quality is often marginal with respect to current standards of acceptability (see Part I, Section 6 and Appendix F).

The pipeline system provides for accessible gas energy within a corridor 200 km wide through the states of Rio Grande do Sul, Santa Catarina, Parana, and Sao Paulo. Such access would, in turn, provide a basis for attracting industries that would stimulate economic growth in these regions.

Substituting gas for oil as an industrial fuel will have a dual effect on the air quality in the major cities that have high pollution levels.

- For the same amount of energy, gas produces less air pollutants than oil.
- Dispersing industry to the south will also further decrease the pollutants and improve the air quality of the Santos and Sao Paulo areas.

The drain on the Sao Paulo water district can be reduced by relocating some of the industry to the southern areas where there presently appears to be an abundance of water.

12.3 FEASIBILITY STUDY

The primary goal of this pipeline study is to develop a technically and economically feasible plan for transporting and distributing SNG from a Brazilian coal gasification plant through a pipeline distribution system to

the industrial centers of Southern Brazil. To support this plan Fluor has prepared an order of magnitude cost estimate, economic analysis, and preliminary project schedule for engineering, procurement, and construction of the pipeline. Preliminary design of the pipeline allows distribution not only of any SNG from the coal gasification plant but also of any imported or newly discovered natural gas to augment energy needs of Brazil through the planning year 1990, and further to the end of the century.

Fluor has also evaluated several alternate modes of transporting coal and gas and locations for the SNG plant in terms of technical, economic, social, and environmental factors. One of these alternates, based on transporting coal to a coal gasification plant located in the Santos region, has been compared more fully against the preliminary selection of the gas pipeline system starting at the coal gasification plant located near the coal source in Minas do Leao.

We have used a macroscopic approach to pipeline route selection. The preliminary route selection was described in a trip report, and is analyzed in this feasiblity report.

Project Composition

The major components of the pipeline system (see Figure 12-1 and 12-2) are a gas transmission line from the SNG plant at Minas do Leao to a distribution point near Santo Marinquy (south of Sao Paulo), and a multi-pronged distribution system as follows:

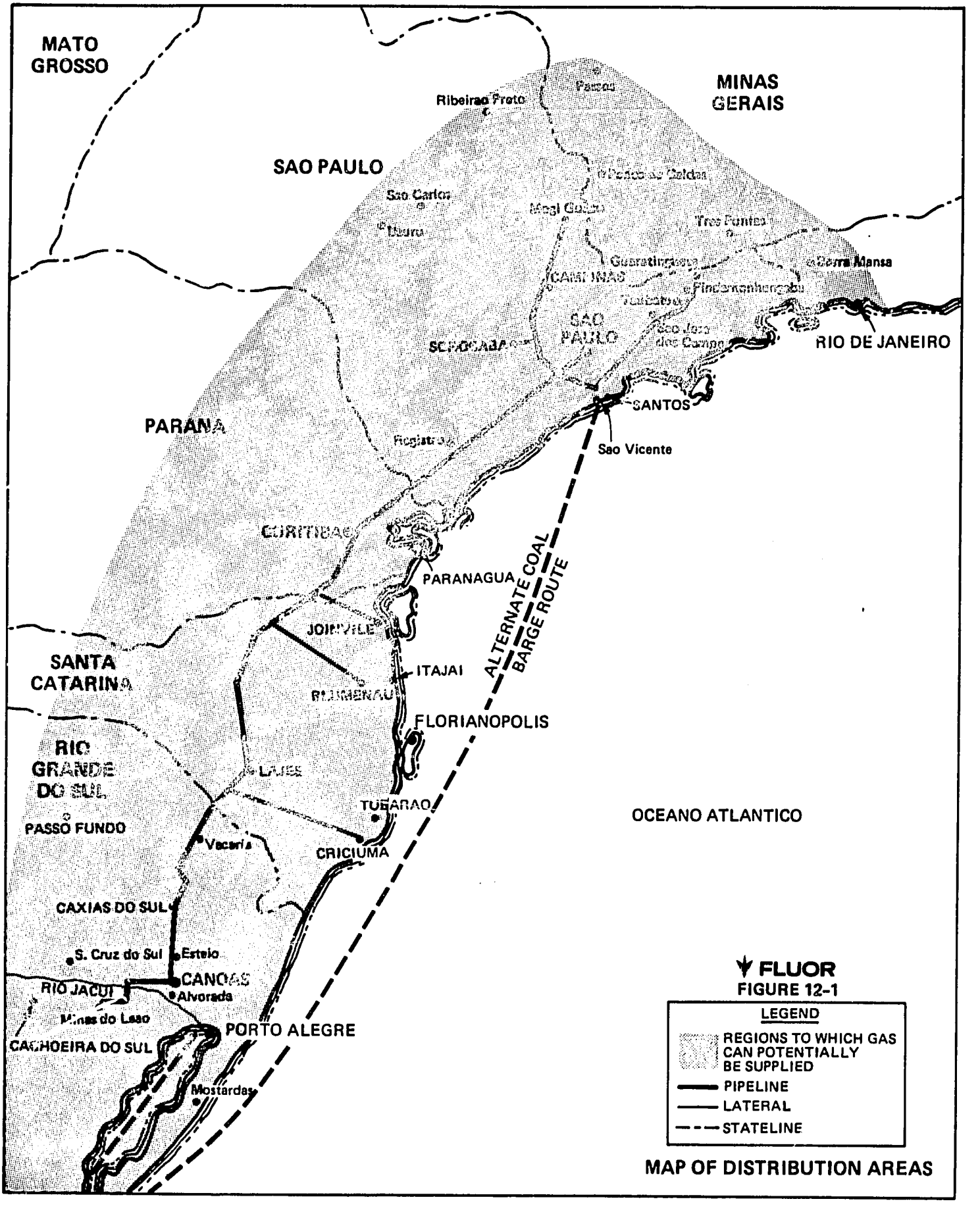
- to the city of Sao Paulo existing grid
- to the northeast of Sao Paulo, to Pindamonhangaba
- to the northwest of Sao Paulo, and, to Mogi Guacu
- to consumers along the transmission pipeline via laterals

System Capacity

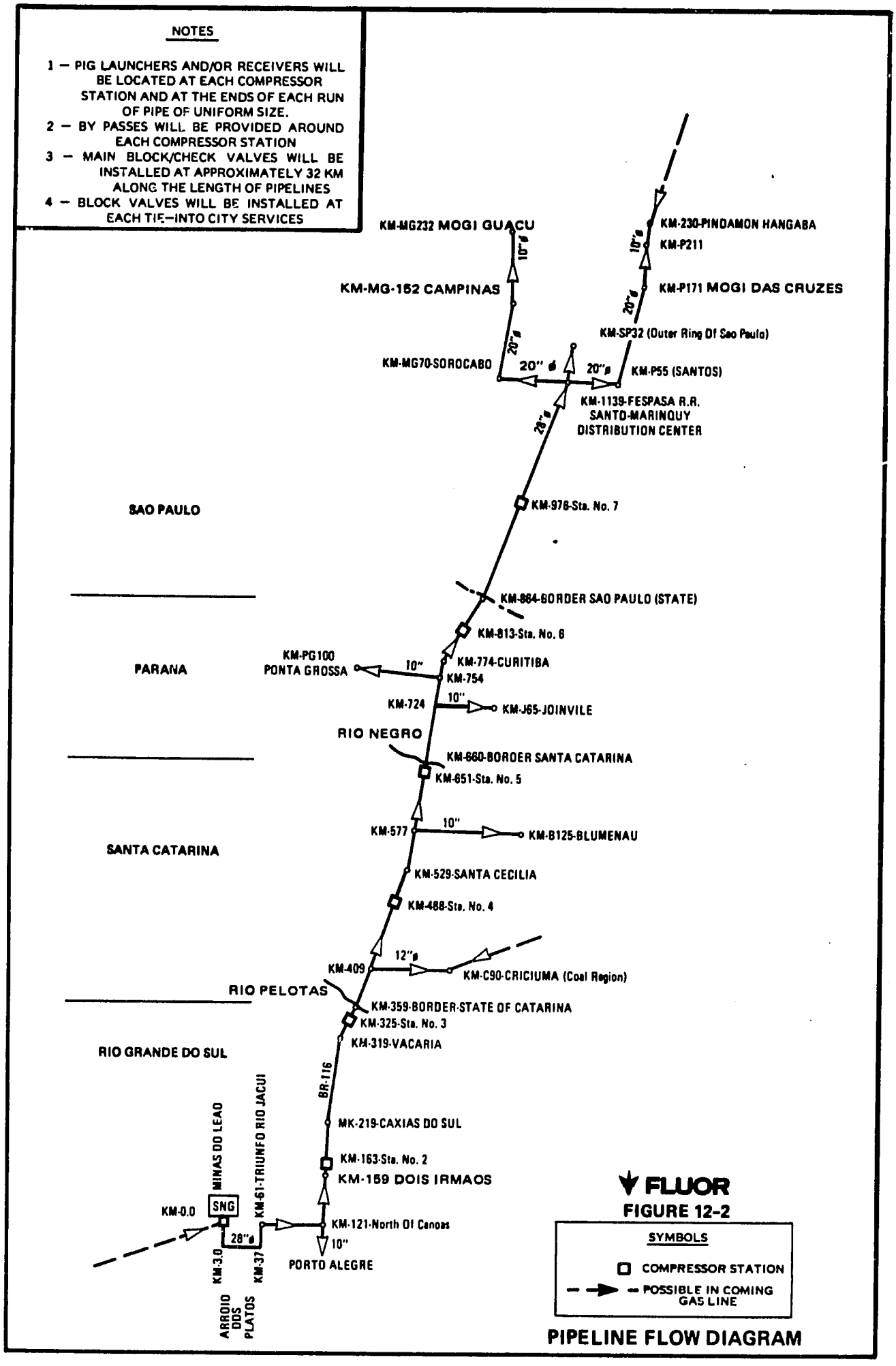
The initial pipeline system thruput design capacity is 13.61 x $10^6 Nm^3/D$ (508 x 10^6 SCFD). The plant will produce 3.61 x 10^6 Nm^3 (135 x 10^6 SCFD) and the balance of 10 x $10^6 Nm^3/D$ (373 x 10^6 SCFD) will be supplied from other sources. A conservative design has been achieved by assuming that the gas from other sources will be injected into the end of the pipeline at the SNG Plant and that all of the gas will be delivered through the main transmission pipeline.

Projected Priority Demand

The total present and projected needs for gas for priority industries (i.e., industrial users that are favored over residential consumers) exceed the presently contemplated SNG Plant output. Hence, additional sources of gas are required to supply these needs.



MAP OF DISTRIBUTION AREAS


NOTES
1 – PIG LAUNCHERS AND/OR RECEIVERS WILL BE LOCATED AT EACH COMPRESSOR STATION AND AT THE ENDS OF EACH RUN OF PIPE OF UNIFORM SIZE.
2 – BY PASSES WILL BE PROVIDED AROUND EACH COMPRESSOR STATION
3 – MAIN BLOCK/CHECK VALVES WILL BE INSTALLED AT APPROXIMATELY 32 KM ALONG THE LENGTH OF PIPELINES
4 – BLOCK VALVES WILL BE INSTALLED AT EACH TIE–INTO CITY SERVICES
KM-MG232 MOGI GUACU
KM-230-PINDAMON HANGABA
KM-P211
KM-MG-152 CAMPINAS
KM-P171 MOGI DAS CRUZES
KM-SP32 (Outer Ring Of Sao Paulo)
KM-MG70-SOROCABO
20" ø
20"ø
KM-P55 (SANTOS)
KM-1139-FESPASA R.R. SANTO-MARINQUY DISTRIBUTION CENTER
SAO PAULO
KM-976-Sta. No. 7
KM-864-BORDER SAO PAULO (STATE)
KM-813-Sta. No. 6
PARANA
KM-PG100 PONTA GROSSA
10"
KM-774-CURITIBA
KM-754
KM-724
10"
KM-J65-JOINVILE
RIO NEGRO
KM-660-BORDER SANTA CATARINA
KM-651-Sta. No. 5
KM-577
10"
KM-B125-BLUMENAU
SANTA CATARINA
KM-529-SANTA CECILIA
KM-488-Sta. No. 4
12"ø
KM-409
KM-C90-CRICIUMA (Coal Region)
RIO PELOTAS
KM-359-BORDER-STATE OF CATARINA
KM-325-Sta. No. 3
KM-319-VACARIA
RIO GRANDE DO SUL
BR-116
MK-219-CAXIAS DO SUL
KM-163-Sta. No. 2
KM-159 DOIS IRMAOS
MINAS DO LEAO
KM-61-TRIUNFO RIO JACUI
KM-0.0
SNG
28"ø
KM-121-North Of Canoas
10"
PORTO ALEGRE
KM-3.0
KM-37
ARROIO DOS PLATOS
FLUOR
FIGURE 12-2
SYMBOLS
COMPRESSOR STATION
POSSIBLE IN COMING GAS LINE
PIPELINE FLOW DIAGRAM

Most of the gas (86 percent) is needed in the Sao Paulo metropolitan area. Quantified gas needs (based on 330 and 365 days consumption/year) for all Brazil and for Sao Paulo areas serviced for 1985 and 1990, related to equivalent oil, are shown in Table 12-1.

TABLE 12-1

PROJECTED GAS CONSUMPTION BRAZIL AND SAO PAULO

Year	Brazil		Sao Paulo	
1985	330 days/yr	365 days/yr	330 days/yr	365 days/yr
Oil per yr (TOE) (mT/y)x10^6	4.65	4.65	4.0	4.0
Equivalent Gas Nm^3/Dx10^6	15.4	14.0	13.3	12.0
SCFDx10^6	581	525	500	452
1990	330 days/yr	365 days/yr	330 days/yr	365 days/yr
Oil per yr (TOE) (mT/y)x10^6	5.5	5.5	4.7	4.7
Equivalent Gas Nm^3/Dx10^6	18.3	16.5	15.6	14.1
SCFDx10^6	688	621	588	531

Expandability of System

The system is readily expandable to increase the throughput by increments as the supply and demand increase with the development of the country. Furthermore, as gas supplies are made available, they could be injected into suitable gas storage reservoirs along the lines to satisfy seasonal demands of future residential users. The first stage of an expansion plan would be to install additional compressor stations (six or more).

Alternate Transportation Modes

Fluor has evaluated the alternate possibility of transporting the coal energy from the mines of southern Brazil to the industrial area of Sao Paulo. Relative to the pipeline system connected to the coal gasification plant in the south, most of the methods investigated were judged to be inferior on the basis of either cost, social impact, environmental impact, long term effects on the development of Brazil, or a combination of these effects.

Particular attention was given to evaluating the relative merits of locating the SNG Plant in Santos and transporting the coal to the SNG Plant vs. the pipeline systems covered by this report. This evaluation was subdivided into various alternative methods of getting the coal from the mines to barges and is discussed in Section 19 of this report.

Phases of Work

The macroscopic definition of the pipeline distribution provided by this feasibility study is further developed in Section 14 with the outline of a project schedule for the design, procurement, and construction work that are precursors of an operating system. The execution of such a project is discussed under the four phases in which it would probably develop, namely:

Phase 1: Feasibility Study
Phase 2: Project Proposal
Phase 3: Design and Bid Documents
Phase 4: Construction/Project Management

13.0 PIPELINE AND DISTRIBUTION SYSTEM

The pipeline system selected for this feasibility study consists of a completely operational pipeline infrastructure to transport gas from the state of Rio Grande do Sul, in the south of Brazil, to the main industrial areas along its length, and to the north of the city of Sao Paulo.

13.1 GENERAL ARRANGEMENT

The main pipeline will cross mostly open country and will generally bypass any populated area, exceptions being laterals that will be tied into either existing city distribution systems or distribution systems that are planned for the future. The city distribution system considerations would be included in Phase 2 of the future pipeline project.

The route selection is discussed separately in Section 18.

The pipeline system consists of three major pipeline components: transmission, distribution, lateral branching. The approximate size, length, and brief description of each is as follows:

- Transmission. The 28-inch main transmission line is 1135 km (705 miles) long and runs in a north, northeast direction from the State of Rio Grande do Sul to the city limits of Sao Paulo in the state of Sao Paulo. Six intermediate compressor stations will be required.

- Distribution. The variable size distribution lines are 567 km (352 miles) long, and service seven major industrial consumer areas. The cities are within a radius of 135 km from the city of Sao Paulo. The gas will free flow to consumers from the main transmission northern terminus.

- Laterals. Laterals have been sized to provide an adequate flow of gas to the following consumer centers located along the main transmission line:

CITY	STATE	LENGTH
Criciuma	Santa Catarina	90 km
Blumenau	Santa Catarina	125 km
Joinvile	Santa Catarina	65 km
Ponta Grossa	Parana	100 km
	TOTAL	380 km

The laterals in combination with taps (see paragraph 13.2.3) could provide an energy corridor some 200 km wide along the entire main transmission line and a second corridor along the distribution system 325 km wide and 260 km long. These energy corridors are equal to an area of some 225,000 square kilometers.

Should a SNG plant be installed in the region of Criciuma, which has developed coal mines, the flow in the lateral could be reversed. This flow reversal principle is also applicable if gas reserves are found or other SNG plants are installed along the length of the pipelines.

The approximate terminal point locations of each of the component pipelines have been established in this conceptual report. However, added studies and field investigation will be required to determine the actual locations during Phase 2 of the future pipeline project.

The summary in Tables 18-1 and 18-2 provide information about degree of difficulty and lengths of pipelines in each state the pipeline traverses.

13.2 Pipeline System (Hydraulics)

The selection pipe diameter is sensitive to the following major parameters:

1. Quantity of gas throughput
2. Inlet pressure
3. Delivery pressure
4. Diameter of pipeline
5. Length of line
6. Compressibility
7. Temperature
8. Specific gravity
9. Internal roughness of the pipe
10. Topography

The throughput and gas properties are essentially established; the topographical effects, as assumed, are within the accuracy of the study, hence ignored; the pipe properties have been assumed but may be subject to change in the final optimization; the length of the pipeline is subject to change when a physical land survey is performed, but will probably not significantly affect the final sizing of the pipeline compressor stations system. The remaining pressure parameters materially effect capital costs.

13.2.1 Pipe Sizes

The differences in pipeline costs for operating pressures of approximately 101 kg/cm^2-g (1440 psig; ANSI Class 900 flange rating) or 68 kg/cm^2-g (960 psig; Class 400 flange rating) is well within the accuracy of the estimate. Hence, judgement prevailing, the Class 400 system has been selected for this study. However, it should be recognized that the Class 900 system may be selected after further optimization studies have been performed in Phase 2 of the future pipeline project.

13.2.1.1 Main Transmission. The entire length of the pipeline will be 28-inch diameter by 0.312 inch wall-grade 5LX-60.

13.2.1.2 Distribution to Sao Paulo. The pipeline will be 20-inches diameter by 0.312 inch wall-grade 5LX-52.

13.2.1.3 Distribution to Mogi Guacu. The pipeline will consist of 20-inch diameter by 0.312 inch wall and 10-inch diameter by 0.165 inch wall, north of Campinas.

13.2.1.4 Distribution to Pindamonhangaba. The pipeline will consist of 20-inch diameter by 0.312 inch wall and 10-inch diameter by 0.165 inch wall, north of Sao Jose.

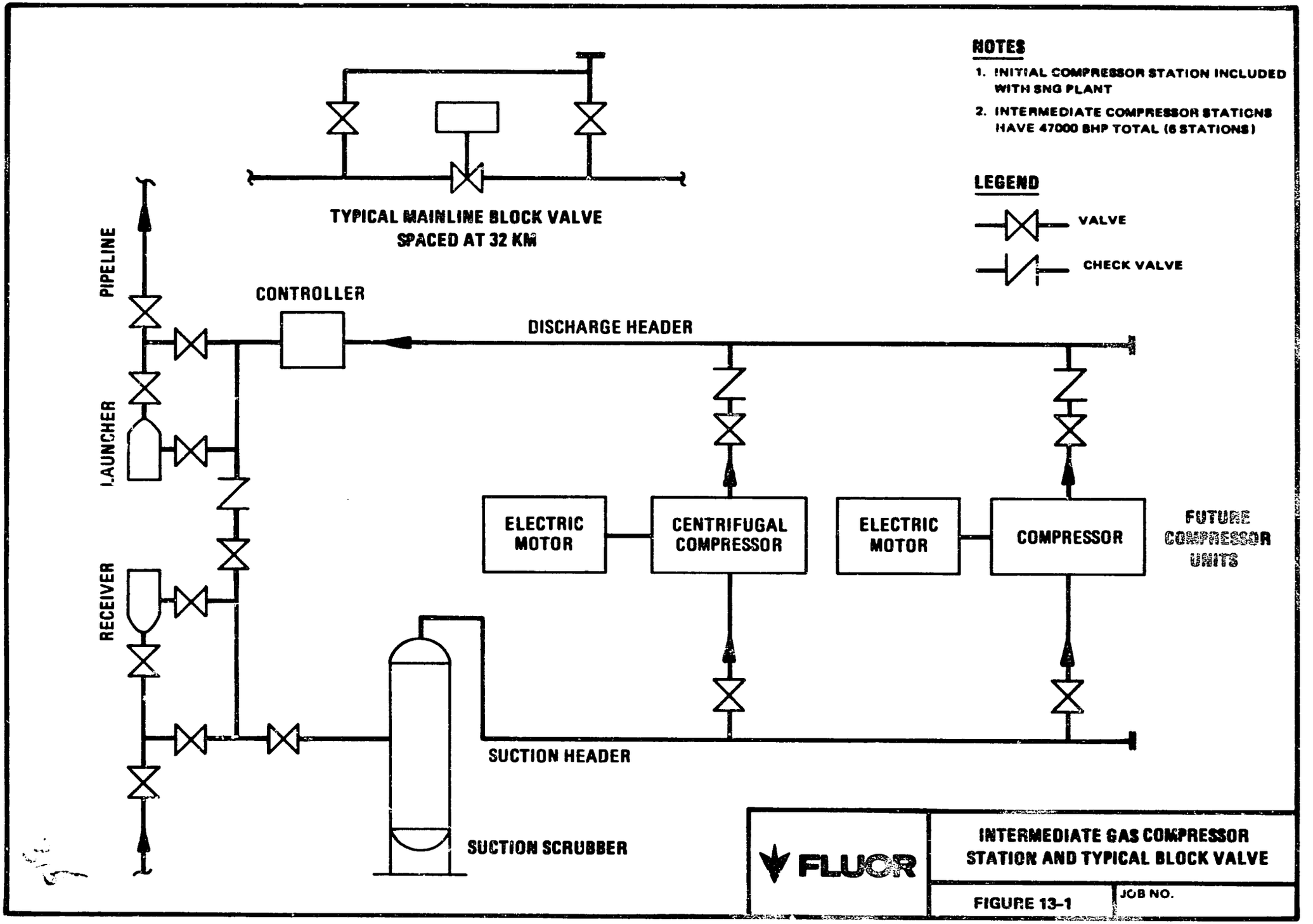
13.2.1.5 Laterals. Laterals will be 10-inch diameter by 0.165 inch wall.

13.2.2 Compressor Stations

The six intermediate compressors will be equally spaced along the pipeline and will require a total of approximately 47,000 BHP. No compressors are required in the distribution systems. However, if in the future the flow is reversed due to additional gas coming in, additional compressors may be required. A typical compressor station concept is shown on Figure 13-1.

13.2.2.1 Intermediate. Each compressor station will operate between pressure limits of 50.6 kg/cm^2 abs (720 psia) inlet and 67.5 kg/cm^2 abs (960 psia) outlet.

13.2.2.2 SNG Plant. The initial pipeline compression to pipeline operating pressure will be accomplished by a compressor within the plant battery limits and has been considered to be part of the SNG Plant rather than the pipeline system.


NOTES
1. INITIAL COMPRESSOR STATION INCLUDED WITH SNG PLANT
2. INTERMEDIATE COMPRESSOR STATIONS HAVE 47000 BHP TOTAL (6 STATIONS)
LEGEND
VALVE
CHECK VALVE
TYPICAL MAINLINE BLOCK VALVE SPACED AT 32 KM
PIPELINE
LAUNCHER
RECEIVER
CONTROLLER
DISCHARGE HEADER
ELECTRIC MOTOR
CENTRIFUGAL COMPRESSOR
ELECTRIC MOTOR
COMPRESSOR
FUTURE COMPRESSOR UNITS
SUCTION HEADER
SUCTION SCRUBBER
FLUOR
INTERMEDIATE GAS COMPRESSOR STATION AND TYPICAL BLOCK VALVE
FIGURE 13-1
JOB NO.

13.2.2.3 Drivers. The compressor drivers can be either gas turbine or electric. The availability of cheap hydroelectric power along the length of the pipeline and the shortage of gas in Brazil suggests that electric drivers be selected for this study. Phase 2 studies (future pipeline project) will evaluate the relative economic and functional merits in greater detail.

13.2.2.4 Instrumentation. The intermediate compressor stations will be fully instrumented to send pertinent operating data via microwave to the central supervisor control system.

13.2.3 Mainline Taps

As consumer centers develop and additional laterals are required, taps can be made into either the main transmission pipeline or distribution system without interrupting the flow of gas in the systems.

13.2.3.1 Incoming. The exploration programs in Brazil are still to be developed. Hence, the system will be flexible enough to receive gas from any gas finds or gas removed from oil/gas production (associated gas).

13.2.3.2 Distribution. There is presently some offshore oil production north of Rio de Janeiro. Possibly the associated gas from this production will be processed and injected into the northeast leg of the distribution system.

13.2.4 Incremental Throughputs

The system lends itself to increases of throughput from a free flow state in excess of 3.61 x $10^6 Nm^3/D$ (135 x 10^6SCFD Initial Gas Plant throughput) to 13.61 x $10^6 Nm^3/D$ (508 x 10^6 SCFD design throughput) with the intermediate compressor stations incorporated into the system.

This system is readily expandable to deliver, in stages, much greater gas throughput than the initial design capacity, should available gas supplies increase dramatically.

13.3 GAS STORAGE FACILITIES

Gas Storage to handle peak demands can be handled by one or more methods depending upon the swings of demand in relatively short periods of time.

The major methods that could be employed are as follows:

1. Packing the pipeline

2. Gas liquification

3. Using abandoned wells

4. Using sealed caverns

The assumption for this study, Phase 1 of the project, is that the demand will be relatively stable, because demand is not sensitive to ambient temperature variations. The industrial useage is assumed to be steady on a 24-hours-a-day, 365-days-a-year basis. Hence, packing the line is the first step in achieving gas storage.

During Phase 2 of the future pipeline project, the required data on useage with respect to time (daily and seasonal cycles) will be collected for review and used to refine the storage specification.

The available gas storage will become a critical item when residential and commercial users are included into the system which are time and ambient temperature sensitive. However, consideration of the demand from these future consumers is beyond the scope of this report.

13.3.1 Packing the Pipeline

The 28-inch transmission line is a natural storage tank. The line has an actual volume of some 425,000 m^3 (15 x 10^6 cubic feet).

Disregarding the volume of the distribution system under normal operating conditions, the pipeline contains in excess of 23.7 x 10^6 Nm^3 (835 x 10^6 SCF) of gas. During periods of low demand, the line will be packed to the MAOP and will contain in excess of 27.1 x 10^6 Nm^3 (1010 x 10^6 SCF) which in effect is storage of 3.4 x $10^6 Nm^3$ (125 x 10^6 SCF), or about one day's output of the SNG Plant, in addition to the approximately seven days of equivalent storage in a normal flowing pipeline. This is a conservative number and will be fully evaluated in Phase 2 when a transient flow analysis is made to include the distribution system and established demands and pressures at each of the consumer tap-in points.

13.3.2 Liquefying the Gas

For this option the gas would be chilled to about -161°C (-259°F), at which temperature the gas is liquefied and stored at atmospheric pressure.

The principal advantage in liquefying the gas is that the required storage facility is materially reduced in size and pressure rating. The gas-to-liquid volume ratio is about 630 to 1.

The principal disadvantage of this system is that an additional capital investment is required for plant facilities to liquefy and regasify the SNG. There would also be a continuing power requirement to operate the refrigeration plant to compensate for heat gains and keep the gas in a liquid state.

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13.3.3 Using Abandoned Wells

Reinjecting the gas in abandoned wells is an excellent means of achieving gas storage facilities with minimal capital investment. However, the availability of abandoned wells along the length of the pipeline is questionable.

13.3.4 Sealed Caverns

The existence of sealed cavern structures that are suitable to store gas can be investigated in Phase 2 (future pipeline project).

13.4 CORROSION CONTROL

A cathodic protection system will include monitoring test stations at specified intervals and at each crossing with other underground metallic utility lines.

The pipeline will have some thirteen separately isolated sections. Each of these thirteen sections will have its own protection system to suit the existing conditions.

Maintenance personnel will be specially trained to monitor and maintain the cathodic protection system.

13.4.1 Internal

Carbon dioxide is one of the constituents of the synthetic gas produced at the SNG Plant. In the presence of water, carbon dioxide forms carbonic acid, which is corrosive to steel. However, the (water) dewpoint of SNG, as delivered by the SNG Plant (See Section 17), is below the pipeline operating temperature, and so should not create any problems of internal pipe corrosion.

13.4.2 External

13.4.2.1 Transmission Line. The corrosion control program for the transmission line will incorporate the use of external coating, electrical isolation fittings, rectifiers, and monitoring test stations.

Coating - Main line coating will be a fusion bonded epoxy coating applied at a coating plant. Girth welds will be coated in the field with a coating that is compatible with the main line coating and suitable for the service temperature involved.

Insulating Flanges - Electrical isolation fittings will be installed on the outlet piping of the SNG Plant, on the inlet and outlet of the compressor stations, and at the inlet to the main line regulator station.

Impressed Current - Rectifiers and ground beds will be located in the vicinity of each compressor station, near the SNG Plant and the main line regulator station and midpoint from each station. Fifteen (15) rectifiers are planned to supply the complete needs for impressed current. Sacrificial anodes could be installed to bolster the system, should investigation show that complete coverage is lacking.

Test Stations - Monitoring test stations will be installed at approximately 2 kilometer intervals along the pipeline to check the effectiveness of the cathodic protection system.

Foreign Pipeline Crossings - Provisions will be made to install test wires on other major pipelines that are exposed during construction activity. These test points will be used to assure that other pipeline voltages are not unduly altered by the rectifiers on the transmission line. Other pipeline potentials will be restored by resistance bonds at these locations.

13.4.2.2 Distribution System. The corrosion control measures for the distribution system will also feature external coating, electrical isolation fittings, rectifiers, and monitoring test stations.

Anodes - Sacrificial anodes will be used to a greater extent than on the transmission line to reduce voltage gradients in the earth near the vicinity of other utility lines. Cathodic protection interference to other utilities will be mitigated in the same manner as on the transmission line.

Insulating Flanges - Isolation fitting will also be used to a greater extent then on the transmission line. This approach is necessary to reduce maintenance and monitoring.

13.5 SUPERVISORY CONTROL, DATA ACQUISITION, COMMUNICATIONS

Following current thought and recommended industrial practice for long distance gas pipeline transmission, a centralized system of supervisory control, monitoring, and data acquisition has been adopted for this feasibility study. Such a system will significantly contribute to a safe, cost effective pipeline operation that can be kept in balance with the SNG plant.

The recommended C^3 (command, control, communications) system is comprised of three major subsystems, as the name implies--command centers, control facilities, and communication facilities. The major components of the command center(s) are trained personnel, display interfaces which enable the personnel to obtain the information they required to perform their duties and the control interfaces to enable the personnel to have their decisions implemented.

The major component of the control system is usually called a SCADA (Supervisory Control And Data Acquisition) system which provides the interface between the system being controlled (in this case the pipeline and associated mechanical components) and the human operators in the command center(s). A modern SCADA system will include microprocessor-based control, a centralized computer facility with stored program memory and operating memory, and the facilities to operate the displays and control interfaces with the human operators.

The communication system will provide the vehicle to interconnect all elements of the SCADA system (i.e. a data communication system) and the vehicle to interconnect all personnel who are involved with the operation and maintenance of the line (i.e., a voice, teletype and a signalling subsystem).

13.5.1 Command

Command facilities will be provided at the master control center, satellite control centers and local control centers. At each of these locations the operators will be provided with audio and visual alarms to alert them to the need of emergency action, and visual presentation of routine information to verify normal operation of the items being controlled. The master control center and ground based satellite control centers will be provided with printing devices to print logs, custody transfer measurements, report, and trend information. Positive display will be presented at all control centers to indicate which center is actively controlling which elements of the line and associated mechanical items such as compressors, valves, etc.

Trade-offs will be made between the use of (schematic indication) mimic panels vs. use of CRT displays, and between manual vs. automatic control during the design of each type of control center. These trade-offs have to be coordinated with the type of operating personnel, personnel training, and maintenance support that will be available for operation of the line.

13.5.2 Data Transmission

The data and message transmission can be accomplished by telephone lines, VHF and UHF radio and microwave. A microwave system was included in this conceptual design.

13.5.2.1 Telephone. The use of public telephone hard wire or microwave systems is not recommended, since the numerous channels would have to be sent over dedicated lines. In addition the operating cost would be prohibitive and the reliability of the system would also be sacrificed.

13.5.2.2 Radio (VHF) and (UHF). The exclusive use of radio (VHF and UHF) is also not recommended. These systems are suitable for directional short distance, low power output from remote locations using government assigned frequencies.

13.5.2.3 Microwave. The microwave as the primary system is the most adaptable to this type of operation, and in the long run the most economical. It also has the advantage of accommodating the system as added sophistication is required.

A possible advantage is that the cost of the system would be materially reduced if the Brazilian telephone system agreed to share part of the cost in return for reliable long distance telephone channels.

13.5.3 Central Control

The Control, SCADA system, will consist of CPU's (Central Processing Units) to service the Master Control Center and the co-located ground based Satellite Control Center. The CPU's will be interconnected with a high speed data link over the microwave system of approximately 120 K BAUD (thousand bits per second) data rate. Each of the CPU's will be able to automatically take over full control of the pipeline in case there is a failure of one or two CPU's. Control microprocessor-based units at each compressor station will perform all control functions at the compressor station and will interface with the ground Satellite Control Center CPU's. Either ground Satellite Control Center CPU will be able to take over the functions of the compressor control units that fail. The compressor station units and the ground satellite control center CPU's will be interconnected with a data channel of approximately 9600 BAUD data rate over the microwave system. Microprocessor-based units located at all block valve sites along the pipeline will communicate to either Satellite Control Center CPU using approximately 1200 BAUD data rate microwave channels. Block valve sites will be implemented with control elements interfaced with the microprocessor units that will, at minimum, monitor pressures, temperatures, valve positions, and flow sensors, and actuate flow direction controlling elements and alarms in the ground based Satellite Control Centers.

The SCADA system will provide all control centers with information required for optimization of pipeline operation, information about pipeline operation abnormalities, and tabular and graphical summary information. Block valve microprocessor-based units will perform line segment isolation, remote location pipeline monitoring, and direct remote control. (See Section 13.5.3.1)

The CPU's at the ground based Satellite Control centers will perform pipeline operational optimization algorithms and will initiate mechanization commands. The Master Control Center will monitor overall line operation, provide line management, and interface with the SNG Plant, coal mines and prepare reports.

Design criteria will be developed during the engineering of the SCADA system to provide for commonality of the CPU's and microprocessor-based units to minimize the spare parts inventories and to provide for similarity of equipment layout and system operation to minimize personnel training requirements. CPU and microprocessor-base design criteria will include protocol techniques, expandability, versatility, capacity, memory sizes and partitioning of sufficient magnitude and flexibility to accommodate failed CPU's duties, and special software systems to support SCADA's daily operational necessities.

Performance of the system designed must be based upon data accuracy, reaction time for pipeline operations, and failsafe operation. Remote location microprocessor-based systems will continuously gather process data and constantly update all data bases.

13.5.3.1 Remote Control. The fully automated system permits the operator or computer to remotely operate the full pipeline system. Some features of remote control include but are not limited to the following options:

1. Compressors can be brought on line or stopped.
2. All station valves can be opened or closed.
3. Compressor stations can be by passed.
4. Intermediate Block valves can be either opened or closed.
5. Flow can be controlled in the distribution systems.
6. Deluge system can be activated in case of fire.
7. Control access to compressor stations.
8. Completely shut down or start the entire system.

13.5.4 Communications

The Communication system must provide all of the interconnecting data paths required by the SCADA system, the interconnecting voice paths between personnel operating and maintaining the line, and voice interfaces with the "outside world."

The communication system will require a backbone system to link the fixed facilities on the line, radio facilities to interface with nonfixed contact points and may interface with the public switched telephone system.

The type of backbone system most generally used with this type of facility is a microwave system capable of handling voice and data channels -- and this gas line will require such a microwave system operating somewhere in the 1.5 to 6.9 GHz frequency spectrum and providing 24, 48 or 96 channels.

Radio facilities operating in the VHF or UHF region of the spectrum will be provided for communication with maintenance personnel, supervisory personnel transient along the pipeline right-of-way, and for data communication with SCADA system sensors and control not co-located at microwave stations. The VHF, or UHF base stations (or repeaters) will be co-located with and interfaced with microwave drop-and-insert stations and interconnected via the microwave backbone system. The location and design of the VHF, or UHF, stations will be coordinated with the type of mobile and portable radio with which they interface to assure propagation in all locations where necessary.

Paging and alert receivers, and associated base stations interfaced with the backbone microwave system will be provided to alert off-duty supervisory, fire, and emergency repair personnel that have to be summoned in the event of an emergency requiring their assistance.

Interconnecting of the microwave backbone system with the public switched telephone system at several locations will provide ready access into the telephone system where needed; and, in turn, will enable the microwave system to provide emergency voice communication facilities for state officials and other vital personnel in case of a national emergency during partial failure of the public switched telephone system.

Teletype facilities at major locations (such as control centers, maintenance centers and offices of key personnel) will be interconnected on independent channels via the backbone microwave system and local drop circuits to provide hardcopy and reduce live voice traffic.

13.5.5 Leak Detection

Systems to detect large to relatively small holes are available and should be incorporated into the total supervisory control system. However, to date there is no substitute for walking the line with sniffers to detect pin hole to small leaks or flying over the line in slow, small frame aircraft to detect earth displacements or discolorations associated with larger leaks.

Gas pipeline rupture behavior is different than that of a liquid line. The liquid line ruptures generally remain confined to a small length while those of a gas line, propagate for long distances, creating a serious hazard. Hence, immediate notification of a rupture at the central control is of utmost importance so that the damaged area could be isolated immediately.

13.5.6 Electric Power Requirements

The assumption has been made that electric power is available along the length of the pipeline to satisfy requirements of the compressor stations.

The power required to operate even the most complex system is relatively small when compared to the total pipeline system and will essentially be concentrated at the compressor stations and distribution points. Minimal power will also be required at block valves along the pipeline.

Automatic stand-by source of control power and power to operate motorized isolation valves would have to be provided for the event of power interruptions.

13.5.7 Personnel

The jump from no supervisory control to any given degree of control means that higher trained but fewer personnel are required to operate the pipeline system.

The compressor control station personnel could be minimized and a roving team of maintenance personnel and trouble shooters would be used in lieu of six complete compressor station operating teams.

This degree of sophistication is used worldwide on large pipeline systems. However, to use it effectively, pipeline management must be dedicated to maintaining an adequately trained staff of technicians and spare parts. If proper on-going training and maintenance is not implemented into the operating scheme, the supervisory control system will eventually be rendered useless.

13.6 OPERATIONS

Proposed organization for management of the pipeline operations has been considered under the following topics:

- Overall and District Organization
- Operations
- Maintenance
- Training (See Section 13.7)

Particular emphasis in this program must be given to developing a highly trained cadre of managers, supervisors, technicians and maintenance personnel and implementing their training with practical office and field experience during the design, procurement, and construction phases of the project. The importance of training becomes more imperative as the sophistication of the system increases. Maintenance will be under the direct control of operations.

13.6.1 Operational Districts

The gas transmission and distribution systems have tentatively been divided into southern and northern operating and maintenance districts. Employees located at these district offices provide the scheduled maintenance required for each facility within their boundary without assistance from other districts, except in cases of emergency.

The center for operations will be an intergal part of the Southern District. (See Figure 12-1) This concept will be fully studied with the operators and modifications made if deemed necessary in Phase 2 of the future pipeline project.

13.6.1.1 Southern District. The Gas Control department of the overall transmission and distribution systems is located in the Operation Center. The Operation Center is also used as communication center for the pipeline system. Quality control and engineering labs are also situated in this Operation Center.

The Southern District office will be located in the Operation Center near the gasification plant. It will be responsible for the pipeline at the southern terminal to the Northern District boundary approximately at Km 600, and will include river crossings, gathering mains, laterals, compressor stations and launches, receivers and other pipeline facilities including metering.

13.6.1.2 Northern District. The Northern District office will be located at the northern terminal of the main transmission pipeline and the starting point of distribution system at Stapecirica in Serra County. This group will be responsible for maintenance and operation of the northern distribution system to the Southern District operation limit on the main transmission pipeline. Included in the district are river crossings, distribution mains, laterals, regulating, sales metering points, launches and receivers.

13.6.2 Functions - Operations

Operation of the pipeline includes the following sections:

- Measurement
- Communication and gas control
- Operation Engineering
- Field Public Relations

13.6.2.1 Measurement. This section ensures the quality and accuracy of all metering equipment used for purchasing or billing for gas products. This section is divided into two groups. One group handles field calibrations and equipment tests with customer gas analysis and shop repair of equipments. The other group handles the integration of charts, calculations and determines volumes to be billed to various customers. They calculate volumes purchased and determine line losses or gains each month through system gas balance.

13.6.2.2 Gas Control. This section controls the gas movement through the transmission system. Daily they determine the requirements for sales gas through discussions with major consumers and determine volumes to be purchased from each producer.

They forecast daily, weekly, and monthly sales projections, schedule equipment maintenance outages, and maintain 24-hour logs of transmission movements of gas, personnel, aircraft and transportation equipment.

13.6.2.3 Communication. This section maintains the company owned communication equipment. They develop maintenance programs and log the performance and reliability of all communication equipment.

This section also develops maintenance programs for supervisory control equipment, logs its performance, and prepares reports of the retirement and replacement of major parts for operating cost estimates.

13.6.3 Functions - Maintenance

Scheduled maintenance program shall include the following:

13.6.3.1 Pipeline Programs

Line Walking

Leak Detection

Valve Inspection and Maintenance

Pipeline Pigging Operation

Aerial Patrols

Right of Way Maintenance

13.6.3.2 Building Maintenance

Office Building

Compressor Building

Warehouse/Shop Building

Utilities, Roads, and Grounds

13.6.3.3 Equipment Maintenance

Communication Equipment

SCADA Computer and RTU's

Compressor and other Rotating Equipments

Metering and other Instrumentations

13.6.4 Functions Engineering

This group is divided into four sections. They are as follows:

13.6.4.1 Corrosion. This group monitors the facilities through pipe-to-soil electrical potential readings and reports the condition of various facilities. This group also develops capital investment reports and maintenance programs with estimates for improving systems protection against corrosion.

13.6.4.2 Mechanical. This section reports on the performance of rotating and mechanical equipment, assists in the development of maintenance program by logging the performance of each piece of equipment, and develops modification programs for improving performance of equipment or reducing maintenance expense.

13.6.4.3 Pipeline/Process. This section assists in the monitoring of the efficiency and performance of compression and transmission facilities.

13.6.4.4 Civil/Electrical/Instrumentation. This section assists the field managers on civil, electrical, and instrumentation problems. It reports on sinking equipment foundations, supervisory equipment, power failure and develops recommendations for improvement and for correction of various problems.

13.7 TRAINING

The successful operation and maintenance of a natural gas transmission and distribution system is dependent on the development of a highly trained, competent operating and maintenance staff.

Design Phase

In Phase 3 of the future pipeline project, a well planned training program will begin at the inception of the engineering definitive detail design and will continue through construction, start-up, and for a reasonable operation period. During the detailed pipeline engineering and design phase of the project, Brazilian operating engineers will review calculations, specifications, fabrication and construction drawings, fabrication and construction bid documents, and be trained in the general technology applicable to the gas transmission facilities. The operating engineers will also work with the design engineers to design, procure, and construct the pipeline systems and the related infrastructure. The full involvement of the operating staff in the project will assure that they will be able to efficiently and safely operate and maintain the pipeline systems.

Construction Phase

The construction phase offers the best training period for the pipeline operation and maintenance personnel. During this period, the Brazilian operating staff may participate as construction engineers, quality assurance personnel, material men, safety inspectors and construction inspectors. Personnel involved during the construction period will gain valuable experience in thoroughly understanding how the system will operate and be introduced to the preventative maintenance procedures, hence possibly limiting the number of major down times that will otherwise have been experienced during the operation of the system.

13.7.1 Transmission Pipeline Systems

The training program will be divided into the following categories:

1. Management Orientation
2. Supervisors Technical Training
3. Technicians Technical Training
4. Operator Training
5. Gas Transmission Emergency and Safety Procedures
6. Maintenance

   o Management

   An overview of the entire operation and training program will be given to the Brazilian Operations Management personnel, including the Director of the Facilities, Administration, Safety-Security, Service, Transmission, Operation Engineering, Measurement, Communication and Gas Control Manager.

This program will assist the managers to establish a workable organization and review the system design, operating program, emergency procedures, and the training program outlines for supervisors, technicians, and operators.

o Supervisors Technical Training

The Supervisors Technical Training program is for the second level of supervision (district manager, foremen, senior technicians, engineers and supervisors) who are directly responsible for the operating and maintenance programs. This training will be given by the design engineers and equipment service representatives both in class and in field training.

This supervisory group will work jointly with start-up engineers to prepare an initial start-up program. Also develop the operation department organization, including operation philosophy, operating sections, operating section interface, duties and responsibilities.

o Technicians

The training program will be given by design engineers and vendor manufacturer engineers and will cover each technical section of the pipeline (dispatching, measurement, communications, supervisory control, corrosion, electrical, engine maintenance, welding, pigging and purging).

o Operators

A detailed step-by-step operating procedure developed jointly by engineers and Brazilian operation supervisors will be used to train the operators. The procedure will include:

- Start-up sequence
- Equipment analysis
- Instrument analysis
- Initial start up
- Normal start-up
- Normal shutdown
- Emergency shutdown
- Normal operations
- Normal operations and operator responsibilities and duties

Flow sheets and other relevant drawings will be used as training material. A more detailed program will be developed in Phase 3 of the future pipeline project.

After the training period, the operators will join the start-up team and assist with system check out prior to start-up.

13.7.2 Gas Transmission Emergency and Safety Procedures

Design Engineers and Brazilian operating supervisors will develop both emergency and safety procedures for the transmission and distribution systems.

Emergency procedure training will be given by the operation supervisors. Safety procedures will be established and a training program set up for supervisors to inform their staffs of these procedures.

14.0 SCHEDULE AND IMPLEMENTATION PLAN

This feasibility report constitutes the first phase of a gas pipeline project that passes through several phases between the decision to build and the mechanical completion of an installed pipeline system.

The pipeline and distribution systems schedule (Figure 14-1) covers the period from the award of a project proposal contract through start-up of the total pipeline facilities and SNG plant. It also includes a reasonable operating period during which time the operators and maintenance personnel would be trained to run the facilities efficiently.

The schedule start date is unknown; hence, the schedule is set up on the number of months required to complete the project rather than specific assigned dates.

14.1 BASIS

The gas supply is expected to come from two sources - from the SNG plant and from other unspecified sources. The availability of gas from the SNG plant (mechanical completion) is 66 months (5-1/2 years) after award of the Phase 2 contract. It is not known when gas from the unspecified sources will be available, so the attached schedule is based on the SNG being the first gas to be shipped through the pipeline.

For the pipeline system to be mechanically complete at the same time as the SNG plant requires that one large spread be assigned to complete the main transmission pipeline and that a smaller spread be assigned to the distribution system and laterals. The time required to complete this work by experienced pipeline contractors would be about 25 months.

14.2 LONG LEAD TIME ITEMS

There are essentially four categories of long lead time activities that will overlap one or more phases of the project. These items have been shown as independent activities rather than included in the specific phase of work. They are as follows:

1. Route selection/survey
2. Land acquisition
3. Microwave communications
4. Purchasing and receiving materials

The time required to complete the above activities will be well within the schedule to complete the SNG Plant facilities.

14.3 PHASES OF WORK

The four phases of the pipeline project are envisioned as follows:

- Phase 1 - Feasibility Study (This study is now complete) which will provide the basic information, including a conceptual design, to determine the technical and commercial viability aspects of the project in addition to providing an order of magnitude estimate. This study also provides scope definition, in general terms, for the projected work to follow.

- Phase 2 - Project Proposal (12 Months) which will fully scope the design engineering efforts, prepare design criteria and duty specifications, scope the field survey, and produce a budget estimate (±25%).

- Phase 3 - Design and Bid Documents (14 Months) which will include a final design, field survey documents to construct the total pipeline system, evaluation of construction proposals, and purchasing of long lead item.

- Phase 4 - Construction/Project Management (25 Months) which will include the award of subcontracts to build the pipeline under a client/contractor agreement for management of the procurement expediting and construction phase of the project. Some of the major management disciplines will include:

  - Project management
  - Cost/scheduling
  - Quality assurance
  - Field engineering
  - Inspection
  - Materials management
  - Contract administration

14.4 APPROVALS

Approval periods by the client have been built into the schedule at the end of each phase of work.

14.5 BIDDING

The bidding and bid evaluation periods have been grouped together and referred to as bidding period.

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14.6 ACCELERATED SCHEDULE

During Phase 2 of the project, the possible earlier delivery (before mechanical completion of the SNG Plant) of the other unspecified gas supply will be studied. Assuming that the gas is urgently needed, an accelerated schedule could be developed to accomodate an earlier delivery date by taking action to accomplish one or more of the following:

14.6.1 Phases of Work

The phases of work would be accelerated or combined. The Contractor's manpower assigned to engineering design and procurement would be increased to obtain earlier dates of completion.

14.6.2 Revisions and Approvals

The client representatives would be in residence at the Contractor's Engineering office, with authority to give approvals as each element of the project is completed.

14.6.3 Construction

The construction period could be materially reduced by having two spreads, each, on the main transmission pipeline and distribution systems.

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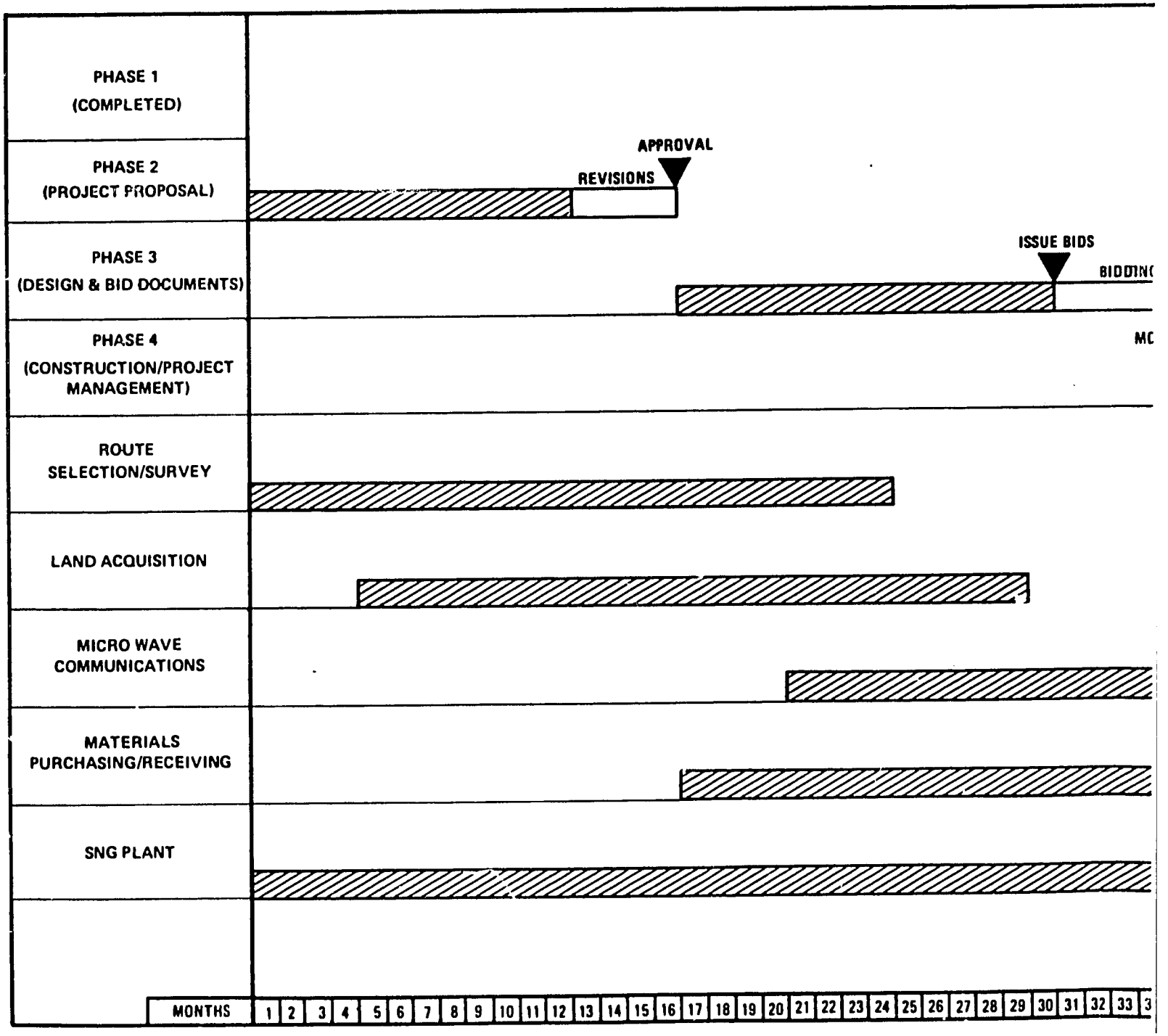
FIGURE

PROJECT PHAS

PIPELINE AND DISTI



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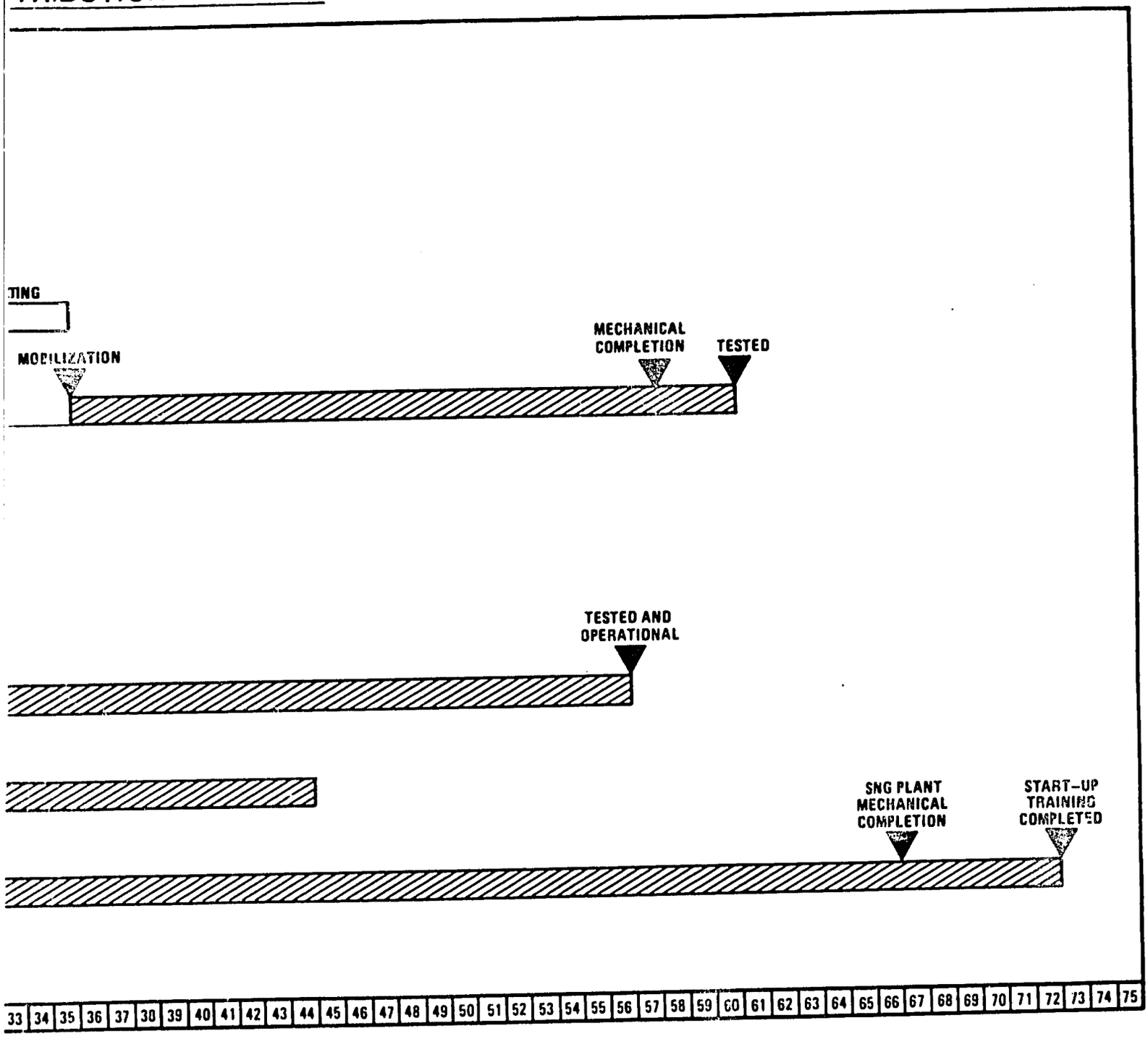
RE 14-1

ASE SCHEDULE

TRIBUTION SYSTEMS

JOB NO. _____



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15.0 COST ESTIMATE

Direct capital cost estimates have been made for the Main Transmission Pipeline and the Distribution Systems. However, differential costs have been made to evaluate alternate modes of transporting energy with smaller capacity pipeline to handle the output of the SNG Plant. (See Section 19 for cost figures.)

Yearly operating costs have been computed as a factor based on previous pipeline cost studies. It is recognized that this cost is subject to many variables which really cannot be definitely established until the project is fully scoped in Phase 2 of the future pipeline project.

15.1 COST ESTIMATE

A summary of costs in thousands of dollars to build the pipeline are as follows:

	PIPELINE COST ($\cdot 10^3$)			
	TRANSMISSION	DISTRIBUTION	LATERALS	TOTAL PIPELINE
Direct field costs	465 900	131 100	53 500	650 500
Indirect field costs	34 900	4 300	6 100	45 300
Total office costs	13 500	3 600	1 600	18 700
Pipeline project cost	514 300	139 000	61 200	714 500
Contingency*	89 700	24 000	10 800	124 500
Total	604 000	163 000	72 000	839 000

* Contingency for transmission, distribution, and lateral systems, as a percentage of total field and office costs, has been set at the same value as applied to the Coal Gasification Plant. For a discussion of cost risk and contingency, see Part 1, Section 4.

15.2 OPERATING COSTS

15.2.1 Pipeline

Based on previous experience, pipeline maintenance costs average approximately $2 175/km/yr ($3 500/mile/yr) for pipelines in the diameter range being considered. This cost includes the following items:

- Personnel wages and benefits
- Overhead
- Operating expense of equipment
- Operating expense of the pipeline systems
- Maintenance depots
- Consumables (tools and hand equipment)
- Travel
- Training

15.2.2 Compressor Stations

The operating and maintenance costs for the compressor stations for the pipeline were estimated at an average of $41 dollars per horsepower over a period of 20 years.

The items included in this cost are as follows:

- Personnel wages and benefits
- Overhead
- Operating expenses of equipment
- Consumables
- Training

15.2.3 Energy

Energy costs are based on electricity being supplied at $0.037 per kilowatt hour. The total horsepower for all intermediate compressor stations is:

Energy cost/day = 47000 HP x 0.7457 KW hr/ HP x $0.037/KW hr x 24 hr/day = $31 122/day.

(The operating cost of the inplant compressor is included in the SNG Plant's operating cost.)

15.2.4 Summary

Pipeline = $2 175/km x 2082 km	=	4 528 000
Compressors = 47 000 HP x $41/HP yr	=	1 927 000
Energy = $31 122/day x 365 days	=	11 360 000
TOTAL OPERATING COST/YR	=	$17 815 000

15.3 ORGANIZATION AND TRAINING

Initial organization and training cost for the pipeline's system = $30 000 000.

15.4 BASIS OF ESTIMATE

This is a conceptual-type estimate, and all costs are presented as first quarter 1982 US dollars.

Construction costs are estimated for U.S. Gulf Coast, adjusted for Brazilian location. Conversion of Brazilian currency to U.S. dollars is at the exchange rate of January 31, 1982.

15.4.1 Objectives

The objectives of the "Basis of Estimate" are:

1. To serve as the information document for preparation of the cost estimate.

2. To identify methods and factors utilized in the development of cost estimates.

15.4.2 Materials

1. Material take-offs for the pipeline were made from preliminary routing maps. The lengths were based on the distances scaled from topographic maps.

2. Pipe unit costs are based on Brazilian manufacturers' costs.

3. Valves and component unit costs are based on preliminary quotes from U.S. suppliers and from in-house pricing sources.

4. Pricing for fittings is based on in-house pricing sources.

5. The cost for the pipeline coating is based on preliminary quotes for thin film epoxy coating factory-applied. The cost for the pipeline joints, based on using shrink sleeves, is estimated from quotes received from local U.S. vendors.

6. For the compressor stations along the pipeline, permanent equipment, compressors, meter runs, etc... were priced on an individual basis, from vendor preliminary quotes. An equipment factor-type method was utilized to estimate the total cost of the compressor stations.

15.4.3 Subcontractor Costs

Subcontractors' costs include all labor, construction equipment, contractor supplied materials, temporary facilities, contractor's overhead, and profit.

15.4.3.1 Subcontracts. This estimate is based on using the following subcontracts:

Direct Subcontracts	Indirect Subcontracts
Pipeline Construction	Camps and Catering
Pipeline Coating	Temporary Construction Facilities
X-ray Inspection	Pipe Transportation
Cathodic Protection	
Communications	
*Compressor Stations	

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Direct Subcontracts

*Block Valve Stations

*Alternately, general subcontracts may be awarded by trade specialty (e.g., civil, mechanical, instrumentation, electrical)

15.4.3.2 Pipeline Installation. The cost estimate of pipeline installation is derived from estimating the size of the spreads and the time required, allowing for one spread on the line and working a 10 hour shift, six days per week, per given section.

The subcontractor cost includes all the work associated with:

a. Survey of right-of-way

b. Clearing and grading the right-of-way

c. Unloading, handling, hauling and stringing of pipe (13 meter nominal lengths)

d. Ditching and trenching

e. Bending operations

f. Aligning and welding

g. Cleaning, priming, and coating pipe construction joints

h. Lowering pipe in trench

i. Backfilling the trench

j. Pipe cleaning and hydrotesting

k. Drying and purging

l. Cleaning the area

m. Installing pipeline markers and miscellaneous supports

15.4.3.3 Valves and Components, Pipeline Tie-ins, and Miscellaneous. Subcontract unit costs are based on the in-house data for the installation of valves, scraper traps, anchors, and supports.

15.4.3.4 Pipeline Crossings. Individual cost estimates plus adjustments have been developed for boring or ditching for highways, roads, streams, river, railroads, or other pipeline.

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15.4.3.5 Pipeline Inspection and Testing. Pricing is based on unit cost estimates from in-house sources for X-raying and tuboscope inspection.

15.4.3.6 Cathodic Protection. The subcontract cost for the installation of cathodic protection is based on in-house data from previous projects.

15.4.3.7 Intermediate Compressor Stations. The subcontract costs for the installation of intermediate (pipeline) compressor stations were developed using a major equipment factoring method and some material take-offs.

15.4.3.8 SCADA and Communications. In-house data were used to make an allowance for the entire SCADA and communications systems.

15.4.4 Other Cost

Other cost includes cost elements associated with the total capital costs. The costs include the following:

1. Office Costs includes all costs associated with the engineering, procurement, business services supporting field construction, training, and expenses performed at permanent home office locations. The costs include: Design Contractor Engineering, Project Management, Central Engineering, Drafting, and Technical Service, Purchasing, Office Expenses, Payroll Burdens, Indirect Office Expenses, Payroll Burdens, Indirect Office Expense, and Engineering Fee.

   Design Contractor Engineering is the cost of engineering and management necessary to manage, control, and perform the detailed engineering required to purchase material, produce drawings, write specifications, and other data required to construct the pipeline facilities.

2. Project Construction Management is the cost of a construction management team and related expenses to monitor construction of the pipeline facilities.

3. Vendor Representatives. This is the cost of manufacturers' installation and/or service representatives sent to the construction site to check out the installed equipment.

4. Start-up Spares. This is the cost of extra parts and miscellaneous items needed to replace or repair defective equipment during start-up.

15.4.5 Excluded Costs

The following items are not included in the estimate:

1. Escalation, duties, taxes or other levies
2. Interest during construction
3. Owner overhead and intangible costs
4. Installation of shoring piles and pipeline bridges
5. Cost associated with underwater diving/inspection
6. Land acquisition or cost associated with right-of-way
7. Construction of any bridge by-passes
8. Temporary construction radio system
9. City distribution system (Sao Paulo)
10. Pipelines from other sources of gas
11. Initial pipeline fill

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16.0 ECONOMIC ANALYSIS - PIPELINE SYSTEM

The following analysis was performed in order to determine the incremental product price required for the Brazil Southern Cone Energy Network pipeline system to achieve a target real return on investment. The analysis incorporates conventional time discounting methods to solve for a January 1982 incremental SNG price. This is the increase in SNG price required to cover the costs of the pipeline distribution system.

The analysis includes pro forma cash flow projections and a sensitivity analysis which establishes the effect of key variables on the required incremental SNG price. A more detailed description of the facilities required by the project, their estimated capital costs, and operating expenses is presented in Section 15.

16.1 METHODOLOGY

The economic analysis was conducted on the basis that the pipeline should generate a real post-tax return on investment (ROI) of 8 percent. The analysis method incorporates capital costs, operating expenses, and SNG volume, and solves for the incremental product price which would provide the predetermined ROI.

An economic computer model was developed to generate the pro forma cash flows associated with the project. Net cash flows were derived using nominal (inflated) dollars in order that the correct relationship between income, depreciation, and taxes would be reflected. These net cash flows were then deflated at the rate of inflation prior to performing the ROI calculation. The resulting ROI is thus expressed in real (as opposed to nominal) terms.

All computations were done on a semiannual basis. All cash flows assumed a project release date of 1 January 1983. For convenience, in referring to the timing of expenses and revenues in the computer-generated pro forma financial reports, the convention of minus years is used prior to the construction completion date (for example, year -1 indicates the 12-month period from 1 July 1987 through 30 June 1988). Positive years indicate operating period (for example, year 1 indicates the 12-month period from 1 July 1988 through 30 June 1989). Investments were assumed to occur at the start of a time period, while all other cash flows were assumed to be end of period.

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16.2 SUMMARY OF BASE CASE RESULTS

The results of the base case analysis are presented in Table 16-1. The base case required a January 1982 incremental SNG price (distribution cost) of U.S. $23.92 per 1000 Nm^3 (U.S. $2.62 per gigacalorie or U.S. $0.66 per million BTU for the output of the associated coal gasification plant) to satisfy the post-tax return on investment (ROI) goal of 8 percent. This incremental price is assumed to escalate at 13.3 percent per year.

Detailed pro forma cash flow projections for the base case are presented in Appendix I. Semiannual disbursements of debt and equity funds during the construction period are presented in Figure 16-1. Figure 16-2 presents the uses of revenues produced during the project's operating life.

Figure 16-1

SEMI-ANNUAL FUNDING REQUIREMENTS
(INCLUDING ESCALATION)

BRAZIL SOUTHERN CONE ENERGY NETWORK
PIPELINE SYSTEM

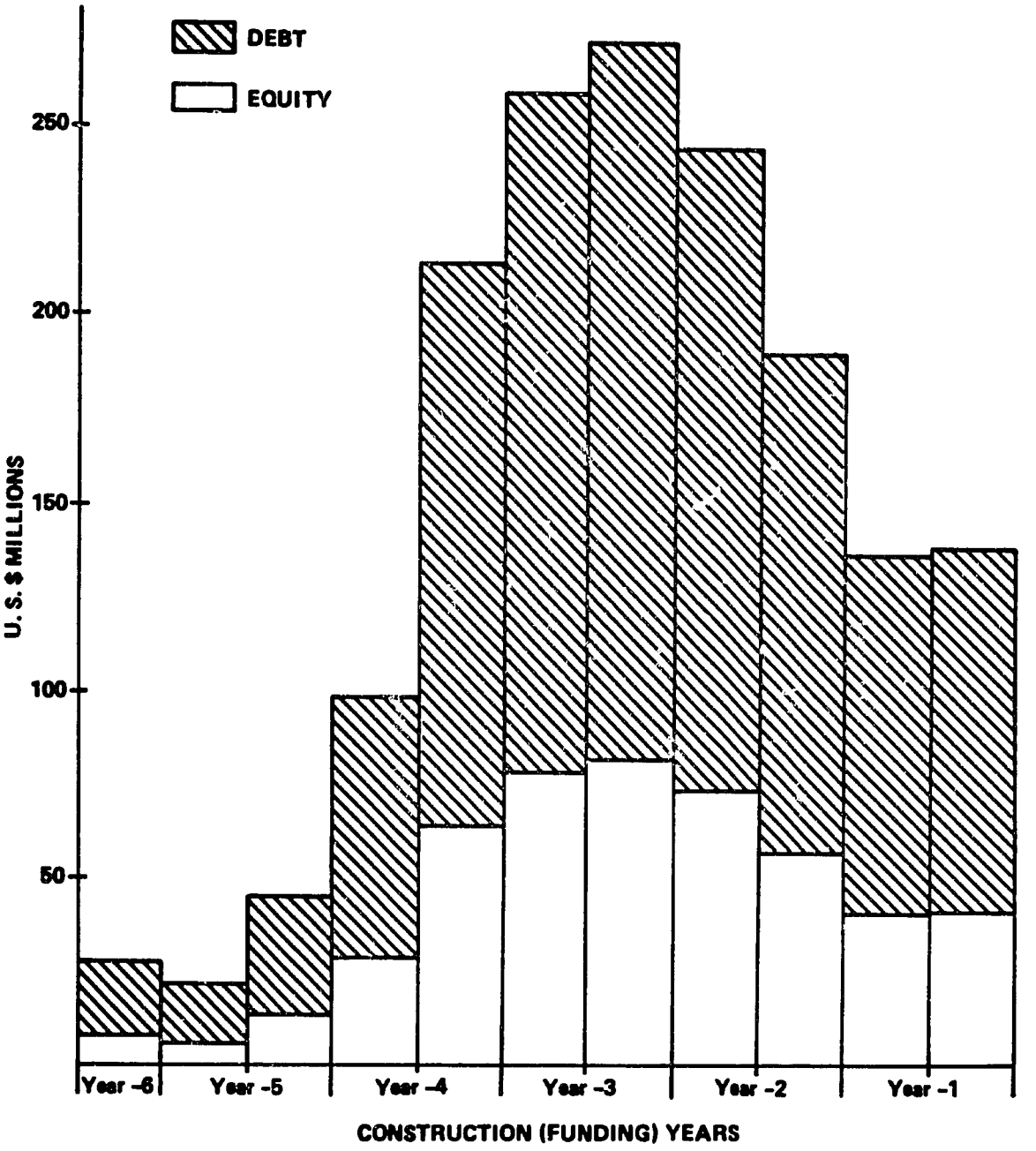

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Figure 16-2

REVENUE UTILIZATION

BRAZIL SOUTHERN CONE ENERGY NETWORK
PIPELINE SYSTEM

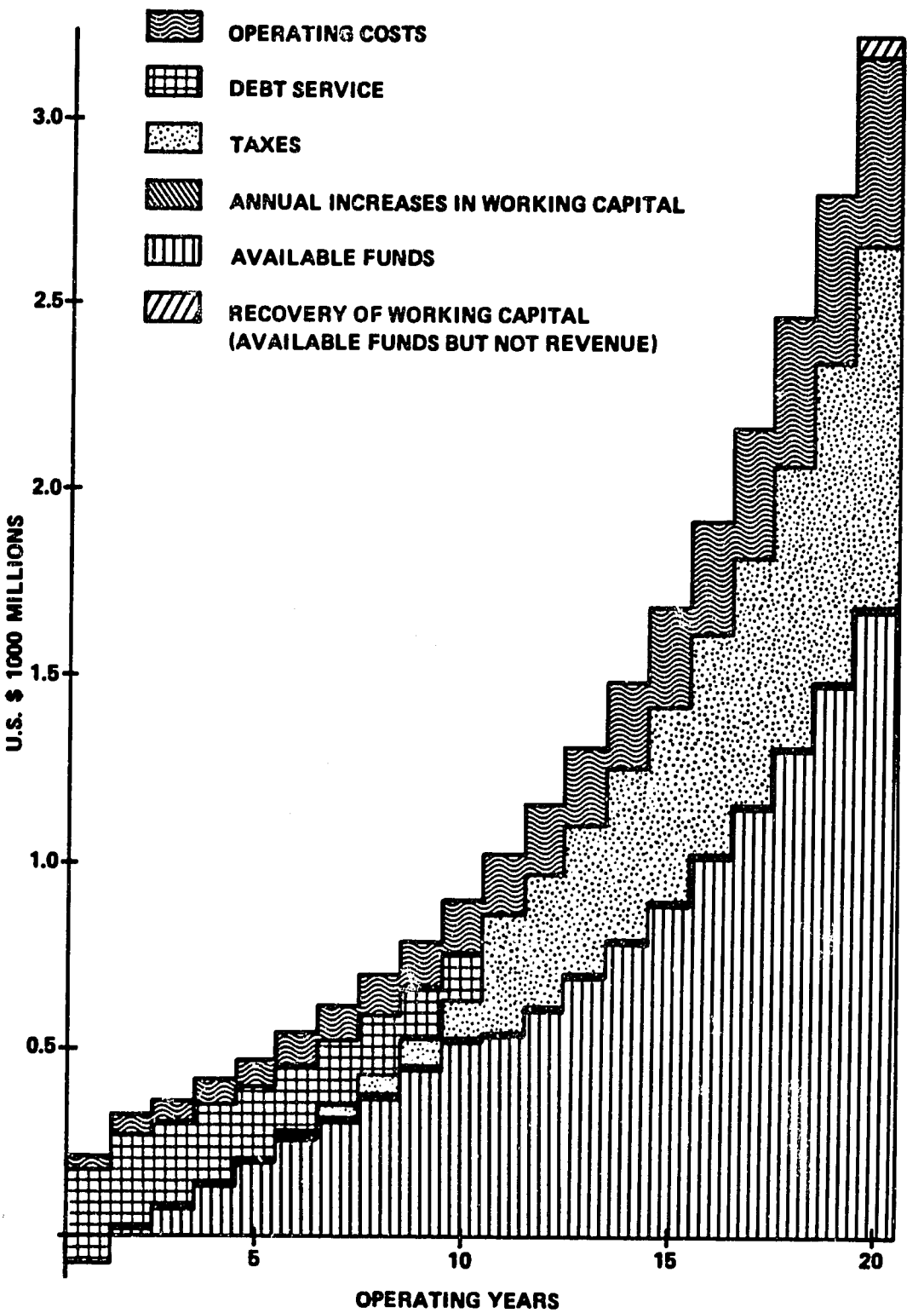

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TABLE 16-1

SUMMARY OF RESULTS

CAPITAL INVESTMENT	U.S. $ (Millions) January 1982 Basis	U.S. $ (Millions) Escalated Basis
Plant and Equipment	$839.0	$1 298.5
Owner's Costs	30.0	46.4
Interest During Construction	--	298.9
Total Depreciable Assets	869.0	1 643.8
Initial Working Capital	1.5	3.8
Total Capital Investment	$870.5	$1 647.6

INCREMENTAL SNG PRICE (Distribution Cost)	U.S. $ (January 1982 Basis)
Per 1000 normal cubic meters (Nm^3)	$23.92
Per 1000 standard cubic feet (SCF)	0.64
Per Gigacalorie (Million kcal)*	2.62
Per Million BTU*	0.66

*For output of associated coal gasification plant.

RATES OF RETURN	Nominal	Real
ROE	24.1%	12.8%
Pretax ROI	21.4	10.4
Post-tax ROI	18.8	8.0

POST-TAX NET PRESENT VALUE	U.S. $ (January 1982 Basis)
at 5% discount rate	$296 million
at 10% discount rate	- 118 million

DEBT SERVICE COVERAGE RATIOS	
Year 1	0.72
Year 2	1.16
Year 3	1.40
Year 4	1.69
Year 5	2.05

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TABLE 16-2

REVENUE & OPERATING COST SUMMARY (1982 $ Millions)

REVENUES	
SNG Distribution (imported gas)	87.325
SNG Distribution (from gasification plant)	28.508
Total	115.833*
OPERATING EXPENSES	
Pipeline	4.528
Compressors	1.927
Electricity**	11.360
Total	17.815
OPERATING INCOME* **	98.018*

* Base case result for 8 percent real post-tax ROI
** Includes compulsory loan component.
*** Exclusive of interest on compulsory loan.

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16.3 BASIS OF ANALYSIS

The following premises were followed in the base case analysis. All figures are expressed in January 1982 terms.

- Currency -- U.S. Dollars

- Exchange Rate -- All Brazilian Cruzeiro estimates were converted to U.S. Dollars at the rate of Cr$134.20 = $1.00.

- Plant and Equipment -- Engineering, procurement, and construction costs, including contingency, of $839 million.

- Owner's Costs -- Owner's supervision, permitting, staffing, and recruiting and training of operating and supervisory personnel. $30 million expended according to the plant and equipment drawdown schedule.

- Drawdown Schedule -- Drawdown of funds (disbursement) for plant and equipment and owner's costs as follows:

Semester Beginning 1 January 1983	Percent Completed Per Semester
1	2.8%
2	2.0
3	3.8
4	8.0
5	16.4
6	18.2
7	17.4
8	13.8
9	8.9
10	4.7
11	4.0
Total	100.0%

- Operating Expenses -- Pipeline, compressor, and electricity costs as detailed in Section 15 and summarized in Table 16-2. Operating expenses for tax purposes do not include the compulsory loan portion of electricity costs.

- Electricity Costs and Compulsory Loan -- Overall electrical power requirements total 34.7 mW. The charge for electrical power usage is $24.41/mW-hr, plus an additional $12.99/mW-hr as a compulsory loan to the government. The total charge of $37.40/mW-hr ($11.360 million per year) is treated as an expense for financial reporting and cash flow purposes, but only the non-loan portion is recognized as an expense for tax purposes.

Interest on the loan is computed at a rate of 6 percent per year on the inflation adjusted loan balance, credited once yearly. Inflation adjusted principal is repaid after 20 years.

- Pipeline Capacity (SNG) -- Imported gas and SNG produced by the coal gasification plant as follows:

Imported Gas (365 D/yr)	SNG From Gasification Plant (330 D/yr)
10×10^6 Nm^3/D	3.61×10^6 Nm^3/D
373×10^6 SCF/D	135×10^6 SCF/D
	(33 000 Gigacalories/D)
	(131×10^3 million BTU/D)

Total capacity 4.84×10^9 Nm^3/yr

- Incremental SNG Price -- Determined by the model such that the target ROI is obtained.

- Land -- No land costs or property taxes are assumed.

- Inflation/Real Price Increases --

Monetary Price Inflation	10% per annum
Real Price Increases on:	
Capital Costs	3% per annum
Non-Labor-Intensive Operating Costs	3% per annum
Labor-Intensive Operating Costs	5% per annum
Feedstock Costs	3% per annum
Product Prices	3% per annum

Labor-intensive operating costs include 35 percent of pipeline and compressor costs. Non-labor intensive costs include electricity and 65 percent of pipeline and compressor costs.

- Working Capital -- 10 percent of total annual operating expenses. Funded in the last semester of construction for the first year of operation by debt and equity. Increases during operations are taken from operating income. Working capital is returned to equity holders at the end of the project.

- Project Release Date -- 1 January 1983 (initiation of engineering, procurement, and construction activity).

- Project Life -- 20 years of operation.

- Operating Year -- Annual operating expenses are based on a 365 day operating year.

- Operating Capacity -- 50 percent of product volume and variable operating expenses during the first semester of operation, 100 percent thereafter.

- Post-tax Return on Investment (ROI) -- Target rate of 8.0 percent (in real terms).

- Debt/Equity -- Project funded 70 percent by debt funds and 30 percent by equity funds.

- Depreciation -- Depreciation for financial reporting and tax purposes is calculated at a rate of 10 percent per year on the inflation adjusted asset base, with no salvage value, beginning in the first year of operations.

- Tax Rate -- 35 percent of operating income less interest and tax depreciation, but recognizing available tax loss carry forward.

- Tax Loss Carry Forward -- When applicable, negative taxable income was carried forward up to three years as a future allowance.

- Debt Financing -- Two sources of debt financing were assumed: A Project Loan and an Interest During Construction (IDC) Loan. The Project Loan is assumed to represent a mix of commercial, development, and export credit loans, with overall terms as follows:

  - Grace Period -- Construction period plus six months.
  - Repayment -- Twenty equal semiannual payments.
  - Interest Rate -- 12 percent per annum.

  The IDC Loan was assumed to be rolled into the Project Loan at the end of construction, and therefore, was repaid according to the same terms as the latter loan. The interest rate on the IDC Loan was also assumed to be 12 percent.

  Interest charges for the Project Loan were funded during construction by the IDC Loan and computed semiannually on 50 percent of current borrowing plus 100 percent of the outstanding principal. The IDC Loan accrued its own interest charges during the construction period. Interest during construction was paid by a combination of debt funds (70%) and equity (30%). During operations, interest was computed semiannually on unpaid loan balances and paid as incurred.

16.4 SENSITIVITY ANALYSIS

Changes in the following key variables were measured in terms of their impact on the required incremental SNG price: (The results of these changes to base case assumptions are presented in tabular form in Table 16-3 and 16-4, and graphically in Figures 16-3 through 16-8.)

o	Plant and Equipment, plus Owner's Costs (Figure 16-3)	± 20%
o	Operating Expenses (Figure 16-3)	± 20%
o	Inflation/Real Price Increases (Figure 16-4 and Table 16-4)	
	Monetary Price Inflation With and Without Various Real Price Increases	8%, 12%
o	Operating Life (Figure 16-5)	15 years, 25 years
o	Target Post-Tax ROI Percentage (Figure 16-6)	4%, 6%, 10%
o	Debt/Equity* (Figure 16-7)	80%/20%, 50%/50%
o	Interest on Debt* (Figure 16-8)	10%, 15%

* These two sensitivities will affect Return on Equity (ROE), but will not affect the ROI or required gas price.

Results of the sensitivity analysis, as presented in the accompanying Tables and Figures, are generally self-explanatory. Table 16-3 summarizes all the sensitivity results, allowing the effects of changes in all variables to be compared. Specific comments follow on the effects of inflation and real price changes.

Inflation

The required 1982 incremental SNG price (distribution cost) is virtually unaffected by changes in inflation rate assumptions. This is due to two considerations. First, the post-tax return on investment goal is a real

rate of return, adjusted for inflation. As the inflation rate changes, the required nominal rate of return changes, but the real rate does not change:

Real ROI	Inflation Rate	Nominal ROI
8%	8%	16.6%
8%	10%	18.8%
8%	12%	20.1%

Second, Brazilian tax depreciation is based on an inflation adjusted depreciation base (as described in Section 16.3), whereas tax depreciation in the U.S. is based on historical costs unadjusted for teh effects of inflation. Different inflation rate assumptions in a U.S. project analysis would affect the required 1982 incremental SNG price because of the impact on taxes. This is not the case in Brazil.

The rate of increase in the required incremental SNG price after 1982 does change, however, as the rate of inflation changes:

Inflation (% per annum)	Real Price Increase (% per annum)	Nominal Price Increase (% per annum)
8%	3%	11.2%
10%	3%	13.3%
12%	3%	15.4%

It should be noted that the inflation rates used here represent U.S. dollar inflation, not cruzeiro inflation, as all cost and price estimates have been made in U.S. dollars. The difference between dollar and cruzeiro inflation has resulted in a steady devaluation of the cruzeiro against the dollar, and it is assumed that the cruzeiro/dollar exchange rate will continue to adjust for the inflation differential.

Inflation rate sensitivities are summarized in the bottom half of Table 16-4.

Real Price Increases

A change in a cost or price after the effects of general inflation have been removed is termed a real increase or decrease. All costs and prices in this analysis have been assumed to increase at a real rate of 3 percent per annum (except labor costs at 5 percent per annum), that is, 3 percent per annum on top of the general inflation rate. Assuming a 3 percent real rate of increase and a 10 percent inflation rate results in a 13.3 percent nominal rate of increase (1.03 x 1.10 = 1.133).

Unlike inflation rate changes, different real price increase assumptions do have a significant impact on the required 1982 incremental SNG price, as shown in the top half of Table 16-4. For example, assuming that all costs and prices would increase at the rate of inflation only, would require a 1982 incremental SNG price 17 percent higher than the base case.

TABLE 16-3

SENSITIVITY ANALYSIS

January 1982 $/1000 Nm^3 incremental SNG price required to maintain 8 percent post-tax ROI (except for target ROI sensitivity) and percent change from Base Case price.

	$/1000 Nm^3	$/1000 SCF	% Change from Base
BASE	23.92	0.64	
PLANT AND EQUIPMENT			
+ 20%	27.89	0.75	+16.6%
- 20%	19.96	0.53	-16.6
OPERATING COSTS			
+ 20%	24.74	0.66	+ 3.4
- 20%	23.11	0.62	- 3.4
OPERATING LIFE			
15 years	26.10	0.75	+17.4
25 years	21.28	0.57	-11.0
INFLATION			
8%	23.87	0.64	- 0.2
12%	23.98	0.64	+ 0.2
REAL PRICE INCREASES			
0%	31.57	0.85	+31.9
TARGET POST-TAX ROI			
4%	15.81	0.42	-33.9
6%	19.28	0.52	-19.4
10%	29.28	0.78	+22.4

The following sensitivities impact the ROE:

	Nominal ROE	Real ROE
BASE	24.1%	12.8%
DEBT/EQUITY		
80%/20%	26.0	14.5
50%/50%	21.8	10.7
INTEREST ON DEBT		
10%	25.2	13.8
15%	22.4	11.3

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TABLE 16-4
INFLATION/ESCALATION SENSITIVITIES

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
CASE: PIPELINE SYSTEM

ESCALATION ASSUMPTIONS	(1)	(2)	(3)	(4)	(5) BASE	(6)	(7)
GENERAL INFLATION RATE	10%	10%	10%	10%	10%	10%	10%
REAL CAPITAL COST ESCALATION	0%	1%	2%	3%	3%	2%	2%
REAL PRODUCT PRICE ESCALATION	0%	1%	2%	3%	3%	3%	3%
REAL COAL COST ESCALATION	0%	1%	2%	3%	3%	3%	3%
REAL LABOR COST ESCALATION	0%	1%	2%	3%	5%	5%	3%
REAL NON-LABOR COST ESCALATION	0%	1%	2%	3%	3%	3%	3%
JANUARY 1982 INCREMENTAL SNG PRICE FOR 8% REAL POST-TAX ROI							
$/GCAL	$3.45	$3.14	$2.86	$2.60	$2.62	$2.54	$2.52
$/MMBTU	$.87	$.79	$.72	$.66	$.66	$.64	$.64
$/1000 Nm^3	$31.57	$28.71	$26.11	$23.76	$23.92	$23.23	$23.06
$/1000 SCF	$.85	$.77	$.70	$.64	$.64	$.62	$.62
CHANGE FROM BASE CASE PRICE	31.9%	20.0%	9.2%	-.7%	.0%	-2.9%	-3.6%

ESCALATION ASSUMPTIONS	(8)	(9)	(10) BASE	(11)	(12)
GENERAL INFLATION RATE	6%	8%	10%	12%	14%
REAL CAPITAL COST ESCALATION	3%	3%	3%	3%	3%
REAL PRODUCT PRICE ESCALATION	3%	3%	3%	3%	3%
REAL COAL COST ESCALATION	3%	3%	3%	3%	3%
REAL LABOR COST ESCALATION	5%	5%	5%	5%	5%
REAL NON-LABOR COST ESCALATION	3%	3%	3%	3%	3%
JANUARY 1982 INCREMENTAL SNG PRICE FOR 8% REAL POST-TAX ROI					
$/GCAL	$2.61	$2.61	$2.62	$2.62	$2.63
$/MMBTU	$.66	$.66	$.66	$.66	$.666
$/1000 Nm^3	$23.81	$23.87	$23.92	$23.98	$24.03
$/1000 SCF	$.64	$.64	$.64	$.64	$.64
CHANGE FROM BASE CASE PRICE	-.5%	-.2%	.0%	.2%	.4%

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16.5 DEFINITIONS

Descriptions, definitions, and information relating to the cash flows presented in this report are as follows:

- Revenues -- Income generated from the piping of SNG and interest earned on the compulsory electric loan.

- Operating Expense -- Insurance, labor, maintenance, and general/administrative expenses.

- Operating Income -- Revenue less operating expenses less annual increases in working capital plus recovered working capital. This item represents the pretax cash flow to be discounted against capital investment when calculating pretax return on investment.

- Depreciation -- Defined above under "Basis of Analysis."

- Income Before Tax -- Operating income less interest expense and depreciation.

- Income Tax -- Taxes are computed as discussed under "Basis of Analysis."

- Income After Taxes -- Net income after taxes, less income tax, after recognition of available tax loss carry forward.

- Cash Flow from Operations -- Net income after taxes, plus depreciation and recovered working capital, less annual increases in working capital.

- Net Cash Flow -- Cash flow from operations less debt principal repayment. This is the cash available to the equity holders. This cash flow is discounted against equity investments to determine the time-value return on equity.

- Available Funds -- Funds in excess of operating costs and debt service (interest and principal repayment) are assumed to be available to equity holders as dividends or for other uses outside the project. Should operating funds be insufficient to meet debt service requirements, it is assumed that additional equity funds will be provided to make up the differential. Working capital is returned to equity holders at the end of the project.

Analytical measurements which help management to evaluate the desirability of this project are:

- Pretax Return on Investment (Pretax ROI) -- Operating income (income before taxes plus depreciation and interest = revenues less operating expenses), less increases in working capital, plus recovered working capital, discounted against capital investment. This technique allows the project to be analyzed, evaluated, and compared with other investment alternatives without regard to the method of financing used for the projects. Interest during construction and interest expenses during operations are excluded from cash flows utilized in this calculation.

- Post-Tax Return on Investment (Post-Tax ROI) -- Operating income, less taxes on operating income less depreciation, less increases in working capital, plus recovered working capital, discounted against capital investment. Interest during construction and interest expenses during operations are excluded from cash flows utilized in this calculation.

- Return on Equity (ROE) -- Net cash flow available to equity holders, discounted against equity investment. The financing plan has a significant effect on this figure since the equity holder receives a return after interest and principal payments are made; synonymous with post-tax ROI for 100 percent equity funded projects.

All cash flows are discounted back to 1 January 1982.

Two ratios of significant importance to financial institutions in examining projects of this type are "Interest Cover" and "Debt Service Cover." They are defined as follows:

- Interest Cover -- Income before interest and taxes, divided by interest.

- Debt Service Cover -- Net cash flow plus principal repayment and interest, divided by principal repayment plus interest.

Figure 16-3

SENSITIVITY ANALYSIS – VARIOUS

INCREMENTAL SNG PRICE REQUIRED
FOR 8% POST-TAX ROI

BRAZIL SOUTHERN CONE ENERGY NETWORK
PIPELINE SYSTEM

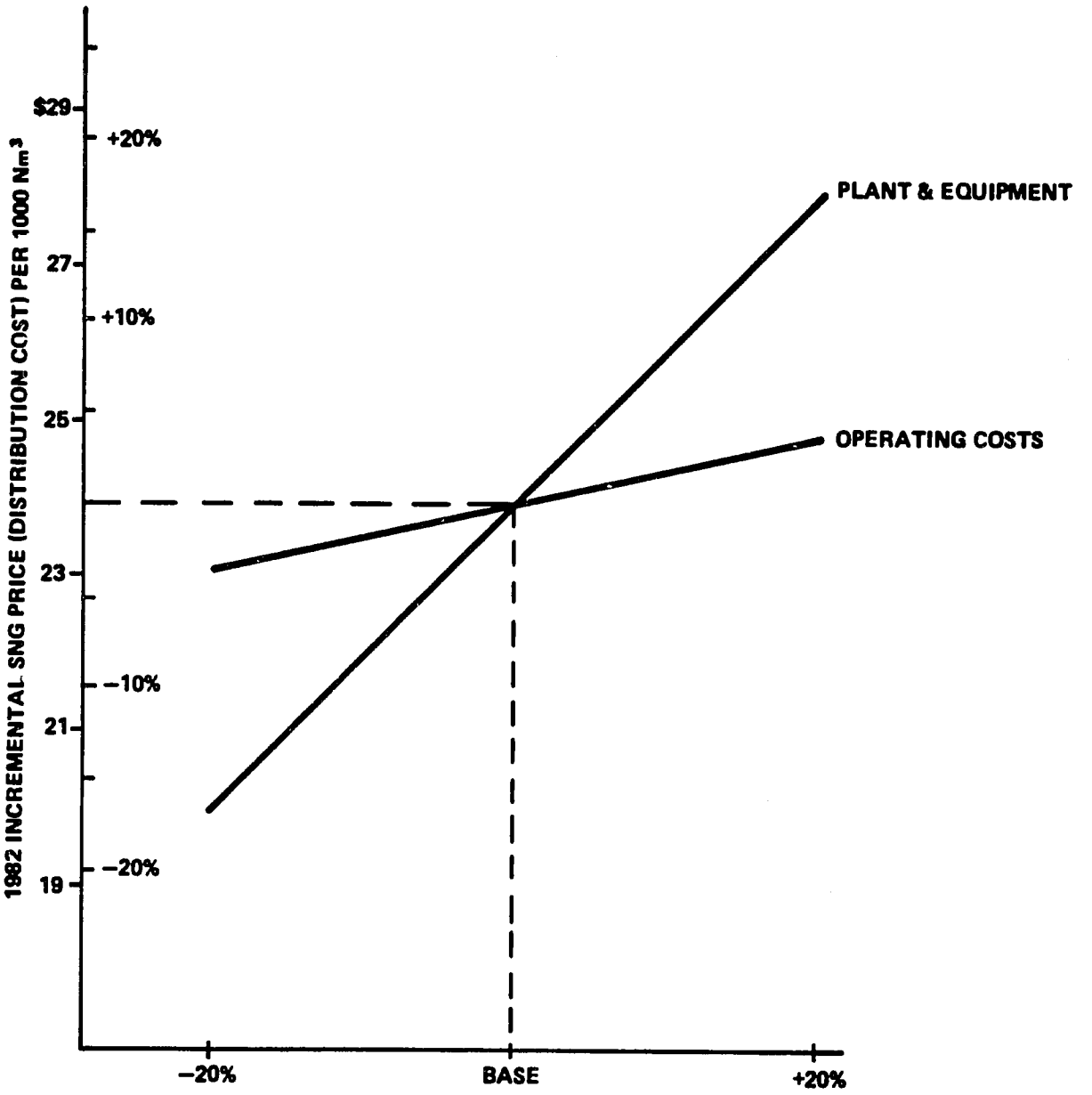

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Figure 16-4

SENSITIVITY ANALYSIS – INFLATION

INCREMENTAL SNG PRICE REQUIRED
FOR 8% POST-TAX ROI

BRAZIL SOUTHERN CONE ENERGY NETWORK
PIPELINE SYSTEM

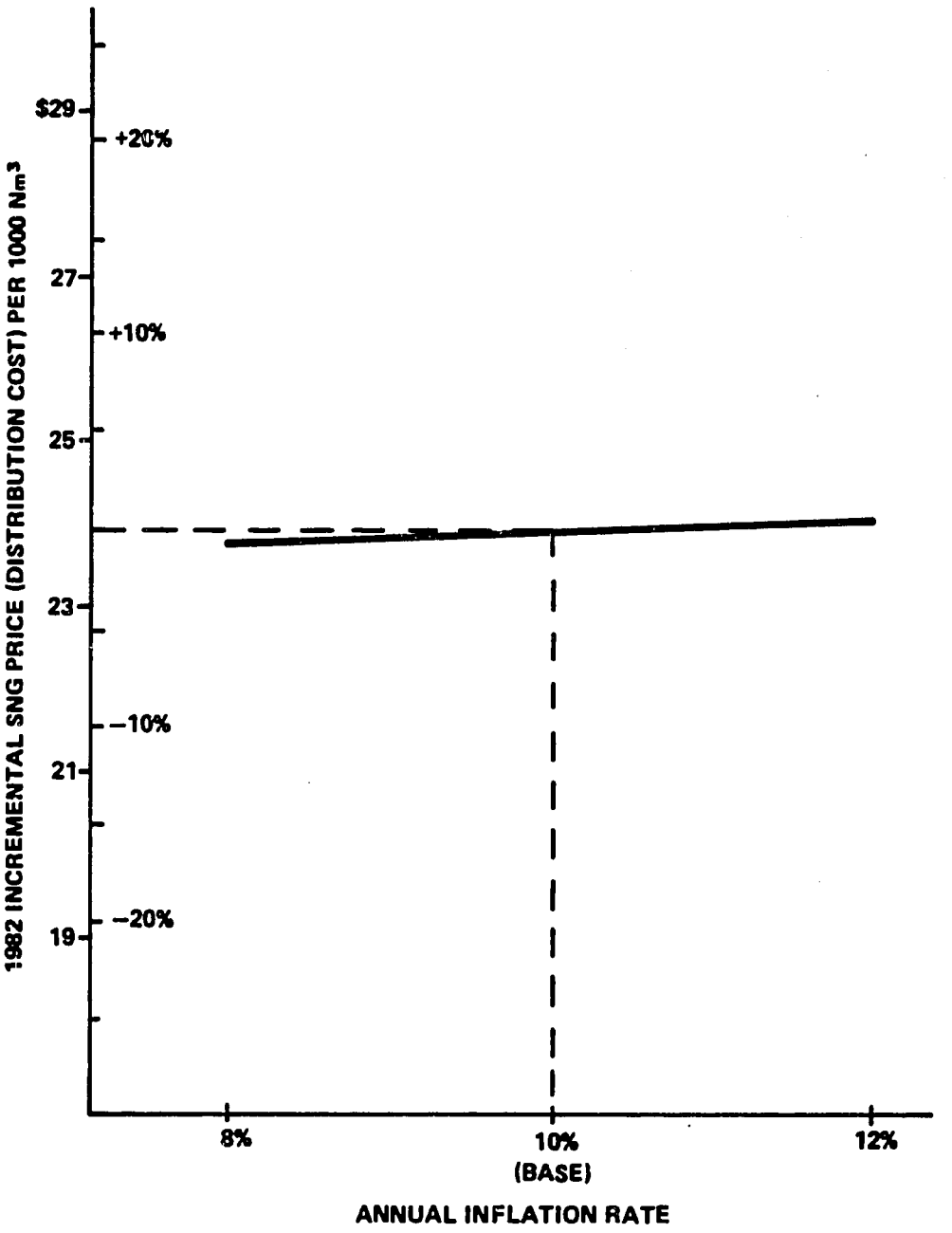

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Figure 16-5

SENSITIVITY ANALYSIS – OPERATING LIFE

INCREMENTAL SNG PRICE REQUIRED
FOR 8% POST-TAX ROI

BRAZIL SOUTHERN CONE ENERGY NETWORK
PIPELINE SYSTEM

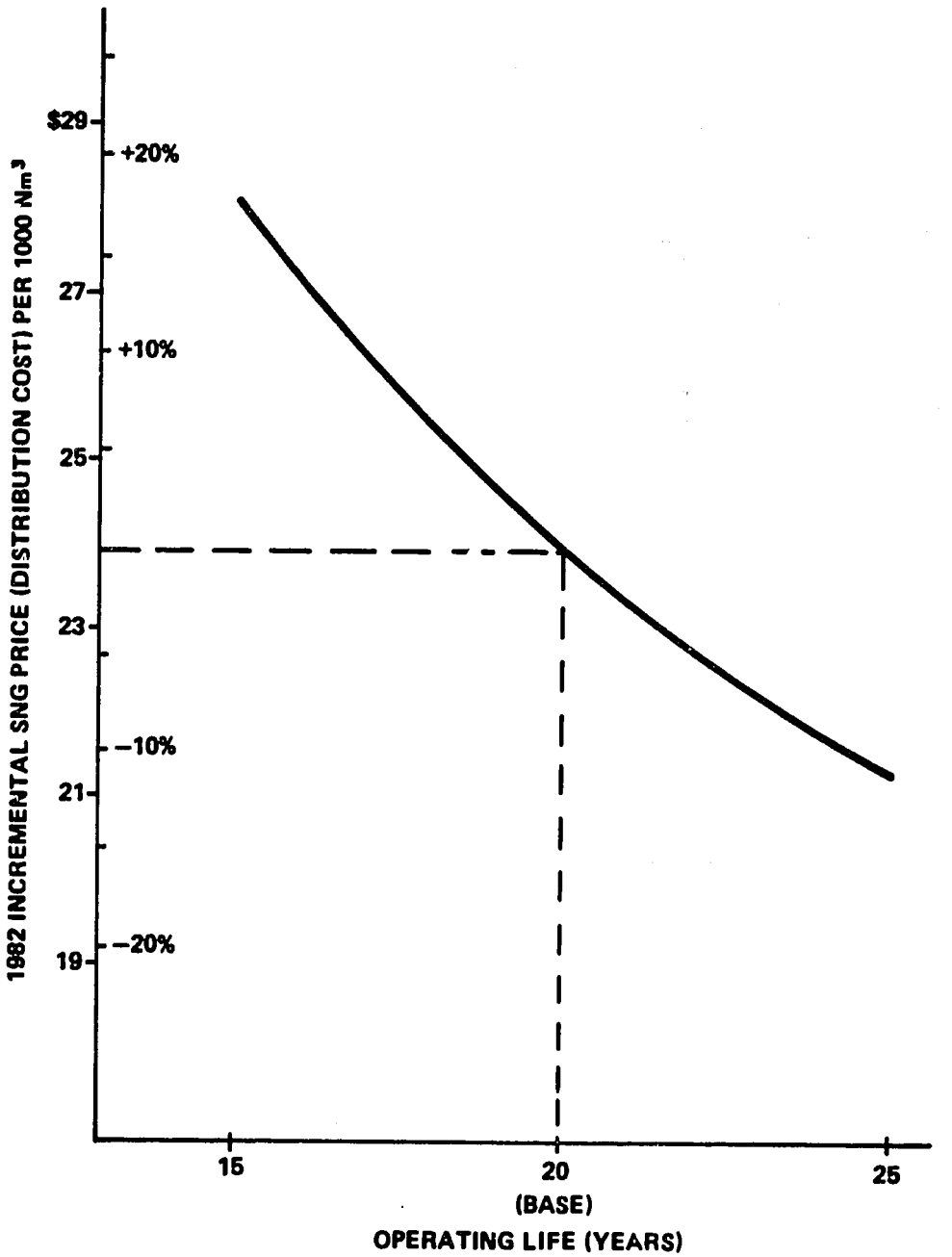

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Figure 16–6

SENSITIVITY ANALYSIS – ROI GOAL

INCREMENTAL SNG PRICE REQUIRED TO SATISFY DIFFERENT POST-TAX ROI GOALS

BRAZIL SOUTHERN CONE ENERGY NETWORK PIPELINE SYSTEM

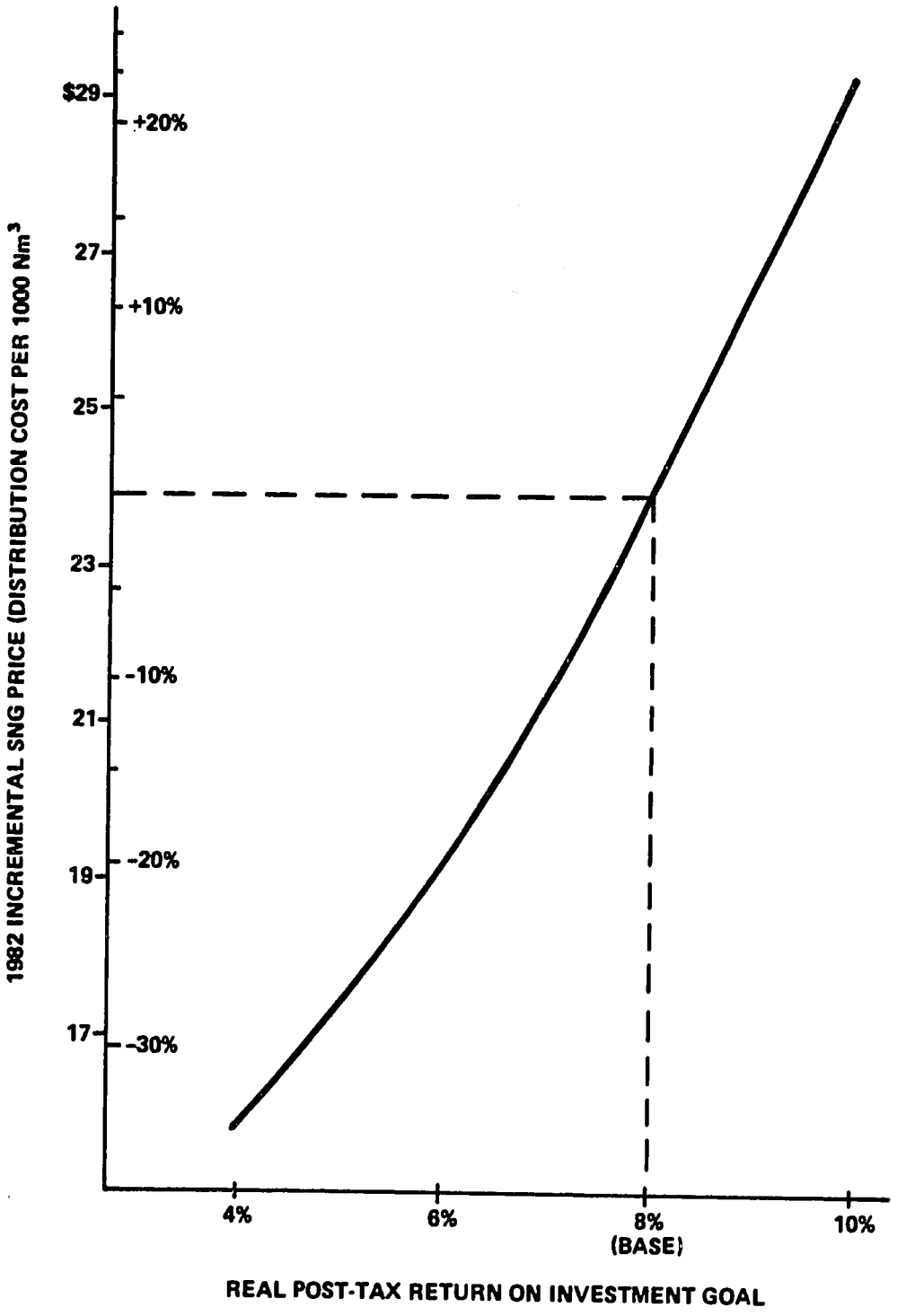

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Figure 16-7

SENSITIVITY ANALYSIS –PERCENT EQUITY

RETURN ON EQUITY AT DIFFERENT DEBT/EQUITY RATIOS

BRAZIL SOUTHERN CONE ENERGY NETWORK PIPELINE SYSTEM

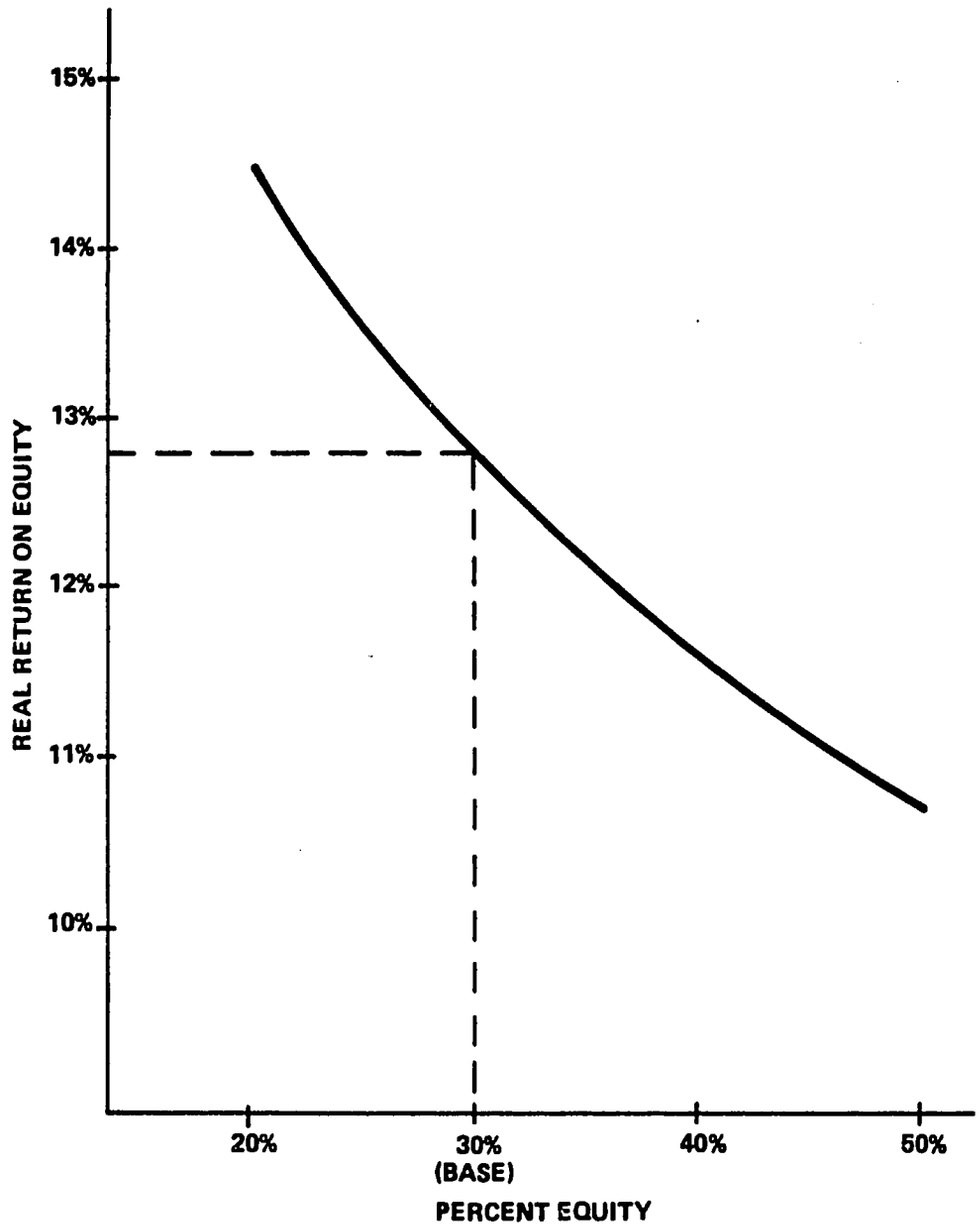

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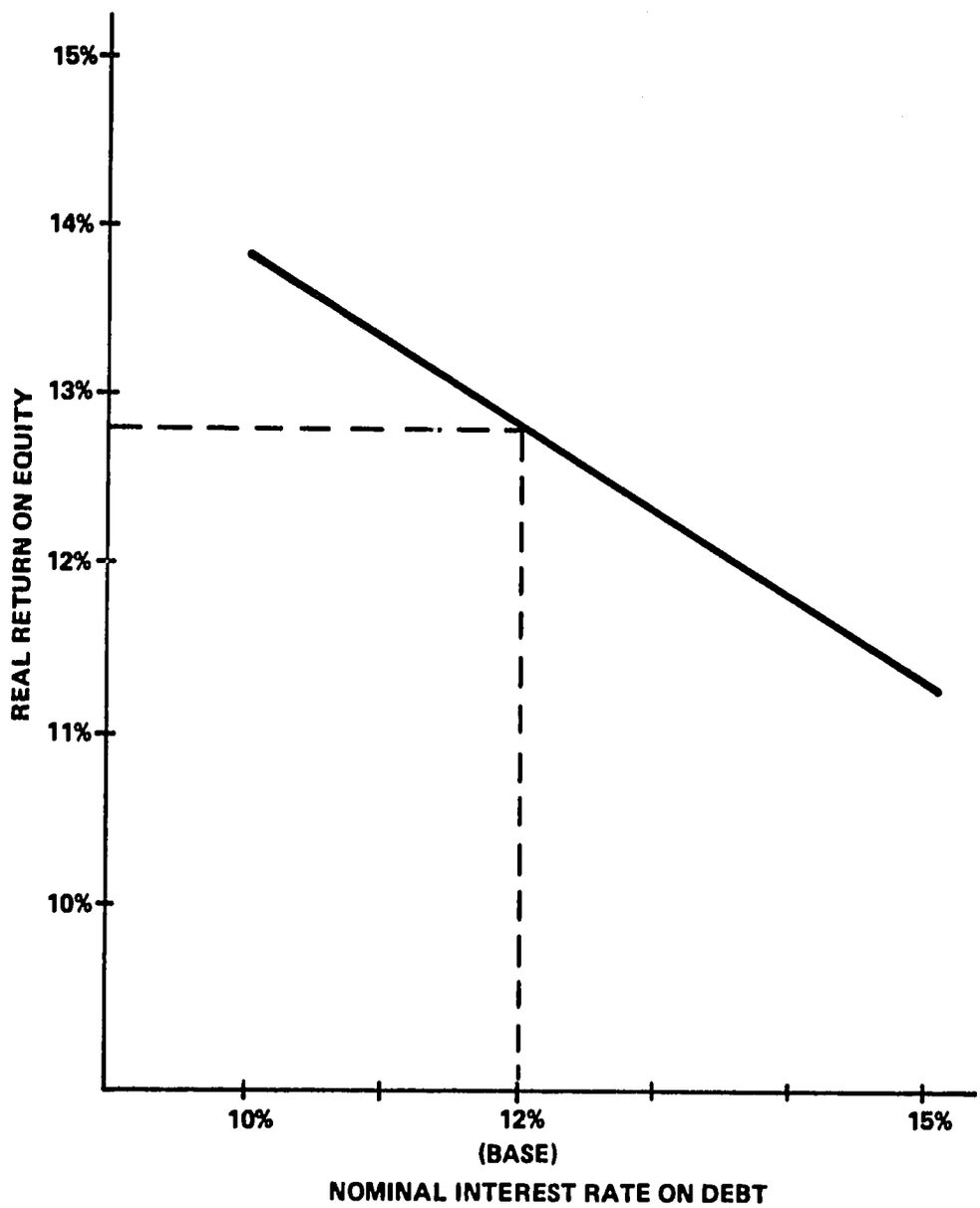
Figure 16–8

SENSITIVITY ANALYSIS – INTEREST ON DEBT

RETURN ON EQUITY AT DIFFERENT DEBT/EQUITY RATIOS

BRAZIL SOUTHERN CONE ENERGY NETWORK PIPELINE SYSTEM



17.0 BASIS OF DESIGN

17.1 GENERAL

This chapter provides the basis for the pipeline studies which were made for Part II of this report. Local Brazilian data and relevant gas data required for this pipeline feasibility report have been obtained from Section 11 of the Gasification report.

Experience and judgement have been used to limit and simplify the basis for this study, with the knowledge that final optimization will be performed during Phase 2 of the future pipeline project.

17.1.1 Energy Consumption Centers

Fuel oil demand in Brazil had grown steadily by nine percent per year* from 1972 to 1979. This trend has gone through a sharp inversion in 1980/1981. Demand figures for 1980 are similar to 1979, but forecasts for 1981 indicate a sharp fall of 15 percent over 1980.

Substitute fuels and conservation measures account for this reduction of fuel requirements. It is assumed that the industrial needs (priority demand) experienced the same reduction. Hence the 1979 energy requirements have been used as a base to determine the gas needs in each of the major consumer areas projected to the year 1990, and to trend these results to the turn of the century.

The 1990 projected fuel consumption for the major industrial cities listed in Table 17-1 are in metric tons of oil (TOE x 10^3/yr) and have been converted to calorific equivalent Nm^3/D and SCFD of gas.

Because Brazil is making a concerted effort to use alternate sources of energy and to conserve energy, the figures provided in this report for the Sao Paulo region will require additional refinement when evaluated with the total Brazilian Energy Plan and projected needs. This should be done in Phase 2 of the future pipeline project. The basic data will have to be improved in the following major areas of concern:

a. The limits to which Brazil is willing to commit its resources to recover energy from their huge subbituminous coal reserves and thereby reduce the need to import energy.

b. The availability of other reliable Brazilian gas, its composition and characteristics.

c. The availability of reliable imported gas from neighboring countries.

*Gasification Report, Section 11

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TABLE 17-1

ENERGY DISTRIBUTION TO STATES AND CITIES

BASE 1979

		Oil (TOE) Consumption ($mT/yr \times 10^3$)	Equivalent ($Nm^3/D \times 10^6$)	Equivalent SCFD ($\times 10^6$)
Sao Paulo (State)				
Greater S.P. Area		2 667	8.07	301.04
Campinas/Aulinia		486	1.47	54.86
Cubatao/Santos		465	1.41	52.49
Sao Jose dos Compos		198	0.60	22.35
Sorocaba		227	0.69	25.62
Mogi Guacu		177	0.54	19.98
Limeria		180	0.54	20.32
Taubate/	227	348	1.05	39.28
Pindamonhangaba	+ 121			
TOTAL, Sao Paulo		4 748	14.37	535.94
Parana (State)				
Ponta Grossa		103	0.31	11.63
Curitiba (greater)		145	0.44	16.37
TOTAL, Parana		248	0.75	28.00
Santa Catarina (State)				
Criciuma		90	0.27	10.16
Blumenau		87	0.26	9.82
Joinvile		37	0.11	4.18
TOTAL, Santa Catarina		214	0.64	24.16
Rio Grande do Sul (State)				
Porto Alegre (greater)		219	0.66	24.72
Triunfo		99	0.30	11.17
TOTAL, Rio Grande do Sul		318	0.96	35.89
Total Projected need in 1990		5 528	16.72	623.99

d. Improved energy consumption figures for present and future needs, including additional consumers along the main transmission pipeline.

e. More accurate cost of producing gas and electric power, including escalation.

f. Availabilities of tie-in points into high tension power lines along the pipeline right of ways as source of power for the pipeline compressors.

17.1.2 Assumptions

17.1.2.1 The Gasification Plant will be located near Minas Do Leao.

17.1.2.2 The definitive locations of the terminal points of each part of the pipeline will be established in Phase 2 of the future pipeline project (Project Proposal). The approximate locations have been provided in this report.

17.1.2.3 The definitive compressor station locations have been tentatively established in this report, but also must be finalized in Phase 2. The pipeline estimate includes for six compressor stations.

17.1.2.4 The compressors at the origin of the pipeline will be located and operated from within the Gas Plant battery limits. The capital cost of these compressors has been included in the SNG Plant cost estimate.

17.1.2.5 The cities initially to be included in the distribution systems are those listed in Table 17-1.

17.1.2.6 There is an available surplus of hydroelectric power in Brazil. As noted in 17.1.1 (Energy Consumption Centers), the pipeline right of way is presumed to follow power lines to which power supply tie-ins can be made for the compressor stations.

17.1.2.7 A future pipeline project is presumed to carry forward from this feasibility study, future phases of development being as outlined in Section 14. Developments from concept to mechanically complete pipeline are broken down into four phases, as follows:

- o Feasibility Report
- o Project Proposal

- Design and Bid Documents

- Construction/Project Management

17.1.2.8 Parameters that affect pressure drop calculations, but have not been considered in this study because variations are well within acceptable design limits, are as follows:

- Pipeline Profile - Because gas has a very low density, changes in elevation throughout the pipeline have not been considered in the initial evaluation of pressure loss along the pipeline. The resulting error in head losses will be well within the limits of the major parameters used in this study. Elevation changes will be considered during Phase 2 of the future pipeline project.

- Heat Loss - Heat transfer calculations from the pipeline to the ground have not been made. The gas mass flow is small; hence, the initial temperature of approximately 80°C (175°F) at the outlet of the compressor stations will rapidly approach ground temperature. Ground temperature is assumed to be 15.5°C (60°F), when covered with 1 meter of fill, throughout the pipeline length except in the immediate areas near compressor stations.

17.1.2.9 The initial plan is to supply gas primarily to an industry which is a 24 hr/day, 7 day/wk consumer. Thus, no variations have been considered for peak demand during this initial study.

17.1.2.10 The gas coming from the gas plant and other sources will be of sufficiently low dew point that no condensation of water or hydrocarbons will occur in the pipeline.

17.1.2.11 Plant upset conditions that could cause two phase flow will be studied in Phase 2 of the future pipeline project.

17.1.2.12 Alternative Transportation Modes. The alternative forms of transport of energy from Minas do Leao to Santos would be:

- Railroad haul of coal to Porto Alegre, followed by barge haul to Santos

- A slurry pipeline to south of Sao Paulo

- Railroad haul of coal direct to Santos

- A gas line to Porto Alegre, liquefaction plant at Porto Alegre, and transport by LNG tanker to Santos

- Trucking coal to the Jacui River load on small barges and subsequent transfer of the coal to sea going barges at Porto Alegre

The existing roads would be overloaded if 15 700 mT per day of coal were transported by truck from Leao to Porto Alegre; hence a railroad is a viable alternative.

17.1.2.13 Rolling stock considered in the Alternate Barge Study (coal transportation) will be comparable to the largest available in the U.S. The characteristics of its components are as follows:

- o Locomotive (6 axle-high traction)

  - Horse Power = 3500 (supercharged)
  - Total Weight = 195 short tons
  - Pull = 2256 short tons or 2051 mt of freight cars (1 percent grade @ 20 mph)
  - Fuel Consumption (max.) = 181 U.S. gal/hr
  - Cost = $1 000 000 each

- o Freight Cars

  - Live load = 90.90 mt (100.0 short tons)
  - Dead load = 33.1 mt (36.4 short tons)
  - Total = 124.00 mt (136.4 short tons)
  - Cost = $ 55 000

- o Dock Facilities capable of supporting locomotive

17.1.2.14 The cost to install the railroad is $650,000/km.

17.1.2.15 Energy Costs

- o Electrical power 3.7¢/kWhr
- o Diesel fuel $2.00/gal (US)

17.1.2.16 Cost of Land (Not used in feasibility study)

o Pipeline right-of-way	Not included
o Railroad right-of-way	Not included
o Pump stations 10 acres @ $3000/acre	Not included

17.1.3 Limitations

This is a feasibility study which has been limited to developing sufficient information to assure that the pipeline is technically viable and to preparing an order of magnitude cost estimate.

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17.1.3.1 This study essentially stands alone as a pipeline report. However, the basic data is derived from the companion Gasification Report Part I, which should be read in conjunction with this report.

17.1.3.2 The documentation for gas composition, quantities, etc., have been reproduced from the above mentioned companion report.

17.1.3.3 Because this is a conceptual design, most of the decisions were based on initial calculations, experience, and judgement.

17.1.3.4 A brief field trip substantiated the validity of topography shown on available maps and produced general information that was used for the conceptual design.

17.1.3.5 An initial selection of the sizes for the pipeline and compressor stations is presented in this report. Final optimization studies will be conducted in the Project Proposal phase of work.

17.1.3.6 The cost comparison between the pipeline and the alternate mode study provides a trend in capital investment, operation costs, maintenance requirements and organizational structures.

17.1.3.7 Values scaled off available maps have been used for the kilometer markers shown on the flow diagram Figure 12-2 for the pipeline.

17.1.3.8 An attempt was made during the field trip to check road kilometer markers with automobile odometer readings. However, some regions over which the pipeline will traverse could not be traversed with the 2 wheel drive car available.

17.1.3.9 The assumption that the cost of electricity is low enough to favor electric motors over gas turbine drivers for the compressor stations must be substantiated early in the engineering phase of the future pipeline project.

17.2 PROCESS DESIGN

The pipeline will be sized to satisfy the specified temperatures, pressures and flow rates at the inlets and outlets of the pipeline. Under normal operating conditions the gas will be single phase flow.

17.2.1 Gas Supply

The gas supply is from two sources which will be mixed together at the origin or along the length of the main transmission pipeline. The system shall also be readily adaptable to receive gas at any point in the distribution systems.

The origin and quantities of each of the gas supplies are as follows:

SNG Plant	= 3.61 $Nm^3/D \times 10^6$ (135×10^6 SCFD)
Other sources	= 10.0 $Nm^3/D \times 10^6$ (373×10^6 SCFD)
TOTAL	= 13.61 $Nm^3/D \times 10^6$ (508×10^6 SCFD)

It should be noted that other sources of gas may become available from additional gas developments in Brazil and/or from gas imported from neighboring countries. The origins of other sources of supply will be resolved in Phase 2 of the future pipeline project.

17.2.2 Lengths of Pipelines

Approximate pipeline lengths are as follows: (See Figure 12-2)

- o Main transmission line:

  - 1135 km (705 miles) of main transmission line

- o Distribution lines:

  32 km (20 miles) of tie in line to Sao Paulo
  254 km (158 miles) of distribution lines to Mogi Guacu
  291 km (180 miles) of distribution lines to Pindamonhangaba
  with intermediate consumers.

- o Laterals:

  - 380 km (236 miles) of laterals along the main transmission line,
    - 90 km (56 miles) to Criciuma (coal region)
    - 125 km (78 miles) to Blumenau
    - 65 km (40 miles) to Joinville
    - 100 km (62 miles) to Ponta Grossa

17.2.3 Consumers/Delivery Pressures

It is obvious from Paragraphs 17.1.1 (Energy Consumption Centers) and 17.2.1 (Gas Supply), that there is an imbalance between "the gas design quantities of flow" and consumer needs both for the state of Sao Paulo and the total system. The imbalance will be reconciled in Phase 2 of the future pipeline project. However, as a conservative design basis for this study, the entire design amount of gas will be delivered through the main transmission pipeline to the distribution system into the state of Sao Paulo.

17.2.4 Composition of Gas

The composition of the gas from the SNG Plant is as follows:

Component		Volume %
CO	=	0.06
CO_2	=	0.51
H_2	=	1.47
CH_4	=	95.67
$N_2 + A_2$	=	2.29
		100.00

The composition of gas from other sources will have to be compatible with that from the SNG Plant.

17.2.5 Properties of Gas

- Molecular Weight = 16.454
- Critical Properties

  Temperature = 343°R
  Pressure = 673 psia

- Compressibility

Pressure psig	1300	1000	250
Temperature °F	120	80	80
Z Compressibility	0.90	0.89	0.975
Density lb/ft^3	3.861	3.237	0.771

- Dew Point

  The dewpoint of SNG, as delivered by the SNG Plant at its battery limit, has been specified as follows:

Pressure psia	Dewpoint °F
14.6	-89.5
975	-33.2
1445	-31.8

17.2.6 Throughput

The Transmission pipeline will be designed for the total capacity of $13.61 \times 10^6 Nm^3/D$ (508×10^6 SCFD).

The Northwest leg of the distribution system will be designed for $2.7 \times 10^6 Nm^3/D$ (101×10^6 SCFD).

The Northwest leg of the distribution system will be designed for $2.38 \times 10^6 Nm^3/D$ (89×10^6 SCFD).

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The Sao Paulo feeder will be designed for 8.52 x $10^6 Nm^3D$ (318 x 10^6 SCFD).

17.2.7 System Design Pressure (See Section 17.3.2)

A design pressure of 67.5 kg/sq.cm.-g (960 psig) has been selected for this study. A maximum allowable operating pressure (MAOP) of 960 psig and ANSI Class 400 fittings have been used for cost estimating purposes.

17.2.8 Delivery Pressures

Sao Paulo Loop	= 17.6 kg/sq.cm.-g (250 psig)
Mogi Guacu	= 3.5 kg/sq.cm.-g (50 psig)
Pindamonhangaba	= 3.5 kg/sq.cm.-g (50 psig)

17.2.9 Terrain

The terrain varies from flat to very hilly country. (See Section 18 for descriptions.)

17.2.10 Head Loss Calculations

The AGA Equation was used to determine the throughput of gas throughout the main transmission and distribution system pipelines.

The variations in elevation along the pipeline were neglected in this study. During Phase 2 of the future pipeline project, major changes in elevation will be considered for the final design.

The fixed parameter values used in all calculations are as follows:

Compressibility factor (Z)	= 0.905
Temperature (T)	= 520°R (Rankine)
Gravity (G)	= 0.5749
Friction Factor (Ke)	= 0.00075

17.3 PIPELINE DESIGN

The entire pipeline system will be designed for the same MAOP throughout its length.

The system will be designed to pack the line which will then serve as a short term storage reservoir to handle variations peaks and valleys of short term demand. This subject is further discussed in Section 13.

17.3.1 Design Criteria

The pipeline will be buried with a minimum of one meter (3.28 feet) cover. Possible exceptions are aerial crossings, bridge supported crossings, and difficult areas of construction. The buried pipeline will be placed a minimum of 15 meters (50 feet) from existing pipelines and other obstructions wherever possible.

The pipeline will tentatively follow the alignment shown on the Figure 12-1. The definitive final alignment will be established in Phase 2 of the future pipeline project.

Spacing and types of block and check valves will be established in Phase 2 of the pipeline project and will reflect considerations of population density. Minimum bend radii for elastic and cold bends will also be established at this time.

The pipeline will be protected against corrosion in accordance with the requirements and procedures prescribed in ANSI B31.4 and NACE-RP-01-69.

Phase 2 will provide the parameters necessary to specify the system based upon field investigations:

- Soil resistivity field tests
- Water table studies for determining deep well ground beds

Above ground sections of pipelines will be analyzed for stress during the design phase of the future pipeline project in accordance with ANSI standards. Soil-pipeline interaction will be considered in determining stresses for buried pipeline.

Phase 2 will also be the appropriate time to establish the properties and locations of pig launchers and receivers necessary to test, commission, operate, and maintain the pipelines.

17.3.2 Design Conditions

The following design parameters used for this study will be evaluated and adjusted in Phase 2 of the future pipeline project:

Ambient design temperatures:

Maximum ambient ground temperature	80°F
Minimum ambient ground temperature	60°F
Tie-in temperature	80°F

The pipeline design criteria for establishing design pressures (MAOP) are as follows:

The shut-in pressure of the compressors is 68.6 kg/sq.cm.-abs (975 psia), at the operating temperature of 33°C (60°F) and design temperature of 44°C (80°F).

17.3.3 Road Crossing

Pipeline crossings will be designed to support the maximum wheel and axle loads of trucks used in Brazil and in accordance with modern pipeline design practice.

17.3.4 River and Stream Crossings

Stream crossings will be designed to account for the hydraulic characteristics of the river or stream and the soils encountered. Weight coating will be required for all flooded areas and crossings.

17.3.5 Stress Analysis

A stress analysis will be performed at critical locations along the lengths of the pipeline in Phase 2 of the pipeline project.

The major areas to be analyzed are as follows:

- Field bends (cold bends during construction)
- Elastic bends (roping pipe into ditch)
- Anchors, pipeline
- Road crossings
- River crossings
- Laterals
- Areas of potential soil instability (including seismic analysis)

17.4 CORROSION CONTROL

Corrosion control measures will be provided to minimize corrosion attack on the pipeline.

Corrosion on a pipeline manifests itself in the form of pitting in both the exterior and interior walls of the pipe. This resulting localized weakness produces stress concentrations in the pipe which in turn lead to holes and the gas migrating through the metal, hence, jeopardizing the safety of the pipeline and local inhabitants.

17.4.1 External Protection

Corrosion abatement will be achieved by a combination of an external pipe coating and cathodic protection.

The coating will be a thin film, fusion bonded epoxy or equivalent.

The cathodic protection system will be either impressed current or a combination of impressed current and sacrificial anodes. The pipelines will be electrically isolated from the plant and station piping by insulating joints or insulating flange sets.

The type of coating will be selected during Phase 2; however, the details of the cathodic protection system will not be developed until Phase 3 of the future pipeline project.

17.4.2 Internal Protection

Internal coating of the pipeline will be considered during Phase 2. On a recent project, the cost of the internal coating was justified by reduced pressure drop in the pipeline. The pipeline of this study handles gas which normally is noncorrosive, so an internal coating is not needed for corrosion control. Provisions will be made to inject a corrosion inhibitor in the event of a plant upset or if the other sources of gas supply prove to be corrosive. The extent of inhibitor injection and special metallurgy will be fully evaluated in Phase 2 of the project.

17.4.3 Right-of-Way Considerations

Precautions must be taken to restrict corrosion effects due to DC and/or AC power lines in the vicinity of the pipeline. If possible, the pipeline right-of-way will be selected to minimize the length of pipe that runs parallel to electric current carrying conductors. A source of AC current is required at each of the rectifier locations to cathodically protect the pipeline and at the compressor stations.

17.4.4 Congested Areas

In Phase 2 the cathodic protection system design will be closely coordinated with utility companies to avoid damaging their distribution systems or this pipeline.

17.4.5 Crossings

A summary of the terrain to be traversed and the types and numbers of crossings are shown in Table 18-1 and 18-2. Each of the crossings will require special attention with respect to cathodic protection devices.

17.5 SUPERVISORY CONTROL SYSTEMS AND DATA ACQUISITION (SCADA) AND COMMUNICATIONS

A remote central command, control, and communication system (C^3) will be provided to perform the following functions:

- Start and stop compressors
- Open and close some block valves
- Collect operating data
- Transmit operating data
- Process operating data
- Operate the system efficiently
- Monitor fire and security control
- Monitor for leak detection
- Pin point trouble areas
- Telephone communications

Automatic control will provide routine operation of the line and reporting of line operation. Manual control will provide for control when unexpected non-routine and catastrophic events occur and when human judgement is necessary to determine and effect the best course of action.

A central or master control center will be located and function in conjunction with that of the SNG Plant. Local control centers will be located at the compressor stations and any major switching stations. The central and local control centers will have an integrated system of automatic control facilities to implement routine control, to present alarms pertaining to unusual and emergency conditions, to present trend information, and to print logs and reports. The local control centers will provide local manual control for use in case of loss of automatic control from the master control center and during start-ups and other unusual conditions.

Standby power will be provided to maintain essential services required for a emergency situatuion.

17.6 TRAINING/OPERATION

The successful operation and maintenance of a natural gas transmission and distribution system is dependent on the development of a highly trained, competent operating and maintenance staff.

In Phase 3 of the future pipeline project a well planned training program would begin with the engineering definitive detail design and continue through construction, start-up and a reasonable operating period thereafter. During the detail pipeline engineering and design phase of the project, operating engineers would review calculations, fabrication and construction drawings, fabrication and construction bid documents, and be exposed to the general technology applicable to the gas transmission facilities. The operating engineers will also observe the contractor's engineers during design, procurement and construction of the pipelines. The full involvement of the operating staff in the project will assure that they will be able to efficiently and safely operate and maintain the pipeline systems.

The construction phase offers the best opportunity for training pipeline operation and maintenance personnel. During this period, Brazilian operating staff may participate as construction engineers, quality assurance personnel, material men, safety inspectors and construction inspectors.

Personnel involved during the construction period will gain valuable experience and knowledge how the system will operate and they will be introduced to the preventive maintenance procedures.

- Supervisors

  A supervisory group will work jointly with start-up engineers to prepare an initial start-up program. This group will also develop an operations department organization, including operating section's duties and responsibilities and operating section interface.

- Technician Technical Training

  Technical training for technicians will be given by design engineers and manufacturers' service representatives. The program will cover each technical section of the pipeline (dispatching, measurement, communications, supervisory control, corrosion, electrical, maintenance, welding, pigging, and purging).

- Operator Training

  A detail step by step operating procedure developed jointly by the engineers and Brazilian operations supervisors will be used to train the operators. The procedure will include start-up sequence, equipment study, instrument study, initial start-up, normal start up, normal shutdown, emergency shutdown, normal operations and operator responsibilities and duties for normal operations. Flow sheets, equipment functions and equipment location drawings will be used as part of training material.

- Gas Transmission Emergency and Safety Procedures

  Design engineers and Brazilian operating supervisors will develop both emergency and safety procedures for the transmission and distribution systems.

  Emergency procedure training will be given by operation supervisors. Safety procedures will be established and a training program set up for supervisors to hold periodic meetings with their staff to discuss these procedures.

17.6.1 Transmission System Training

The training program for the transmission/distribution system operating and maintenance staff will be divided into five parts, following the outline presented in Section 17.6.

- Management Orientation
- Supervisory Technical Training
- Technician Technical Training
- Operator Training
- Gas Transmission Emergency and Safety Procedures

o Management Orientation

An orientation program for Brazilian Operation Management Personnel, will include the Director of Facilities, Administration, Safety-Security, Service, Transmission, Operation Engineering, Measurement, Communication, and Gas Control Manager. This program will review the system design, operation program, organization and the training programs outlined for supervisors technical training, operation, operator training and emergency procedures.

o Supervisor Technical Training

The Supervisor Technical Training program will be for the second level of supervision (district manager, foremen, senior technicians, engineers and supervisors) who are directly responsible for operating and maintenance program. This training will be given by the design engineers and manufacturers' service representatives both in class and in hands-on field training.

17.6.2 Functions-Operations

Operation of the pipeline shall include the following sections:

- Measurement
- Communication and Gas Control
- Operation Engineering
- Field Public Relations
- Gas Sales and Accounting

o Measurement

This section ensures the quality and accuracy of all metering equipment used for purchasing or billing for gas products. This section is divided into two groups. One group handles field calibrations and equipment tests with customer gas analysis and shop repair of equipments. The other group handles the integration of charts, calculations, and determines volumes of gas to be billed to various customers. They calculate volumes purchased and determine line losses or gains each month through system gas balance.

- Gas Control

  This section controls the gas movement through the transmission system. Daily they determine the requirements for sale gas through discussions with major consumers and determine volumes to be purchased form each producer.

  They forecast daily, weekly, and monthly sales projections, schedule equipment maintenance outages, and maintain 24-hour logs of transmission movements of gas, personnel, aircraft and transportation equipment.

- Communication

  This section maintains the company owned communication equipment. They develop maintenance programs and log the performance and reliability of all communication equipment.

  This section also develops maintenance programs for supervisory control equipment, logs its performance, and prepares reports on the retirement and replacement of major parts for operating cost estimates.

18.0 ROUTE SELECTION

18.1 PIPELINE ROUTE SELECTION

The ideal pipeline alignment generally is a straight line between the two terminals of the pipeline in spite of the fact that a given increment in length through a difficult area may prove to be more expensive than the average cost of a circuitous route.

Additional Factors

There are many factors which will materially affect the route to be finally selected, such as acquiring rights-of-way, additional major cities that will request gas deliveries, sophistication of available construction equipment, access to existing highways and railroads, access to electric power, etc. All of these factors will be evaluated in the pipeline project phase.

Compromise Routing

This study presents an alignment that is a compromise between a straight line from Minas do Leao to Sao Paulo and a route that follows existing roads and railroad rights-of-way. The same principle has been proposed for the remaining components of the pipeline system. Tables 18-1 and 18-2 summarize the type of terrain to be traversed and include the anticipated number of river, stream, road, and railroad crossings.

In addition to the topography and route description, Section 18 includes a trip report that relates first hand observations with commentary on the feasibility of implementing this route.

Coastal Routing

The coast road BR-290/101 from Porto Alegre to Curitiba was compared to the inland route BR-116 and was rejected on the basis of:

- The length of pipeline would be longer.
- The pipeline would either have to make a wide detour around Porto Alegre or go through several highly populated areas.
- Greater difficulty would be encountered because of:
  - Larger rivers to cross
  - More river crossings
  - More swamp or where the water table is close to the ground surface
  - More confined areas to install the pipeline, where the beach is narrow and the hills are steep.

TERRAIN AND CROSSING - SUMMARY

TRANSMISSION PIPELINE

	Distance in km	NUMBER OF CROSSINGS						TERRAIN, km.			
		Streams	Rivers	Swamps	Railroads	Paved Roads	Unpaved Roads	Flat	Mild	Hilly	Very Hilly
Rio	34 km	5	-	-	-	-	2	34	-	-	-
Grande	24 km	-	1	-	-	-	3	24	-	-	-
do	60 km	5	-	-	-	3	3	60	-	-	-
Sul	38 km	1	-	-	-	2	3	38	-	-	-
	60 km	6	-	-	-	-	2	-	30	-	30
	100 km	.13	-	-	-	1	3	-	-	-	100
	40 km	-	1	-	1	-	1	-	40	-	-
Total	356 km	30	2	-	1	6	17	156	70	-	130
Santa	170 km	18	-	-	1	5	2	-	51	-	119
Catarina &	245 km	7	-	-	3	3	5	-	244	-	-
Parana	90 km	9	-	-	1	7	10	-	-	90	-
TOTAL	505 km	34	-	-	5	15	17	-	295	90	119
Sao Paulo	275 km	21	-	10	10	23	16	45	69	75	76
GRAND TOTAL	1 136	85	2	10	16	44	50	202	434	165	325

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TABLE 18-2

TERRAIN AND CROSSING - SUMMARY

DISTRIBUTION SYSTEMS

Distribution Line	Distance in km.		NUMBER OF CROSSINGS							Terrain, km.			
	Mainline	Tie	Streams	Rail-Road	Railroad Crossings	River	Paved Road	Swamp	Unpaved Road	Flat	Mild	Hilly	Very
Sao Paulo		32	4	1	1	-	-	-	-	-	4	-	-
Sorocaba	70	10	4	1	1	-	2	-	5	-	80	-	-
Campinas	82	12	11	3	3	-	7	-	6	-	-	92	-
Mogi Guacu	80		7	1	3	-	2	-	3	-	-	80	-
TOTAL	232	22	22	6	7	-	11	-	14	-	80	172	-
Santos	55	22	4	2	2	-	3	-	1	-	-	55	22
Cubatao		15											
Sao Jose dos Campos	40	12	0	-	-	-	3	-	2	-	-	-	52
Pindamon-hangaba	19	-	3	-	-	-	-	-	-	-	19	-	-
TOTAL	230	61	27	3	6	-	13	-	8	-	19	55	202

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- More difficult to circumvent the cities along the route

o The shore route does not offer any advantages when installing laterals to consumer cities of the states of Rio Grande do Sul, Santa Catarina and Parana.

18.2 TOPOGRAPHY AND SOIL CONDITIONS

18.2.1 Topography

o Transmission Pipeline and Laterals

The terrain is relatively flat along the pipeline route in the province of Rio Grande do Sul. The route lays on rolling country with some hilly terrain once into the provinces of Santa Catarina and Parana. The principal geographical features in the province of Sao Paulo are generally rolling and hilly with areas containing high percentage of rock and some swamp area along pipeline right-of-way.

o Distribution System

The terrain is generally hilly along the pipeline route in provinces of Mogi Guacu and Pindamonhangaba.

18.2.2 Soil Conditions

Detailed soil information along the right-of-way must be obtained in Phase 2 of the future pipeline project. It should establish detail soil properties along the pipeline right-of-way and, especially, identify the extent of rocky areas. Soil borings will be made to determine the best method of crossings the rocky areas. For estimating purposes 10 percent rock excavation has been assumed for this report, rock being here defined as material that cannot be removed with conventional pipeline construction equipment and which requires blasting or other equivalent means for excavation.

18.3 MAIN TRANSMISSION PIPELINE

The pipeline will originate at the SNG Plant, which will be located near Minas do Leao on Route BR-290 in the state of Rio Grande do Sul. Minas do Leao is located approximately 100 km west of Porto Alegre.

The main pipeline northern terminal in the state of Sao Paulo will be located in Stapecirica, Serra County, where the Repasa Railroad (Santo-Mairinguy) crosses the Regis Bittencourt Highway. The main Sao Paulo distribution pipeline will tie into the outer ring of the city's existing gas distribution system. The actual tie-in point to the distribution lines will be established in Phase 2 of the pipeline project.

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The pipeline routing master scheme is to have the pipeline bypass populated areas and essentially follow the existing main roads and railroads. Where possible, laterals will be installed to accommodate future consumers. However, deviations from this master plan are anticipated to avoid difficult areas and obstructions.

A preliminary semidetailed route is outlined below for each State that the pipeline will traverse. The final alignment will be defined during Phase 3 of the pipeline project when the field surveys are completed.

18.3.1 State of Rio Grande do Sul

A summary of the route, approximate distances and type of terrain traversed are shown in Tables 18-1 and 18-2. The incremental descriptions are as follows:

(The actual road crossings will be determined during the field survey)

- o East along the highway Route BR-290 for 34 km to Arroio dos Ratos.
  - The terrain is relatively flat.
  - It is anticipated that there will be 5 stream crossings.
  - The pipeline will bypass the city.
- o North along an unpaved road for 24 km, crossing the flat lands to the city of S. Jeronimo, thence north across the Rio Jacui to the city of Triunfo to the VFGS Railroad.
  - One river crossing is anticipated.
  - The pipeline will bypass these cities.
- o East along the VFGS Railroad for 60 km to the city of Canoas to Highway Route BR-116.
  - Five stream crossings are anticipated.
  - The pipeline will bypass all towns and cities.
  - The terrain is essentially flat.
- o North along BR-116 for 38 km to the city of Dois Irmaos.
  - The terrain is essentially flat with some mild hills at the northern end.
  - One stream crossing is anticipated.
  - The pipeline will bypass all towns and cities.

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- North along BR-116 for 60 km to the outskirts of the city of Caxias do Sul.

  - Half of the route has mild hills and the balance of the route has steep hills.

  - Six stream crossings are anticipated.

  - The alignment can be straightened out to bypass all towns and cities.

- North, bypassing the city of Caxias do Sul. (The routing around this major city will be determined during the second phase of the pipeline project.) Thence, north along Route BR-116 for 100 km to the city of Vacaria.

  - The terrain has steep hills.

  - Thirteen stream crossings are anticipated.

  - The alignment can be straightened out to bypass all towns and cities.

- North along Route BR-116 for 40 km crossing the Rio Pelotos and the state of Santa Catarina border.

  - The terrain is mildly hilly.

  - One river and six stream crossings are anticipated.

  - The alignment can be straightened out to bypass all towns and cities.

The first part of the route will deviate, for a short run, from the master routing scheme. This deviation is an attempt to minimize the number of stream and navigable river crossings, thereby reducing the difficulty of laying the line and gaining a corresponding reduction in cost.

18.3.2 State of Santa Catarina

- North 170 km along Route BR-116 to Lajes and Santa Cecilia.

  - The terrain is about 60 percent hilly and the remainder is rolling.

  - Eighteen stream crossings are anticipated.

  - The alignment can be straightened out to bypass all towns and cities.

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- North 245 km along BR-116 to Matra, Rio Negro, Campo do Tenente, Quitandinha, Mandirituba and Curitiba.

  - The pipeline will deviate from the main highway north of Mandirituba and will proceed east of Curitiba.

  - All of the cities and towns will be bypassed.

  - The terrain is mildly hilly.

  - Thirty-seven stream crossings are anticipated.

  - Additional straightening of the route may be considered.

18.3.3 State of Parana

- North 90 km intersecting BR-116 at the border with the State of Sao Paulo.

  - The terrain is hilly.

  - Nine stream crossings are anticipated.

  - All towns and cities will be bypassed.

18.3.4 State of Sao Paulo

The terrain from the Santa Catarina border to the Sao Paulo terminus is an example of extremes from very hilly to swamp lands. In addition it is heavily populated.

- North 275 km along BR-116 to Registro, Juquia, Miracatu, Musacea, Juguitiba, S. Lourence da Sorra to the Fespasa Railroads (Santo-Mairinquy).

  - The terrain is very hilly for about 25 percent of its length, 20 percent thru level and swamp lands, and 55 percent mildly hilly country.

  - Twenty-one stream crossings are anticipated.

  - The alignment can be straightened out to bypass all towns and cities along the major part of the route.

18.4 DISTRIBUTION SYSTEM

The distribution system will service the industrial needs of the cities of Sao Paulo, Santos, Sorocaba, Compinas, Mogi Guacu, Sao Jose dos Compos, Taubate, Pindamonhangaba and others as required.

There will be three main distribution lines in the system with secondary feeder lines to include all of the aforementioned cities. Throughout this report they have been referred to as the Sao Paulo, Mogi Guacu (northwest) and Pindamonhangaba (northeast) lines.

The origin of the main distribution lines will be the distribution center at the northern terminus of the main transmission pipeline.

The following distances between main consumption centers are conservative. Major efforts will be made in the second phase of the future pipeline work to determine the actual distances since information will be available on such items as the type of terrain, availability of land, acquisition for rights of way, and actual tie-in points at each of the major consumer centers.

Developing and/or tying into consumer distribution systems will be undertaken during Phase 2 of the pipeline project.

18.4.1 Sao Paulo Line (city)

The existing Sao Paulo distribution system consists of two rings around the city. The inner ring operates at low pressure, the outer at high pressure (250 psig).

The distribution line from the main transmission pipeline will tie into the high pressure ring. The location of the tie-in will be determined in the second phase of the project when agreements can be reached with the operators of the existing distribution systems.

The trunk line will be routed through an area of high population density and expensive real estate. Hence, it is the intent of this conceptual report to tie into the distribution system as close as possible to the terminus of the main transmission pipeline.

The distance to be used for determining the estimate cost in this report will be 32 km.

- Four stream crossings are anticipated.
- The terrain is mildly hilly.

18.4.2 Mogi-Guacu Line (Northwest)

The Mogi-Guacu distribution line will essentially be following the railroad and highway rights of way.

The route and its general characteristics are as follows:

- o From the Northern main transmission pipeline terminus northwest 70 km along the FEPASA Railroad to Sorocaba (a major consumer) a 10 km tie line is to be required.
  - The pipeline will go east of Soroaba.

- The terrain is mildly hilly.

- Four stream crossings are anticipated.

- One railroad crossing is anticipated.

- All towns will be bypassed.

o North, Northeast 82 km cross country, thence along the FEPASA railroad right of way to Compinas (a major consumer) a 12 km tie line is required.

  - The pipeline will go east of the city.

  - The terrain is hilly.

  - Eleven stream crossings are anticipated.

  - Three railroad crossings are anticipated.

o North 80 km along the FEPASA railroad directly into the Mogi-Guacu distribution system.

  - The terrain is hilly.

  - Seven stream crossings are anticipated.

  - Three railroad crossings are anticipated.

18.4.3 Pindamonhangaba Line (Northeast)

The Pindamonhangaba distribution line will essentially be following railroad and highway rights of way.

The route and its general characteristics is as follows:

o From the main transmission pipeline north terminus East Southeast 55 km along the FEPASA railroad to a point west of Santos (a major consumer) a 22 km line will be required to tie into the Santos distribution system.

  - The terrain is very hilly.

  - Four stream crossings are anticipated.

  - Two railroad crossing are anticipated.

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- Northeast 116 km cross country for half of the distance the remainder will be along the FEPASA Central railroad east of Mogi das Cruzes thence to S. Jose dos Compos (a major consumer) a 12 km line is required to tie into the cities distribution system.
  - The pipeline will go to the east of both cities.
  - The terrain is very hilly.
  - Eleven stream crossings are anticipated.
  - Four railroad crossings are anticipated.
- Northeast 40 km cross country to Taubate (a major consumer) a 12 km line is required to tie into the cities distribution system.
  - The pipeline will go east of the city.
  - The terrain is hilly.
  - Nine stream crossings are anticipated.
- North, Northeast 19 km cross country and directly into the Pindamonhangaba distribution system.
  - Terrain is hilly.
  - Three stream crossings are anticipated.

18.5 FIELD TRIP REPORT

A preliminary investigation of right-of-way was made by driving the length of the main transmission pipeline. Critical portions of the distribution system, previously identified from topography maps, were inspected more closely during this field trip.

The distribution line going to Pindamonhangaba was examined with particular attention being given to the alignment going around the Sao Paulo Reservoir area adjacent to the west face scarp of the first range of mountains inland from the sea.

The main pipeline route started at Sao Paulo, continuing south to the Leao mine site.

18.5.1 Confidence Levels

The findings of the investigations improved the confidence level and gave credence to the judgement used in selecting the right-of-way based upon the Brazilian Institute of Geography and Statistics (IBGE) maps. The initial descriptions in Sections 18.3 and 18.4, which were made by reading the maps, did not require any revisions.

18.5.2 Rock

The second benefit derived from driving the route was to improve the confidence level of the amount of rock that might be encountered. The estimate of 10 percent the entire length of the lines appears to be a valid assumption and is based upon observations of the cuts made to construct the roadway without performing any excavations.

18.5.3 Straightening the Pipeline

The trip confirmed that in Phase 2, we should consider adjusting the pipeline alignments away from the highway and straightening long sections of the pipeline, particularly in the very steep hilly regions and near the heavily populated areas.

18.5.4 River Crossings

The presently available information on river stages, flow velocity, and bathymetry is extremely limited. Since detailed searches and field readings were not made a part of this feasibility study, this data should be developed during the pipeline project phase, particularly for the major rivers to be crossed.

18.5.5 Stream Crossings

No real problems in stream crossings are anticipated.

18.5.6 Road Crossings

No problems in road crossings are anticipated. However, in the distribution systems some eight-lane highways will be encountered.

18.5.7 Railroad Crossings

Care will have to be exercised in designing the FEPASA railroad crossing at Road marking km 1136 near Itapecirica in the state of Sao Paulo. The railroad track is set in steep cuts.

18.5.8 High Tension Lines

When a steel pipeline is laid near a high tension electric power transmission line, special design considerations are needed for cathodic protection of the pipeline.

- Power lines either cross or run parallel with the pipeline right-of-way throughout the state of Sao Paulo.

- Power lines were not visible from the main highway BR116 throughout the state of Parana.

- Towers were not visible, but there were some low voltage lines in the state of Santa Catarina.

- There were some high tension power lines along the road in the State of Rio Grande do Sul.

18.5.9 Pipeline Burial

The pipeline can readily be buried throughout the length of the pipeline system. However, in the very steep hilly country it may be preferable to select a design in which small portions of the pipeline are not buried.

18.5.10 Kilometer Readings

The various points of interest i.e., streams, rivers, railroads, etc. were indexed to the federal Km post and (when possible) odometer readings. Each state has an independent system of km marking for the roads; hence, there is not any visible continuity throughout the length of the North/South road system that could be used in conjunction with the pipeline.

18.5.11 Fill

There seemed to be ample fill material throughout the length of the pipeline. Most of the manmade cuts indicated that a dark red material, which appears to be a low grade iron ore, was included in soil.

19.0 ALTERNATIVE TRANSPORTATION MODES

The primary goal of this study of alternative modes of transportation was to evaluate the quantitative and qualitative (intangible) factors that impact the decision process for selecting a means to provide the industrial sections of Brazil with the energy available from an abundant natural resource, coal. Part of this study included the evaluation of locating the gasification plant at Santos rather than at Leao. The main gas transmission pipeline concept would be replaced by a plan to either ship coal directly to Santos for gasification, or to liquefy the gas and ship the liquefied gas to be regasified into the distribution system at Porto Alegre. The gas distribution system from Sao Paulo to Mogi Guacu and Pindamonhangaba would remain as presented in this base study, and the same capital investment would be incurred for all cases analyzed.

Case Descriptions

The transportation modes selected for study were grouped according to location of the coal gasification plant, as follows:

- Case I places the coal gasification plant at Leao.
- Case II places the coal gasification plant at Santos.

Each of the cases is further subdivided by letter to represent different modes of transportation, as follows:

Case I-A Gas Pipeline System (Base Study)

a. Coal Gasification Plant located at Minas do Leao.

b. Mainline gas transmission system from Minas do Leao to Sao Paulo.

c. Distribution system to Sao Paulo, Mogi Guacu, and Pindamonhangaba.

Case I-B Liquefied Gas Transports

a. Coal Gasification Plant located at Minas do Leao.

b. Gas pipeline from Minas do Leao to Porto Alegre.

c. Liquefication Plant located at Porto Alegre. (The alternate plant location at Minas do Leao was eliminated from consideration because of the concurrent requirement of a 110-km cold pipeline to Porto Alegre.)

d. LNG tankers transport gas to Santos from Porto Alegre.

e. Regasification facility at Santos.

f. Gas distribution system at Sao Paulo, Mogi Guacu, and Pindamonhangaba.

Case II-A Barge Coal Haul to Santos

a. Coal Gasification Plant located at Santos.

b. Coal hauled from Minas do Leao to Porto Alegre by rail. (Barging coal from a location closer to the mining site was eliminated because of costs. The coal would have to be loaded on shallow draft barges, then transferred to ocean going vessels at Porto Alegre. A second option would be to dredge the river to near Minas do Leao and install a deep water terminal there for ocean going vessels.)

c. Coal barged from Porto Alegre to port at Santos.

d. Coal hauled from Santos port to Coal Gasification Plant location.

e. Gas distribution system to Sao Paulo, Mogi Guacu, and Pindamonhangaba.

Case II-B Coal Slurry Pipeline to SNG Plant, south of Sao Paulo

a. Coal Gasification plant located at pipeline terminus.

b. Coal Slurry Pipeline from Minas do Leao to Santos.

c. Gas distribution system to Sao Paulo, Mogi Guacu, and Pindamonhangaba.

Case II-C Haul Coal by railroad to SNG Plant, south of Sao Paulo.

a. Coal Gasification Plant located at pipeline terminus.

b. Coal hauled from Minas do Leao to Santos by rail.

Evaluation Methods

Our evaluation methods addressed the important considerations of the mutually exclusive cases described above, and serve to identify the case that best fits the project requirements.

- The quantitative method used to determine the most feasible of the transportation modes employed the following assumptions and procedures:

  a. The savings realized from the use of product gas was not considered in the methodology because all systems produced gas. The transportation modes were considered as cost centers and evaluated on a least cost basis.

b. The capital investments were determined for each transportation mode as defined in 19.1.1.

c. Respective operating cost for each transportation mode was determined.

d. The transportation modes were ranked by the least total of capital investment and operating costs.

o The qualitative method used to determine the most feasible transportation mode evaluated each case by the following specific factors:

- Social
- Technological
- Ecological
- Political
- National Security
- Utilization of Natural Resources
- Safety
- Manpower Utilization
- Master Plan Objectives

Ratings

Each alternative was rated according to its impact. The alternative with the most positive impact was rated one (1), the next most positive was rated two (2), etc., within the evaluation of a specific factor. The total relative ratings of a particular mode was determined summing the ratings of that mode by the specific factors. The mode with the lowest cumulative total was selected as the best compromise of the specific factors considered, and was rated accordingly in meeting master plan objectives.

19.1 RELATIVE MERITS (Summary)

The evaluation shows that the gas pipeline system adopted for the base study is preferable to the other alternatives studied. Furthermore, it is the least sensitive to labor disturbances, inclement weather, and equipment failure. Gas pipelines have proven to be the cheapest, ecologically cleanest, and most reliable means of transporting energy over long distances.

Regional Growth

The accessibility to or denial of energy can determine whether a given country/state/city/community will continue to progress or retrogress. The pipeline will provide access to clean useable energy in a band some 160 km wide throughout a length of 1 400 km of coastal and interior regions. The country areas will be completely deprived of this available energy if the barge alternative is selected. The specific advantage to the industrial regions south of Sao Paulo that favor the pipeline are economic, social, and political in nature.

19.1.1 Quantitative Evaluation

The economic evaluation rankings are shown on Table 19-1. Considering the initial capital investment and the annual operating costs, the gas pipeline is considered to be the most favorable of the alternate methods.

19.1.2 Qualtitative Evaluation

Qualitatively the gas pipeline is considered to be the most favorable of all the systems evaluated. The basic comparison to follow is essentially between the pipeline and the coal barging system. Since these two systems are included in the scope of this report, the other cases have been eliminated.

The qualitative evaluation rankings are shown on Table 19-2. These values are subjective and require an explanation. The basis of the evaluation is as follows:

- Economic

  The best selection would be the system that has the most desirable effects on the overall economy of the States of Rio Grande do Sul, Santa Catarina, Parana, and Sao Paulo. The base pipeline system offers the most advantages to southern Brazil. The barging of coal would offer an advantage only to Brazil's marine industry.

- Social

  The movement of industry into the southern states by installing the pipeline would attract the migration of people to those states and would help to relive the difficult growth rate in the Sao Paulo area. It would also serve to attain greater social homogeneity through these ares.

  The coal barging case does not offer any real social advantages.

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TABLE 19-1

Evaluation of Alternative Transportation Modes

QUANTITATIVE

CASE DEFINITION			INVESTMENT ($1,000)	RANK	ANNUAL ENERGY COST ($1000)	RANK
1.	Case I-A	Gas Pipeline System (Base Case)	322 440	1	1 934	1
2.	Case I-B	Liquefied Gas Transportation	Not Determined	-	Not Determined	-
3.	Case II-A	Barge Haul to Santos	373 658	3	64 576	3
4.	Case II-B	Coal Slurry Pipeline to Santos	521 740	2	6 453	2
5.	Case II-C	Railroad Haul to Santos	994 400	4	134 758	4

T[redacted] 19-2

Evaluation of Alternative Transportation Modes

QUALITATIVE

SPECIFIC FACTORS	CASE I-A GAS PIPELINE SYSTEM	CASE I-B LNG TRANSPORTS	CASE II-A BARGE HAUL AND PIPELINE	CASE II-B COAL SLURRY PIPELINE	CASE II-C RAILROAD COAL HAUL
1. Economic	1	-	3	2	4
2. Social Homogeneity	1	5	4	2	3
3. Technology	1	5	4	2	3
4. Ecological	1	3	4	2	5
5. Political	1	4	3	2	5
6. National Security	1	5	4	2	3
7. Utilization of Natural Resources	1	4	3	2	5
8. Manpower	1	4	3	2	5
9. Safety	2	5	3	1	4
10. Master Plan Objectives	1	4	3	2	5

- Technological

  The pipeline is essentially one installation while coal barging is a series of operations. Hence, the reliability of the barging operations is at a severe disadvantage since it is subject to the foibles of nature, people, and equipment that is more prone to downtime.

- Ecological

  The pipeline is the cleanest system particularly when considering the disposal of the ash and the fines (coal) that are lost during the numerous handlings and shipment.

- Political

  The migration of people to the southern states, with the pipeline, would provide a more uniform tax base throughout the area.

- National Security

  The pipeline is buried and reasonable surveillance can be maintained. The barges are vulnerable to any action by sea.

- Utilization of Natural Resources

  All energy required to operate the pipeline is presently available in Brazil. The Barging scheme would require fuel that is presently being imported.

- Manpower

  The pipeline operation initially would require less people than barging. However, with the growth potential for the southern states with the pipeline, in the long run the pipeline system would provide for greater employment.

- Safety

  The pipeline operation is the safest of those studied, except for the coal slurry pipeline. Again the barging scheme is more vulnerable to weather and people problems.

19.2 BASIS OF STUDY

Coal deliveries are required on a reliable, continuous basis to the coal gasification plant. However, some leeway is permissible since a minimum of 30 days coal should be stock piled at the gasification plant and the loading terminal to handle minor unusual contingencies.

The major factors that cause interruptions in delivery are:

SHORT TERM	LONG TERM
Weather	Catastrophic loss/damage at sea
Labor fluctuations	Strikes
Maintenance	Dry docking of vessels
Equipment breakdown	Lack of spare parts

19.2.1 Coal Consumption

The amount of washed coal required to feed the gasification plants is 14 283 mT per day. The coal has an ash content of about 35 percent.

Since coal fractures readily, the assumption has been made that a 10 percent loss can be expected due to the handling in shipment to Santos. The assumed shipment is 15 700 mT/day.

19.2.2 Roads

The existing roads would be severely overtaxed by using trucks to haul coal from the mines to the marine terminal.

19.2.3 Barges/Tugs

A smooth inner bottom unit barge will be used to transport the coal. A tug will push the barge while nestled in a notch in the stern of the barge.

19.2.4 Unit Costs

The equipment prices will be based on U.S. prices.

19.2.5 Rolling Stock

Comparable cars to those used in the U.S. will be used for transporting the coal. Capacity of 100 short tons or 90.9 mT.

19.3 LOGISTICS OF BARGE TRANSPORT

The derivation for determining the amount of rolling stock and floating equipment required to transport the coal is as follows:

19.3.1 Land Transport

Coal shipment	=	15 700 mT/day
No. of railroad cars	=	$\frac{15\ 700}{90.9}$ = 172.7 say 173
Trip each direction	=	110 km = 68 miles
Average speed	=	32.2 km = 20 m/h
Trip duration	=	3.5 hr. + 3.5 hr. return
Car unloading rate	=	6/hr/unloader
Assume 2 unloaders	=	12 cars/hr
Time unloading	=	14.4 hrs; assume 15 hrs
Loading rate (1 day turnaround)	=	173 cars/22 hrs
Switching engines and refueling	=	2 hrs
Minimum number of cars	=	345
10% Contingency and Spares	=	34
Recommended number of cars	=	379 (say 380)

Assume 4 trains of 95 cars (each train)

Assume 6 locomotives/train

Number of locomotives = 26 (2 spares)

19.3.2 Sea Transport

Length of trip	=	1400 km (755 nautical miles)
Rate of tow	=	9 knots
Tow duration one way	=	83.94 hrs
Making way and docking	=	4.0 hrs

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Tug time	=	88 hrs
Refuel and Reprovision	=	8 hrs
Trip time	=	96 hrs (4 days)
Number of barges	=	8 (no spares)
Coal transported/barge	=	15 700 mT (cargo load)
Weight of bare barge	=	6 280 mT
Barge total displacement	=	21 980 mT
Tug horsepower	=	5 000 (to be reevaluated in Phase 2 of pipeline project)
Number of tugs	=	6 (no spares)

Recommended: 9 barges and 7 tugs

19.4 DESCRIPTION OF COAL HANDLING SYSTEM

The coal handling components of the system in general terms, from the mine to the coal gasification plant, are as follows:

19.4.1 At The Mine

The mining equipment, mine storage area, and coal moving equipment will essentially be common to the barge alternate and the gasification plant at Leao. (Base Study)

19.4.2 Ground Transport

The ground transportation will require a dedicated fleet of 380 railroad cars (90.9 mT) and 26 locomotives. A new railroad bed would also have to be laid to handle the large volume of heavy standard gage cars and locomotives from Leao to the Porto Alegre area. Truck transportation is not considered to be a viable means of transporting this large amount of coal.

19.4.3 Shipping Terminal

The coal shipping terminal would require train unloading facilities to unload 2 railroad cars every 10 minutes, conveyor systems to off load coal cars and load barges, 45 day coal storage areas, and two barge berths.

19.4.4 Floating Marine Equipment

The sea transport would consist of 9 unit barges (with hatch covers) and 7 tugs. The logistics of routing barges dictates that some 6 barges will be on the high seas and two in a berth at any given point in time, assuming that the ports are readily accessible.

19.4.5 Offloading Terminal

The offloading terminal would require two berths and offloading equipment to unload 15 700 tons of coal in 15 hours. (This allows some time for minor repair to unloaders.) A conveyor system would be required to move the coal to a storage area and/or transport coal to the gas plant.

If the gas and power plants are not located at the terminal, ground transportation would be required similar to that used to transport the coal from the mine to the loading terminal.

19.5 CAPITAL INVESTMENTS AND OPERATING COSTS

Capital investments and operating cost estimates are order of magnitude numbers developed from base unit costs used in the feasibility determination.

The following cost items included in the definitions of the modes are common to all of them and consequently were not considered for evaluation purposes.

a. The Coal Gasification Plant

b. Distribution system to the Sao Paulo, Mogi Guacu, and Pindamonhangaba

c. Mining operations and coal preparation

d. Ash disposal

The following energy and process requirements were used for configuration of modes and development of cost estimates.

a. 15 700 metric tons per day of coal (17 200 Short tons/day)

b. 3.61×10^6 Nm^3/D of pipeline gas (135×10^6 SCFD)

c. Equipment and material prices based on U.S. market

d. Distances

- o 1 140 km land distance Minas do Leao to pipeline terminus
- o 1 400 km sea distance Porto Alegre to Santos

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- o 110 km land distance Minas do Leao to Porto Alegre

e. Land Purchase Cost (Right-of-way)

Not included

f. Gas Pipeline Base Unit Costs - 18 inch pipe

- o Lay @ $0.90 per diameter inch-ft (DIF)
- o Material @ $1.46 per DIF

g. Slurry Pipeline Base Unit Costs - 20 inch pipe

- o Installed price of pipe - $5.00 per DIF (Diameter-inch-ft)
- o Dewatering/Drying Plant @ $5 200 per thruput ton
- o Tankage with mechanical agitator $75.00 per barrel of storage capacity

h. Installed pumping of slurry horsepower @ $2000 per HP

i. Railroad installed @ $650 000 per km ($1 050 000 per mile). The rail system is diesel power

j. Railroad car 90.9 mT capacity @ $55 000

k. Locomotive, diesel fueled, @ $1 000 000

l. Loading, unloading marine terminal @ $60 000 000 (Dredging not included)

m. Floating Equipment

- o Barges @ $1 500 per short ton (bare weight displacement)
- o Tugs @ $6 000 000

n. Energy Costs

1. Electricity $0.037 per kWhr
2. Diesel fuel $2.00 per gallon

o. Operating Parameters

1. Locomotive fuel consumption 155 gal/hr @ 20 mph
2. Tug fuel consumption 155 gal/hr @9 knots
3. 2.500 HP required for barge loading or unloading

4. 7.500 HP required for railroad car loading or unloading

5. Coal unloader sized to unload six (6) R.R. cars per hour

6. Loading barge for R.R. cars - 9 cars per hour

7. Barge unloading complete in 15 hours

8. Barge loading complete in 6 hours

9. Manpower requirements for operation were considered to be beyond the scope of this report, however, a relative evaluation of manpower requirements is included in Section 19.4

10. Maintenance and equipment replacement expenses are not included.

19.5.1 Gas Pipeline System

Case I-A The pipeline was sized for a throughput of 3.61×10^6 Nm^3/D (135×10^6 SCFD) which represents the output from the Coal Gasification Plant.

19.5.1.1 Capital Investment. The mainline gas transmission pipeline would traverse 1140 km transporting 3.6×10^6 Nm^3/D from the gas plant site at Minas do Leao to the distribution system at Sao Paulo. The pipeline size for this evaluation is 18 inch O.D. Two intermediate compressor stations with total HP of approximately 8000 HP were used in the configuration.

o Installed Price of Pipe $4.60 DIF (1140 km) (.62) (5280) (18) (4.60) =	$309 000 000
o Compressor Station Installed HP $1680 per HP (8000 HP) ($1680) =	13 440 000
o Right-of-Way Cost	(Not Included)
TOTAL	$322 440 000

19.5.1.2 Operating Costs. Costs were determined based on energy consumption rates:

o (8000 HP) (.7457) ($.037) (24) = $5 297 Annual Energy Cost	$ 1 934 000

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19.5.2 Liquefied Gas Transportation

Case I-B Liquefied Gas Transportation System Investment and operation costs were not quantified. This mode was considered to be beyond the scope of this report. However, a qualitative evaluation of this mode is included in Section 19.4. A quantification, if required, will be undertaken in Phase 2 of the future pipeline project.

19.5.3 Barge Haul

Case II-A Barge Haul from Porto Alegre to Santos System. The coal would be hauled from the mining site to Porto Alegre by rail a distance of 110 km (68 miles). A train loading facility will be required at the mining site and a train unloading facility will be required at Porto Alegre. A new rail system would be installed. Approximately 380 rail cars with a normal capacity of 90.9 mT and 26 locomotives would be needed to deliver the daily processed coal of 15 700 mT.

The sea haul would start at Porto Alegre and would terminate at Santos in the state of Sao Paulo, a distance of some 1400 km (868 miles). The large amounts of coal to be handled on a daily basis dictates a dedicated fleet of vessels/barges. The duration of the tow and accessibility to ports determine the size and number of units required to supply the necessary amount of coal. The fleet of supply vessels would consist of nine barges and seven tugs. The logistics of routing barges dictates that six barges will be in transit and two in berth at any given time.

19.5.3.1 Capital Investment

- Land Facilities

Railroad	-	110 km @ 650 000	=	$71 500 000
Coal Cars	-	380 @ 55 000	=	$20 900 000
Locomotives	-	26 @ 1 000 000	=	$26 000 000
Land Cost	-	not included		
		SUBTOTAL		$118 400 000

- Loading Terminal

Berths and Storage	=	$20 000 000
Loading Facilities	=	$40 000 000
SUBTOTAL	=	$60 000 000

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- Floating Equipment

  Barges:

($1 500/T) (6908 T) (9)	=	$93 258 000	
Tugs: ($6 000 M) (7)	=	$42 000 000	
SUBTOTAL	=	$135 258 000	

- Unloading Terminal

Berths and Storage	=	$20 000 000	
Loading Facilities	=	$40 000 000	
SUBTOTAL	=	$60 000 000	
TOTAL	=		$373 658 000

19.5.3.2 Operating Cost. Costs were determined based on energy consumption.

		$
o Load Railroad Cars (7500 HP) (.7457) (.037) (24)	=	4 966
o Locomotives, Diesel Fueled (24) (16 hrs/dy) (155 gal/hr) ($2.00/gal)	=	119 040
o Unloading Railroad Cars (7500 HP) (.7457) (.037) (24)	=	4 966
o Loading Barges (2500 HP) (.7457) (.037) (24)	=	1 655
o Tugs Diesel Fuels (6 Tugs) (24) (155) (2.00)	=	44 640
o Unloading Barges (2 500 HP) (.7457) (.037) (24	=	1 665
SUBTOTAL		$ 176 922/Day
Annual Energy Cost (365 days/year)		$ 64 576 000

19.5.4 Coal Slurry Pipeline

Case II-B The slurry pipeline was sized for the thruput of 15 700 mT which represents the daily input requirement for the Coal Gasification Plant. (Gas Plant south of Sao Paulo)

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19.5.4.1 Capital Investment. The slurry pipeline would traverse 1140 km transporting 15 700 mT per day from the mining site at Minas do Leao to the Gas Plant site at Santos. The pipeline size for this evaluation is 20 inch. O.D.. Pump stations with a total of 21 500 HP were used in this configuration. Water was assumed to be available near the mining site. The dewatering drying facilities would be located at the gas plant. Twelve (12) 17 500 barrels of associated tankage with mechanical agitators would be installed.

o	Installed Cost (1140 km) (.62) (5280) (20) ($5.00)	=$373 190 000
o	Pump Stations Installed HP $2 000/HP (21 500 HP) ($2 000)	= 43 000 000
o	Dewatering Drying Facilities Installed Plant @ $5 200 Ton (15 700) (1.1) (5200)	= 89 800 000
o	Tankage w/Mechanical Agitators Installed Tank @ $56.00/Bbl (12) (17 500) ($75)	= 15 750 000
o	Land Cost (not included)	
	TOTAL	$521 740 000

19.5.4.2 Operating Cost. Costs were determined based on energy consumption.

o	Pipeline (21 500 HP) (.7457) (0.37) (24)	$ = 14 237
o	Dewatering Drying and Tankage (5 200 HP) (.7457) ($0.37) (24)	= 3 443
	SUBTOTAL	17 680/Day
	Annual Energy Cost (365 days/year)	$ 6 453 000

19.5.5 Railroad Haul

Case II-C Railroad haul from Minas do Leao mining site to Santos Coal Gasification Plant located in the state of Sao Paulo.

The coal would be hauled from the mine site to the gas pipeline terminus south of Sao Paulo by rail a distance of 1 140 km (706 miles). A train unloading facility would be required. A new rail system would be required and installed at the offloading facilities. Approximately 2 080 rail cars with a nominal capacity of 90.9 mT/each, would be needed to deliver the daily process coal of 15 700 mT. Considering the time

required for loading, transit, and unloading, 24 trains with approximately 87 cars and 72 locomotives each would be employed.

19.5.5.1 Capital Investment.

o	Railroad - 1 140 km @ $650 000	= $741 000 000
o	Coal Cars* - 2 080 @ $55 000	= 114 400 000
o	Loading/Unloading Facilities	= 35 000 000
o	Locomotives* - 72 @ $750 000	= 54 000 000
o	Land Cost - not included	
	* No Spares TOTAL	$994 400 000

19.5.5.2 Operating Cost. Cost were determined based on energy consumption.

o	Load Railroad Cars	$ 6 040
o	Locomotive	357 120
o	Unloading R.R. Cars	6 040
	SUBTOTAL	$369 200/Day
	Annual Operating Cost (365 days/year)	$134 758 000

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APPENDIX - PART II

APPENDIX I

PRO FORMA FINANCIAL AND CASH FLOW REPORTS

(See Section 16)

Summary
Income Statement
Balance Statement
Balance Sheet (Inflation Adjusted)
Balance Sheet (Historical Cost)
Sources and Uses of Funds
Cash Flows and Ratios
Income Tax Worksheet
Loan Funding and Repayment Schedule
Cash Flow Detail Report (ROI)
Cash Flow Detail Report (ROE)

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

2 JUN 1982

SUMMARY REPORT

	NOMINAL DOLLARS	REAL DOLLARS
PRETAX RETURN ON INVESTMENT (1)	21.44%	10.40%
POST-TAX RETURN ON INVESTMENT (2)	18.80%	8.00%
RETURN ON EQUITY (3)	24.10%	12.82%

(1982 US$ MILLIONS)

POST-TAX NPV @ 5%	$295.73
POST-TAX NPV @ 10%	$-117.74

INCREMENTAL SNG PRICE (DISTRIBUTION COST) (JANUARY 1982)

PER GIGACAL	$2.62
PER MILLION BTU	$.66
PER 1000 NM3	$23.92
PER 1000 SCF	$.64

NOTES

(1) RDI (PRETAX) = OPERATING INCOME, LESS INCREASES IN WORKING CAPITAL, PLUS RECOVERED WORKING CAPITAL, DISCOUNTED AGAINST CAPITAL INVESTMENT.

(2) ROI (POST-TAX) = OPERATING INCOME, LESS TAXES ON OPERATING INCOME LESS DEPRECIATION, LESS INCREASES IN WORKING CAPITAL, PLUS RECOVERED WORKING CAPITAL, DISCOUNTED AGAINST CAPITAL INVESTMENT.

(3) RDE = NET CASH FLOW AVAILABLE TO EQUITY HOLDERS, DISCOUNTED AGAINST EQUITY INVESTMENT.

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

INCOME STATEMENT

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8
REVENUES								
SNG DISTRIBUTION (FROM GAS PLANT)	53.4	79.9	90.5	102.6	116.2	131.7	149.2	169.0
SNG DISTRIBUTION (IMPORTED GAS)	163.7	244.8	277.3	314.2	356.0	403.3	457.0	517.8
INTEREST ON COMPULSORY ELECTRIC LOAN	.1	.8	1.6	2.6	3.8	5.2	6.9	8.9
TOTAL REVENUES	217.3	325.5	369.5	419.4	476.0	540.2	613.1	695.7
OPERATING EXPENSES								
ELECTRICITY (NON-LOAN)	13.9	20.8	23.5	26.7	30.2	34.2	38.8	44.0
COMPULSORY ELECTRIC LOAN	7.4	11.1	12.5	14.2	16.1	18.2	20.6	23.4
PIPELINE	11.8	13.5	15.4	17.5	20.0	22.9	26.1	29.8
COMPRESSORS	5.0	5.7	6.5	7.5	8.5	9.7	11.1	12.7
TOTAL OPERATING EXPENSES	38.1	51.0	58.0	65.9	74.8	85.1	96.7	109.9
OPERATING INCOME	179.2	274.4	311.5	353.5	401.1	455.2	516.4	585.9
OTHER EXPENSES								
DEPRECIATION	214.2	235.6	259.1	285.1	313.6	344.9	379.4	417.4
INTEREST	134.9	121.1	107.3	93.4	79.6	65.7	51.9	38.1
TOTAL OTHER EXPENSES	349.1	356.7	366.4	378.5	393.1	410.7	431.3	455.4
INCOME BEFORE TAXES	-169.9	-82.2	-54.9	-25.0	8.0	44.5	85.1	130.5
INCOME TAX	-	-	-	-	-	4.0	37.0	53.9
NET INCOME	-169.9	-82.2	-54.9	-25.0	8.0	40.5	48.1	76.6
INCREMENTAL SNG PRICE PER 1000 NM3	61.03	69.15	78.35	88.77	100.58	113.95	129.11	146.28
CPI INDEX (JAN 1982 = 100)	204.4	224.8	247.3	272.0	299.2	329.2	362.1	398.3

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

INCOME STATEMENT

	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16
REVENUES								
SNG DISTRIBUTION (FROM GAS PLANT)	191.5	217.0	245.8	278.5	315.6	357.6	405.1	459.0
SNG DISTRIBUTION (IMPORTED GAS)	586.6	664.6	753.0	853.2	966.7	1095.2	1240.9	1406.0
INTEREST ON COMPULSORY ELECTRIC LOAN	11.4	14.2	17.6	21.6	26.3	31.8	38.2	45.7
TOTAL REVENUES	789.5	895.9	1016.5	1153.3	1308.5	1484.6	1684.2	1910.6
OPERATING EXPENSES								
ELECTRICITY (NON-LOAN)	49.8	56.4	63.9	72.4	82.1	93.0	105.4	119.4
COMPULSORY ELECTRIC LOAN	26.5	30.0	34.0	38.5	43.7	49.5	56.1	63.5
PIPELINE	34.0	38.9	44.4	50.8	58.0	66.3	75.7	86.5
COMPRESSORS	14.5	16.6	18.9	21.6	24.7	28.2	32.2	36.8
TOTAL OPERATING EXPENSES	124.8	141.9	161.3	183.3	208.4	236.9	269.4	306.2
OPERATING INCOME	664.7	754.0	855.2	970.0	1100.1	1247.6	1414.8	1604.4
OTHER EXPENSES								
DEPRECIATION	459.1	505.0	-	-	-	-	-	-
INTEREST	24.2	10.4	-	-	-	-	-	-
TOTAL OTHER EXPENSES	483.3	515.4	-	-	-	-	-	-
INCOME BEFORE TAXES	181.3	238.6	855.2	970.0	1100.1	1247.6	1414.8	1604.4
INCOME TAX	72.7	94.0	311.2	353.0	400.3	454.0	514.8	583.8
NET INCOME	108.6	144.6	544.0	617.0	699.8	793.6	900.0	1020.6
INCREMENTAL SNG PRICE PER 1000 NM3	165.74	187.78	212.75	241.05	273.11	309.43	350.59	397.21
CPI INDEX (JAN 1982 = 100)	438.1	481.9	530.1	583.1	641.4	705.6	776.1	853.8

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FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

INCOME STATEMENT

	YEAR 17	YEAR 18	YEAR 19	YEAR 20
REVENUES				
SNG DISTRIBUTION (FROM GAS PLANT)	520.0	589.2	667.6	756.4
SNG DISTRIBUTION (IMPORTED GAS)	1592.9	1804.8	2044.8	2316.8
INTEREST ON COMPULSORY ELECTRIC LOAN	54.4	64.5	76.3	90.0
TOTAL REVENUES	2167.4	2458.5	2788.7	3163.2
OPERATING EXPENSES				
ELECTRICITY (NON-LOAN)	135.2	153.2	173.6	196.7
COMPULSORY ELECTRIC LOAN	72.0	81.5	92.4	104.7
PIPELINE	98.9	113.1	129.2	147.8
COMPRESSORS	42.1	48.1	55.0	62.9
TOTAL OPERATING EXPENSES	348.2	395.9	450.2	512.0
OPERATING INCOME	1819.2	2062.6	2338.5	2651.1
OTHER EXPENSES				
DEPRECIATION	-	-	-	-
INTEREST	-	-	-	-
TOTAL OTHER EXPENSES	-	-	-	-
INCOME BEFORE TAXES	1819.2	2062.6	2338.5	2651.1
INCOME TAX	661.9	750.5	850.8	964.5
NET INCOME	1157.3	1312.2	1487.7	1686.6
INCREMENTAL SNG PRICE PER 1000 NM3	450.04	509.90	577.72	654.55
CPI INDEX (JAN 1982 = 100)	939.1	1033.0	1136.4	1250.0

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

BALANCE SHEET (INFLATION ADJUSTED)

	YEAR -6 2ND HALF	YEAR -5 1ST HALF	YEAR -5 2ND HALF	YEAR -4 1ST HALF	YEAR -4 2ND HALF	YEAR -3 1ST HALF	YEAR -3 2ND HALF	YEAR -2 1ST HALF
LONG-TERM LIABILITIES								
LONG-TERM DEBT	19.5	35.1	66.3	135.3	284.9	466.0	656.8	828.2
EQUITY	8.4	16.4	32.3	66.7	140.6	239.0	355.2	478.1
TOTAL	27.9	51.5	98.6	202.0	425.5	705.0	1012.0	1306.3
ASSETS								
WORKING CAPITAL	-	-	-	-	-	-	-	-
COMPULSORY ELECTRIC LOAN	-	-	-	-	-	-	-	-
DEPRECIABLE ASSETS								
PLANT & EQUIPMENT	26.4	47.6	90.0	183.9	387.3	634.6	897.0	1135.1
OWNER'S COSTS	.9	1.7	3.2	6.6	13.8	22.7	32.1	40.6
CAPITALIZED IDC	.6	2.2	5.3	11.5	24.4	47.6	82.9	130.6
TOTAL DEPRECIABLE ASSETS	27.9	51.5	98.6	202.0	425.5	705.0	1012.0	1306.3
LESS: ACCUM. DEPRECIATION	-	-	-	-	-	-	-	-
NET FIXED ASSETS	27.9	51.5	98.6	202.0	425.5	705.0	1012.0	1306.3
TOTAL	27.9	51.5	98.6	202.0	425.5	705.0	1012.0	1306.3
CPI INDEX (JAN 1982 = 100)	115.4	121.0	126.9	133.1	139.6	146.4	153.6	161.1

NOTE: EQUITY DOES NOT INCLUDE RETAINED EARNINGS.

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

BALANCE SHEET (INFLATION ADJUSTED)

	YEAR -2 2ND HALF	YEAR -1 1ST HALF	YEAR -1 2ND HALF	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
LONG-TERM LIABILITIES								
LONG-TERM DEBT	961.3	1056.7	1153.3	1038.0	922.7	807.3	692.0	576.7
EQUITY	598.9	715.9	843.8	946.7	1031.6	1090.0	1118.0	1110.0
TOTAL	1560.2	1772.6	1997.2	1984.8	1954.3	1897.4	1810.0	1686.7
ASSETS								
WORKING CAPITAL	-	-	3.8	3.8	5.1	5.8	6.6	7.5
COMPULSORY ELECTRIC LOAN	-	-	-	7.5	19.6	34.4	52.3	74.0
DEPRECIABLE ASSETS								
PLANT & EQUIPMENT	1323.3	1462.1	1600.5	1760.5	1936.6	2130.2	2343.2	2577.6
OWNER'S COSTS	47.3	52.3	57.2	63.0	69.2	76.2	83.8	92.2
CAPITALIZED IDC	189.6	258.1	335.7	369.2	406.2	446.8	491.5	540.6
TOTAL DEPRECIABLE ASSETS	1560.2	1772.6	1993.4	2192.7	2412.0	2653.2	2918.5	3210.3
LESS: ACCUM. DEPRECIATION	-	-	-	219.3	482.4	795.9	1167.4	1605.2
NET FIXED ASSETS	1560.2	1772.6	1993.4	1973.4	1929.6	1857.2	1751.1	1605.2
TOTAL	1560.2	1772.6	1997.2	1984.8	1954.3	1897.4	1810.0	1686.7
CPI INDEX (JAN 1982 = 100)	168.9	177.2	185.8	204.4	224.8	247.3	272.0	299.2

NOTE: EQUITY DOES NOT INCLUDE RETAINED EARNINGS.

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

BALANCE SHEET (INFLATION ADJUSTED)

	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13
LONG-TERM LIABILITIES								
LONG-TERM DEBT	461.3	346.0	230.7	115.3	-	-	-	-
EQUITY	1059.8	960.2	803.2	579.4	278.4	341.6	415.8	502.8
TOTAL	1521.1	1306.3	1033.9	694.8	278.4	341.6	415.8	502.8
ASSETS								
WORKING CAPITAL	8.5	9.7	11.0	12.5	14.2	16.1	18.3	20.8
COMPULSORY ELECTRIC LOAN	100.1	131.2	168.3	212.3	264.2	325.5	397.5	481.9
DEPRECIABLE ASSETS								
PLANT & EQUIPMENT	2835.3	3118.8	3430.7	3773.8	4151.2	4566.3	5022.9	5525.2
OWNER'S COSTS	101.4	111.5	122.7	134.9	148.4	163.3	179.6	197.6
CAPITALIZED IDC	594.7	654.1	719.5	791.5	870.6	957.7	1053.5	1158.8
TOTAL DEPRECIABLE ASSETS	3531.4	3884.5	4272.9	4700.2	5170.3	5687.3	6256.0	6881.6
LESS: ACCUM. DEPRECIATION	2118.8	2719.1	3418.4	4230.2	5170.3	5687.3	6256.0	6881.6
NET FIXED ASSETS	1412.5	1165.3	854.6	470.0	-	-	-	-
TOTAL	1521.1	1306.3	1033.9	694.8	278.4	341.6	415.8	502.8
CPI INDEX (JAN 1982 = 100)	329.2	362.1	398.3	438.1	481.9	530.1	583.1	641.4

NOTE: EQUITY DOES NOT INCLUDE RETAINED EARNINGS.

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

BALANCE SHEET (INFLATION ADJUSTED)

	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
LONG-TERM LIABILITIES							
LONG-TERM DEBT	-	-	-	-	-	-	-
EQUITY	604.5	723.2	861.5	1022.5	1209.5	1426.5	1626.8
TOTAL	604.5	723.2	861.5	1022.5	1209.5	1426.5	1626.8
ASSETS							
WORKING CAPITAL	23.7	26.9	30.6	34.8	39.6	45.0	-
COMPULSORY ELECTRIC LOAN	580.8	696.3	830.9	987.7	1169.9	1381.5	1626.8
DEPRECIABLE ASSETS							
PLANT & EQUIPMENT	6077.8	6685.5	7354.1	8089.5	8898.4	9788.3	10767.1
OWNER'S COSTS	217.3	239.1	263.0	289.3	318.2	350.0	385.0
CAPITALIZED IDC	1274.7	1402.2	1542.4	1696.6	1866.3	2052.9	2258.2
TOTAL DEPRECIABLE ASSETS	7569.8	8326.8	9159.4	10075.4	11082.9	12191.2	13410.3
LESS: ACCUM. DEPRECIATION	7569.8	8326.8	9159.4	10075.4	11082.9	12191.2	13410.3
NET FIXED ASSETS	-	-	-	-	-	-	-
TOTAL	604.5	723.2	861.5	1022.5	1209.5	1426.5	1626.8
CPI INDEX (JAN 1982 = 100)	705.6	776.1	853.8	939.1	1033.0	1136.4	1250.0

NOTE: EQUITY DOES NOT INCLUDE RETAINED EARNINGS.

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

SOURCES AND USES OF FUNDS

	YEAR -6 2ND HALF	YEAR -5 1ST HALF	YEAR -5 2ND HALF	YEAR -4 1ST HALF	YEAR -4 2ND HALF	YEAR -3 1ST HALF	YEAR -3 2ND HALF	YEAR -2 1ST HALF
SOURCES OF FUNDS								
DEBT	19.5	15.6	31.2	69.0	149.6	181.1	190.8	171.5
EQUITY	8.4	6.7	13.4	29.6	64.1	77.6	81.8	73.5
NET INCOME AFTER TAXES	-	-	-	-	-	-	-	-
DEPRECIATION	-	-	-	-	-	-	-	-
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL SOURCES	27.9	22.3	44.5	98.6	213.6	258.7	272.6	244.9
USES OF FUNDS								
PLANT AND EQUIPMENT	26.4	19.9	40.1	89.5	194.3	228.5	231.4	194.4
OWNER'S COSTS	.9	.7	1.4	3.2	6.9	8.2	8.3	6.9
INTEREST DURING CONSTRUCTION (IDC)	.6	1.6	3.0	5.9	12.3	22.1	33.0	43.6
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-	-
INCREASES IN WORKING CAPITAL	-	-	-	-	-	-	-	-
DEBT REPAYMENT	-	-	-	-	-	-	-	-
AVAILABLE FUNDS	-	-	-	-	-	-	-	-
TOTAL USES	27.9	22.3	44.5	98.6	213.6	258.7	272.6	244.9
CPI INDEX (JAN 1982 = 100)	115.4	121.0	126.9	133.1	139.6	146.4	153.6	161.1

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

SOURCES AND USES OF FUNDS

	YEAR -2 2ND HALF	YEAR -1 1ST HALF	YEAR -1 2ND HALF	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
SOURCES OF FUNDS								
DEBT	133.1	95.4	96.7	-	-	-	-	-
EQUITY	57.0	40.9	41.4	-	-	-	-	-
NET INCOME AFTER TAXES	-	-	-	-169.9	-82.2	-54.9	-25.0	8.0
DEPRECIATION	-	-	-	214.2	235.6	259.1	285.1	313.6
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL SOURCES	190.1	136.2	138.1	44.3	153.3	204.2	260.1	321.5
USES OF FUNDS								
PLANT AND EQUIPMENT	132.8	74.3	67.0	-	-	-	-	-
OWNER'S COSTS	4.7	2.7	2.4	-	-	-	-	-
INTEREST DURING CONSTRUCTION (IDC)	52.6	59.3	64.9	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	3.8	-	-	-	-	-
INCREASES IN WORKING CAPITAL	-	-	-	-	1.3	.7	.8	.9
DEBT REPAYMENT	-	-	-	115.3	115.3	115.3	115.3	115.3
AVAILABLE FUNDS	-	-	-	-71.1	36.7	88.2	143.9	205.3
TOTAL USES	190.1	136.2	138.1	44.3	153.3	204.2	260.1	321.5
CPI INDEX (JAN 1982 = 100)	168.9	177.2	185.8	204.4	224.8	247.3	272.0	299.2

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

SOURCES AND USES OF FUNDS

	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13
SOURCES OF FUNDS								
DEBT	-	-	-	-	-	-	-	-
EQUITY	-	-	-	-	-	-	-	-
NET INCOME AFTER TAXES	40.5	48.1	76.6	108.6	144.6	544.0	617.0	699.8
DEPRECIATION	344.9	379.4	417.4	459.1	505.0	-	-	-
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL SOURCES	385.5	427.5	494.0	567.7	649.5	544.0	617.0	699.8
USES OF FUNDS								
PLANT AND EQUIPMENT	-	-	-	-	-	-	-	-
OWNER'S COSTS	-	-	-	-	-	-	-	-
INTEREST DURING CONSTRUCTION (IDC)	-	-	-	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-	-
INCREASES IN WORKING CAPITAL	1.0	1.2	1.3	1.5	1.7	1.9	2.2	2.5
DEBT REPAYMENT	115.3	115.3	115.3	115.3	115.3	-	-	-
AVAILABLE FUNDS	269.1	311.0	377.3	450.9	532.5	542.0	614.8	697.3
TOTAL USES	385.5	427.5	494.0	567.7	649.6	544.0	617.0	699.8
CPI INDEX (JAN 1982 = 100)	329.2	362.1	398.3	438.1	481.9	530.1	583.1	641.4

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

SOURCES AND USES OF FUNDS

	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
SOURCES OF FUNDS							
DEBT	-	-	-	-	-	-	-
EQUITY	-	-	-	-	-	-	-
NET INCOME AFTER TAXES	793.6	900.0	1020.6	1157.3	1312.2	1487.7	1686.6
DEPRECIATION	-	-	-	-	-	-	-
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	51.2
TOTAL SOURCES	793.6	900.0	1020.6	1157.3	1312.2	1487.7	1737.8
USES OF FUNDS							
PLANT AND EQUIPMENT	-	-	-	-	-	-	-
OWNER'S COSTS	-	-	-	-	-	-	-
INTEREST DURING CONSTRUCTION (IDC)	-	-	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-
INCREASES IN WORKING CAPITAL	2.9	3.2	3.7	4.2	4.8	5.4	6.2
DEBT REPAYMENT	-	-	-	-	-	-	-
AVAILABLE FUNDS	790.8	896.8	1016.9	1153.1	1307.4	1482.3	1731.6
TOTAL USES	793.6	900.0	1020.6	1157.3	1312.2	1487.7	1737.8
CPI INDEX (JAN 1982 = 100)	705.6	776.1	853.8	939.1	1033.0	1136.4	1250.0

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

CASH FLOWS AND RATIOS

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8
NET INCOME AFTER TAXES	-169.9	-82.2	-54.9	-25.0	8.0	40.5	48.1	76.6
DEPRECIATION	164.4	164.4	164.4	164.4	164.4	164.4	164.4	164.4
INCREASES IN WORKING CAPITAL	-	-1.3	-.7	-.8	-.9	-1.0	-1.2	-1.3
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
CASH FLOW FROM OPERATIONS	44.3	152.1	203.5	259.3	320.6	384.4	426.3	492.7
DEBT PRINCIPAL REPAYMENT	115.3	115.3	115.3	115.3	115.3	115.3	115.3	115.3
NET CASH FLOW	-71.1	36.7	88.2	143.9	205.3	269.1	311.0	377.3
INTEREST	134.9	121.1	107.3	93.4	79.6	65.7	51.9	38.1
CPI INDEX (JAN 1982 = 100)	204.4	224.8	247.3	272.0	299.2	329.2	362.1	398.3
INTEREST COVER (1)	-.26	.32	.49	.73	1.10	1.68	2.64	4.43
DEBT SERVICE COVER (2)	.72	1.16	1.40	1.69	2.05	2.49	2.86	3.46

NOTES

$$(1)\ \text{INTEREST COVER} = \frac{\text{EARNINGS BEFORE INTEREST AND TAXES}}{\text{INTEREST}}$$

$$(2)\ \text{DEBT SERVICE COVER} = \frac{\text{CASH FLOW FROM OPERATIONS + INTEREST}}{\text{PRINCIPAL REPAYMENT + INTEREST}}$$

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

CASH FLOWS AND RATIOS

	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16
NET INCOME AFTER TAXES	108.6	144.6	544.0	617.0	699.8	793.6	900.0	1020.6
DEPRECIATION	164.4	164.4	-	-	-	-	-	-
INCREASES IN WORKING CAPITAL	-1.5	-1.7	-1.9	-2.2	-2.5	-2.9	-3.2	-3.7
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
CASH FLOW FROM OPERATIONS	566.2	647.9	542.0	614.8	697.3	790.8	896.8	1016.9
DEBT PRINCIPAL REPAYMENT	115.3	115.3	-	-	-	-	-	-
NET CASH FLOW	450.9	532.5	542.0	614.8	697.3	790.8	896.8	1016.9
INTEREST	24.2	10.4	-	-	-	-	-	-
CPI INDEX (JAN 1982 = 100)	438.1	481.9	530.1	583.1	641.4	705.6	776.1	853.8
INTEREST COVER (1)	8.49	23.99	-	-	-	-	-	-
DEBT SERVICE COVER (2)	4.23	5.24	-	-	-	-	-	-

NOTES

$$(1)\ \text{INTEREST COVER} = \frac{\text{EARNINGS BEFORE INTEREST AND TAXES}}{\text{INTEREST}}$$

$$(2)\ \text{DEBT SERVICE COVER} = \frac{\text{CASH FLOW FROM OPERATIONS + INTEREST}}{\text{PRINCIPAL REPAYMENT + INTEREST}}$$

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COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

CASH FLOWS AND RATIOS

	YEAR 17	YEAR 18	YEAR 19	YEAR 20
NET INCOME AFTER TAXES	1157.3	1312.2	1487.7	1686.6
DEPRECIATION	-	-	-	-
INCREASES IN WORKING CAPITAL	-4.2	-4.8	-5.4	-6.2
RECOVERY OF WORKING CAPITAL	-	-	-	51.2
CASH FLOW FROM OPERATIONS	1153.1	1307.4	1482.3	1731.6
DEBT PRINCIPAL REPAYMENT	-	-	-	-
NET CASH FLOW	1153.1	1307.4	1482.3	1731.6
INTEREST	-	-	-	-
CPI INDEX (JAN 1982 = 100)	939.1	1033.0	1130.4	1250.0
INTEREST COVER (1)	-	-	-	-
DEBT SERVICE COVER (2)	-	-	-	-

NOTES

$$(1)\ \text{INTEREST COVER} = \frac{\text{EARNINGS BEFORE INTEREST AND TAXES}}{\text{INTEREST}}$$

$$(2)\ \text{DEBT SERVICE COVER} = \frac{\text{CASH FLOW FROM OPERATIONS + INTEREST}}{\text{PRINCIPAL REPAYMENT + INTEREST}}$$

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

INCOME TAX WORKSHEET

	YEAR 1 1ST HALF	YEAR 1 2ND HALF	YEAR 2 1ST HALF	YEAR 2 2ND HALF	YEAR 3 1ST HALF	YEAR 3 2ND HALF	YEAR 4 1ST HALF	YEAR 4 2ND HALF
INCOME BEFORE TAX	-119.3	-50.7	-44.7	-37.5	-31.7	-23.2	-17.6	-7.4
PLUS: COMPULSORY ELECTRIC LOAN	2.4	5.0	5.4	5.7	6.1	6.5	6.9	7.3
TAX BASE	-116.9	-45.6	-39.3	-31.8	-25.6	-16.7	-10.7	-.1
LESS: 3.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-116.9	-45.6
	-116.9	-45.6	-39.3	-31.8	-25.6	-16.7	-10.7	-.1
LESS: 2.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-116.9	-45.6	-39.3
	-116.9	-45.6	-39.3	-31.8	-25.6	-133.6	-56.3	-39.4
LESS: 2.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-116.9	-45.6	-39.3	-31.8
	-116.9	-45.6	-39.3	-31.8	-142.5	-179.3	-95.6	-71.3
LESS: 1.5 YEAR LOSS CARRY FORWARD	-	-	-	-116.9	-45.6	-39.3	-31.8	-25.6
	-116.9	-45.6	-39.3	-148.7	-188.2	-218.6	-127.5	-96.9
LESS: 1.0 YEAR LOSS CARRY FORWARD	-	-	-116.9	-45.6	-39.3	-31.8	-25.6	-16.7
	-116.9	-45.6	-156.2	-194.4	-227.5	-250.4	-153.1	-113.7
LESS: 0.5 YEAR LOSS CARRY FORWARD	-	-116.9	-45.6	-39.3	-31.8	-25.6	-16.7	-10.7
TAXABLE INCUME	-116.9	-162.5	-201.9	-233.7	-259.3	-276.1	-169.9	-124.4
TAX LIABILITY @ 35%	-	-	-	-	-	-	-	-
CPI INDEX (JAN 1982 = 100)	194.9	204.4	214.4	224.8	235.8	247.3	259.4	272.0

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

INCOME TAX WORKSHEET

	YEAR 5 1ST HALF	YEAR 5 2ND HALF	YEAR 6 1ST HALF	YEAR 6 2ND HALF	YEAR 7 1ST HALF	YEAR 7 2ND HALF	YEAR 8 1ST HALF	YEAR 8 2ND HALF
INCOME BEFORE TAX	-2.1	10.0	15.0	29.5	34.0	51.1	55.0	75.4
PLUS: COMPULSORY ELECTRIC LOAN	7.8	8.3	8.8	9.4	10.0	10.6	11.3	12.1
TAX BASE	5.7	18.3	23.9	38.8	44.0	61.8	66.4	87.5
LESS: 3.0 YEAR LOSS CARRY FORWARD	-39.3	-31.8	-25.6	-16.7	-	-	-	-
	-	-	-	22.1	44.0	61.8	66.4	87.5
LESS: 2.5 YEAR LOSS CARRY FORWARD	-31.8	-25.6	-16.7	-10.7	-	-	-	-
	-31.8	-25.6	-16.7	11.4	44.0	61.8	66.4	87.5
LESS: 2.0 YEAR LOSS CARRY FORWARD	-25.6	-16.7	-10.7	-.1	-	-	-	-
	-57.5	-42.4	-27.4	11.3	44.0	61.8	66.4	87.5
LESS: 1.5 YEAR LOSS CARRY FORWARD	-16.7	-10.7	-.1	-	-	-	-	-
	-74.2	-53.1	-27.5	11.3	44.0	61.8	66.4	87.5
LESS: 1.0 YEAR LOSS CARRY FORWARD	-10.7	-.1	-	-	-	-	-	-
	-84.9	-53.2	-27.5	11.3	44.0	61.8	66.4	87.5
LESS: 0.5 YEAR LOSS CARRY FORWARD	-.1	-	-	-	-	-	-	-
TAXABLE INCOME	-85.0	-53.2	-27.5	11.3	44.0	61.8	66.4	87.5
TAX LIABILITY @ 35%	-	-	-	4.0	15.4	21.6	23.2	30.6
CPI INDEX (JAN 1982 = 100)	285.3	299.2	313.8	329.2	345.2	362.1	379.7	398.3

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

INCOME TAX WORKSHEET

	YEAR 9 1ST HALF	YEAR 9 2ND HALF	YEAR 10 1ST HALF	YEAR 10 2ND HALF	YEAR 11 1ST HALF	YEAR 11 2ND HALF	YEAR 12 1ST HALF	YEAR 12 2ND HALF
INCOME BEFORE TAX	78.6	102.8	105.0	133.6	405.8	449.4	459.5	510.5
PLUS: COMPULSORY ELECTRIC LOAN	12.8	13.7	14.5	15.5	16.5	17.5	18.7	19.9
TAX BASE	91.4	116.4	119.5	149.1	422.3	467.0	478.2	530.4
LESS: 3.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	91.4	116.4	119.5	149.1	422.3	467.0	478.2	530.4
LESS: 2.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	91.4	116.4	119.5	149.1	422.3	467.0	478.2	530.4
LESS: 2.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	91.4	116.4	119.5	149.1	422.3	467.0	478.2	530.4
LESS: 1.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	91.4	116.4	119.5	149.1	422.3	467.0	478.2	530.4
LESS: 1.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	91.4	116.4	119.5	149.1	422.3	467.0	478.2	530.4
LESS: 0.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
TAXABLE INCOME	91.4	116.4	119.5	149.1	422.3	467.0	478.2	530.4
TAX LIABILITY @ 35%	32.0	40.7	41.8	52.2	147.8	163.4	167.4	185.6
CPI INDEX (JAN 1982 = 100)	417.7	438.1	459.5	481.9	505.4	530.1	556.0	583.1

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

INCOME TAX WORKSHEET

	YEAR 13 1ST HALF	YEAR 13 2ND HALF	YEAR 14 1ST HALF	YEAR 14 2ND HALF	YEAR 15 1ST HALF	YEAR 15 2ND HALF	YEAR 16 1ST HALF	YEAR 16 2ND HALF
INCOME BEFORE TAX	520.3	579.9	589.1	658.6	667.0	747.9	755.2	849.2
PLUS: COMPULSORY ELECTRIC LOAN	21.2	22.5	24.0	25.5	27.2	28.9	30.8	32.8
TAX BASE	541.4	602.4	613.0	684.1	694.1	776.8	785.9	882.0
LESS: 3.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	541.4	602.4	613.0	684.1	694.1	776.8	785.9	882.0
LESS: 2.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	541.4	602.4	613.0	684.1	694.1	776.8	785.9	882.0
LESS: 2.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	541.4	602.4	613.0	684.1	694.1	776.8	785.9	882.0
LESS: 1.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	541.4	602.4	613.0	684.1	694.1	776.8	785.9	882.0
LESS: 1.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	541.4	602.4	613.0	684.1	694.1	776.8	785.9	882.0
LESS: 0.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
TAXABLE INCOME	541.4	602.4	613.0	684.1	694.1	776.8	785.9	882.0
TAX LIABILITY @ 35%	189.5	210.8	214.6	239.4	242.9	271.9	275.1	308.7
CPI INDEX (JAN 1982 = 100)	611.6	641.4	672.7	705.6	740.0	776.1	814.0	853.8

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

INCOME TAX WORKSHEET

	YEAR 17 1ST HALF	YEAR 17 2ND HALF	YEAR 18 1ST HALF	YEAR 18 2ND HALF	YEAR 19 1ST HALF	YEAR 19 2ND HALF	YEAR 20 1ST HALF	YEAR 20 2ND HALF
INCOME BEFORE TAX	855.0	964.2	968.0	1094.6	1096.0	1242.5	1240.9	1410.3
PLUS: COMPULSORY ELECTRIC LOAN	34.9	37 1	39.5	42.0	44.8	47.6	50.7	54.0
TAX BASE	889.9	1001.3	1007.5	1136.6	1140.8	1290.1	1291.6	1464.3
LESS: 3.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	889.9	1001.3	1007.5	1136.6	1140.8	1290.1	1291.6	1464.3
LESS: 2.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	889.9	1001.3	1007.5	1136.6	1140.8	1290.1	1291.6	1464.3
LESS: 2.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	889.9	1001.3	1007.5	1136.6	1140.8	1290.1	1291.6	1464.3
LESS: 1.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	889.9	1001.3	1007.5	1136.6	1140.8	1290.1	1291.6	1464.3
LESS: 1.0 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
	889.9	1001.3	1007.5	1136.6	1140.8	1290.1	1291.6	1464.3
LESS: 0.5 YEAR LOSS CARRY FORWARD	-	-	-	-	-	-	-	-
TAXABLE INCOME	889.9	1001.3	1007.5	1136.6	1140.8	1290.1	1291.6	1464.3
TAX LIABILITY @ 35%	311.5	350.4	352.6	397.8	399.3	451.5	452.0	512.5
CPI INDEX (JAN 1982 = 100)	895.4	939.1	985.0	1033.0	1083.5	1136.4	1191.8	1250.0

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR -6 2ND HALF	YEAR -5 1ST HALF	YEAR -5 2ND HALF	YEAR -4 1ST HALF	YEAR -4 2ND HALF	YEAR -3 1ST HALF	YEAR -3 2ND HALF	YEAR -2 1ST HALF
PROJECT LOANS								
BORROWINGS THIS PERIOD	19.1	14.5	29.1	64.9	140.9	165.6	167.7	140.9
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	19.1	33.6	62.7	127.6	268.5	434.1	601.9	742.8
INTEREST THIS PERIOD	.6	1.6	2.9	5.7	11.9	21.1	31.1	40.3
INTEREST DURING CONSTRUCTION LOAN								
BORROWINGS THIS PERIOD	.4	1.1	2.1	4.1	8.6	15.4	23.1	30.5
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	.4	1.5	3.6	7.8	16.4	31.8	54.9	85.5
INTEREST THIS PERIOD	-	-	.1	.2	.5	1.0	1.9	3.3
TOTAL OF ALL LOANS								
BORROWINGS THIS PERIOD	19.5	15.6	31.2	69.0	149.6	181.1	190.8	171.5
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	19.5	35.1	66.3	135.3	284.9	466.0	656.8	828.2
INTEREST THIS PERIOD	.6	1.6	3.0	5.9	12.3	22.1	33.0	43.6
CPI INDEX (JAN 1982 = 100)	115.4	121.0	126.9	133.1	139.6	146.4	153.6	161.1

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BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR -2 2ND HALF	YEAR -1 1ST HALF	YEAR -1 2ND HALF	YEAR 1 1ST HALF	YEAR 1 2ND HALF	YEAR 2 1ST HALF	YEAR 2 2ND HALF	YEAR 3 1ST HALF
PROJECT LOANS								
BORROWINGS THIS PERIOD	96.3	53.8	51.2	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	47.2	47.2	47.2	47.2	47.2
PRINCIPAL OUTSTANDING AT CLOSE	839.0	892.9	944.1	896.9	849.7	802.5	755.3	708.1
INTEREST THIS PERIOD	47.5	52.0	55.1	56.6	53.8	51.0	48.1	45.3
INTEREST DURING CONSTRUCTION LOAN								
BORROWINGS THIS PERIOD	36.8	41.5	45.5	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	10.5	10.5	10.5	10.5	10.5
PRINCIPAL OUTSTANDING AT CLOSE	122.3	163.8	209.2	198.8	188.3	177.9	167.4	156.9
INTEREST THIS PERIOD	5.1	7.3	9.8	12.6	11.9	11.3	10.7	10.0
TOTAL OF ALL LOANS								
BORROWINGS THIS PERIOD	133.1	95.4	96.7	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	57.7	57.7	57.7	57.7	57.7
PRINCIPAL OUTSTANDING AT CLOSE	961.3	1056.7	1153.3	1095.7	1038.0	980.3	922.7	865.0
INTEREST THIS PERIOD	52.6	59.3	64.9	69.2	65.7	62.3	58.8	55.4
CPI INDEX (JAN 1982 = 100)	168.9	177.2	185.8	194.9	204.4	214.4	224.8	235.8

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR 3 2ND HALF	YEAR 4 1ST HALF	YEAR 4 2ND HALF	YEAR 5 1ST HALF	YEAR 5 2ND HALF	YEAR 6 1ST HALF	YEAR 6 2ND HALF	YEAR 7 1ST HALF
PROJECT LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2
PRINCIPAL OUTSTANDING AT CLOSE	660.9	613.7	566.5	519.3	472.0	424.8	377.6	330.4
INTEREST THIS PERIOD	42.5	39.7	36.8	34.0	31.2	28.3	25.5	22.7
INTEREST DURING CONSTRUCTION LOAN								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5
PRINCIPAL OUTSTANDING AT CLOSE	146.5	136.0	125.5	115.1	104.6	94.2	83.7	73.2
INTEREST THIS PERIOD	9.4	8.8	8.2	7.5	6.9	6.3	5.6	5.0
TOTAL OF ALL LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	57.7	57.7	57.7	57.7	57.7	57.7	57.7	57.7
PRINCIPAL OUTSTANDING AT CLOSE	807.3	749.7	692.0	634.3	576.7	519.0	461.3	403.7
INTEREST THIS PERIOD	51.9	48.4	45.0	41.5	38.1	34.6	31.1	27.7
CPI INDEX (JAN 1982 = 100)	247.3	259.4	272.0	285.3	299.2	313.8	329.2	345.2

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CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR 7 2ND HALF	YEAR 8 1ST HALF	YEAR 8 2ND HALF	YEAR 9 1ST HALF	YEAR 9 2ND HALF	YEAR 10 1ST HALF	YEAR 10 2ND HALF	YEAR 11 1ST HALF
PROJECT LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	47.2	47.2	47.2	47.2	47.2	47.2	47.2	-
PRINCIPAL OUTSTANDING AT CLOSE	283.2	236.0	188.8	141.6	94.4	47.2	-	-
INTEREST THIS PERIOD	19.8	17.0	14.2	11.3	8.5	5.7	2.8	-
INTEREST DURING CONSTRUCTION LOAN								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	10.5	10.5	10.5	10.5	10.5	10.5	10.5	-
PRINCIPAL OUTSTANDING AT CLOSE	62.8	52.3	41.8	31.4	20.9	10.5	-	-
INTEREST THIS PERIOD	4.4	3.8	3.1	2.5	1.9	1.3	.6	-
TOTAL OF ALL LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	57.7	57.7	57.7	57.7	57.7	57.7	57.7	-
PRINCIPAL OUTSTANDING AT CLOSE	346.0	288.3	230.7	173.0	115.3	57.7	-	-
INTEREST THIS PERIOD	24.2	20.8	17.3	13.8	10.4	6.9	3.5	-
CPI INDEX (JAN 1982 = 100)	362.1	379.7	398.3	417.7	438.1	459.5	481.9	505.4

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CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR 11 2ND HALF	YEAR 12 1ST HALF	YEAR 12 2ND HALF	YEAR 13 1ST HALF	YEAR 13 2ND HALF	YEAR 14 1ST HALF	YEAR 14 2ND HALF	YEAR 15 1ST HALF
PROJECT LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-	-	-	-	-	-
INTEREST THIS PERIOD	-	-	-	-	-	-	-	-
INTEREST DURING CONSTRUCTION LOAN								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-	-	-	-	-	-
INTEREST THIS PERIOD	-	-	-	-	-	-	-	-
TOTAL OF ALL LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-	-	-	-	-	-
INTEREST THIS PERIOD	-	-	-	-	-	-	-	-
CPI INDEX (JAN 1982 = 100)	530.1	556.0	583.1	611.6	641.4	672.7	705.6	740.0

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BRAZIL SOUTHERN CONE ENERGY NETWORK
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ECONOMIC ANALYSIS
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(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR 15 2ND HALF	YEAR 16 1ST HALF	YEAR 16 2ND HALF	YEAR 17 1ST HALF	YEAR 17 2ND HALF	YEAR 18 1ST HALF	YEAR 18 2ND HALF	YEAR 19 1ST HALF
PROJECT LC								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-	-	-	-	-	-
INTEREST THIS PERIOD	-	-	-	-	-	-	-	-
INTEREST DURING CONSTRUCTION LOAN								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-	-	-	-	-	-
INTEREST THIS PERIOD	-	-	-	-	-	-	-	-
TOTAL OF ALL LOANS								
BORROWINGS THIS PERIOD	-	-	-	-	-	-	-	-
REPAYMENT THIS PERIOD	-	-	-	-	-	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-	-	-	-	-	-
INTEREST THIS PERIOD	-	-	-	-	-	-	-	-
CPI INDEX (JAN 1982 = 100)	776.1	814.0	853.8	895.4	939.1	985.0	1033.0	1083.5

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ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

LOAN FUNDING AND REPAYMENT SCHEDULE

	YEAR 19 2ND HALF	YEAR 20 1ST HALF	YEAR 20 2ND HALF
PROJECT LOANS			
BORROWINGS THIS PERIOD	-	-	-
REPAYMENT THIS PERIOD	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-
INTEREST THIS PERIOD	-	-	-
INTEREST DURING CONSTRUCTION LOAN			
BORROWINGS THIS PERIOD	-	-	-
REPAYMENT THIS PERIOD	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-
INTEREST THIS PERIOD	-	-	-
TOTAL OF ALL LOANS			
BORROWINGS THIS PERIOD	-	-	-
REPAYMENT THIS PERIOD	-	-	-
PRINCIPAL OUTSTANDING AT CLOSE	-	-	-
INTEREST THIS PERIOD	-	-	-
CPI INDEX (JAN 1982 = 100)	1136.4	1191.8	1250.0

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ECONOMIC ANALYSIS
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(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROI)

	YEAR -6	YEAR -5	YEAR -4	YEAR -3	YEAR -2	YEAR -1	YEAR 1	YEAR 2
PRETAX CASH FLOWS								
CASH OUT								
DEPRECIABLE INVESTMENT	27.3	62.2	294.0	476.3	338.8	146.3	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	3.8	-	-
TOTAL CASH OUT	27.3	62.2	294.0	476.3	338.8	150.1	-	-
CASH IN								
OPERATING INCOME	-	-	-	-	-	-	179.2	274.4
INCREASES IN WORKING CAPITAL	-	-	-	-	-	-	-	-1.3
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	-	-	-	-	-	-	179.2	273.2
POST-TAX CASH FLOWS								
CASH OUT								
DEPRECIABLE INVESTMENT	27.3	62.2	294.0	476.3	338.8	146.3	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	3.8	-	-
TOTAL CASH OUT	27.3	62.2	294.0	476.3	338.8	150.1	-	-
CASH IN								
OPERATING INCOME	-	-	-	-	-	-	179.2	274.4
INCREASES IN WORKING CAPITAL	-	-	-	-	-	-	-	-1.3
ADJUSTED TAXES	-	-	-	-	-	-	-3.0	-31.4
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	-	-	-	-	-	-	176.2	241.8
REAL POST-TAX NPV @ 5%	-23.6	-71.4	-266.7	-544.3	-716.5	-782.1	-720.9	-647.3
REAL POST-TAX NPV @ 10%	-22.6	-66.5	-237.7	-470.9	-609.3	-659.5	-616.1	-565.9
REAL PRETAX ROI %	-	-	-	-	-	-	-	-
NOMINAL PRETAX ROI %	-	-	-	-	-	-	-	-
REAL POST-TAX ROI %	-	-	-	-	-	-	-	-
NOMINAL POST-TAX ROI %	-	-	-	-	-	-	-	-
CPI INDEX (JAN 1982 = 100)	115.4	126.9	139.6	153.6	168.9	185.8	204.4	224.8

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROI)

	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
PRETAX CASH FLOWS								
CASH OUT								
DEPRECIABLE INVESTMENT	-	-	-	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH OUT	-	-	-	-	-	-	-	-
CASH IN								
OPERATING INCOME	311.5	353.5	401.1	455.2	516.4	585.9	664.7	754.0
INCREASES IN WORKING CAPITAL	-.7	-.8	-.9	-1.0	-1.2	-1.3	-1.5	-1.7
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	310.8	352.7	400.2	454.1	515.3	584.6	663.2	752.3
POST-TAX CASH FLOWS								
CASH OUT								
DEPRECIABLE INVESTMENT	-	-	-	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH OUT	-	-	-	-	-	-	-	-
CASH IN								
OPERATING INCOME	311.5	353.5	401.1	455.2	516.4	585.9	664.7	754.0
INCREASES IN WORKING CAPITAL	-.7	-.8	-.9	-1.0	-1.2	-1.3	-1.5	-1.7
ADJUSTED TAXES	-38.0	-45.7	-54.8	-65.3	-77.5	-91.8	-108.3	-127.4
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	272.8	307.0	345.5	388.8	437.7	492.8	554.9	624.8
REAL POST-TAX NPV @ 5%	-575.4	-505.4	-437.1	-370.6	-305.8	-242.6	-181.1	-121.0
REAL POST-TAX NPV @ 10%	-519.1	-475.7	-435.2	-397.6	-362.6	-330.1	-299.8	-271.6
REAL PRETAX ROI %	-	-	-	-	-	1.55	3.27	4.65
NOMINAL PRETAX ROI %	-	-	2.08	6.19	9.30	11.70	13.60	15.12
REAL POST-TAX ROI %	-	-	-	-	-	-	1.41	2.82
NOMINAL POST-TAX ROI %	-	-	-	4.07	7.20	9.63	11.56	13.10
CPI INDEX (JAN 1982 = 100)	247.3	272.0	299.2	329.2	362.1	398.3	438.1	481.9

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FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROI)

	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18
PRETAX CASH FLOWS								
CASH OUT								
DEPRECIABLE INVESTMENT	-	-	-	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH OUT	-	-	-	-	-	-	-	-
CASH IN								
OPERATING INCOME	855.2	970.0	1100.1	1247.6	1414.8	1604.4	1819.2	2062.6
INCREASES IN WORKING CAPITAL	-1.9	-2.2	-2.5	-2.9	-3.2	-3.7	-4.2	-4.8
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	853.3	967.8	1097.6	1244.8	1411.6	1600.7	1815.0	2057.8
POST-TAX CASH FLOWS								
CASH OUT								
DEPRECIABLE INVESTMENT	-	-	-	-	-	-	-	-
INITIAL WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH OUT	-	-	-	-	-	-	-	-
CASH IN								
OPERATING INCOME	855.2	970.0	1100.1	1247.6	1414.8	1604.4	1819.2	2062.6
INCREASES IN WORKING CAPITAL	-1.9	-2.2	-2.5	-2.9	-3.2	-3.7	-4.2	-4.8
ADJUSTED TAXES	-311.2	-353.0	-400.3	-454.0	-514.8	-583.8	-661.9	-750.5
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	542.0	614.8	697.3	790.8	896.8	1016.9	1153.1	1307.4
REAL POST-TAX NPV @ 5%	-75.9	-31.7	11.8	54.5	96.4	137.5	177.9	217.5
REAL POST-TAX NPV @ 10%	-251.4	-232.4	-214.7	-198.1	-182.5	-167.9	-154.2	-141.3
REAL PRETAX ROI %	5.77	6.70	7.46	8.11	8.65	9.11	9.50	9.84
NOMINAL PRETAX ROI %	16.35	17.37	18.21	18.[illegible]	19.51	20.02	20.46	20.83
REAL POST-TAX ROI %	3.72	4.50	5.17	5.7[illegible]	6.26	6.70	7.03	7.43
NOMINAL POST-TAX ROI %	14.10	14.95	15.69	16.33	16.89	17.37	17.80	18.17
CPI INDEX (JAN 1982 = 100)	530.1	583.1	641.4	705.6	776.1	853.8	939.1	1033.0

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROI)

	YEAR 19	YEAR 20
PRETAX CASH FLOWS		
CASH OUT		
DEPRECIABLE INVESTMENT	-	-
INITIAL WORKING CAPITAL	-	-
TOTAL CASH OUT	-	-
CASH IN		
OPERATING INCOME	2338.5	2651.1
INCREASES IN WORKING CAPITAL	-5.4	-6.2
RECOVERY OF WORKING CAPITAL	-	51.2
TOTAL CASH IN	2333.1	2696.2
POST-TAX CASH FLOWS		
CASH OUT		
DEPRECIABLE INVESTMENT	-	-
INITIAL WORKING CAPITAL	-	-
TOTAL CASH OUT	-	-
CASH IN		
OPERATING INCOME	2338.5	2651.1
INCREASES IN WORKING CAPITAL	-5.4	-6.2
ADJUSTED TAXES	-850.8	-964.5
RECOVERY OF WORKING CAPITAL	-	51.2
TOTAL CASH IN	1482.3	1731.6
REAL POST-TAX NPV @ 5%	256.4	295.7
REAL POST-TAX NPV @ 10%	-129.3	-117.7
REAL PRETAX ROI %	10.14	10.40
NOMINAL PRETAX ROI %	21.15	21.44
REAL POST-TAX ROI %	7.73	8.00
NOMINAL POST-TAX ROI %	18.50	18.80
CPI INDEX (JAN 1982 = 100)	1136.4	1250.0

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FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROE)

R O E C A S H F L O W S	YEAR -6	YEAR -5	YEAR -4	YEAR -3	YEAR -2	YEAR -1	YEAR 1	YEAR 2
CASH OUT								
EQUITY INVESTMENT	8.4	20.0	93.7	159.4	130.5	82.3	-	-
TOTAL CASH OUT	8.4	20.0	93.7	159.4	130.5	82.3	-	-
CASH IN								
OPERATING INCOME	-	-	-	-	-	-	179.2	274.4
INCREASES IN WORKING CAPITAL	-	-	-	-	-	-	-	-1.3
TAXES	-	-	-	-	-	-	-	-
INTEREST	-	-	-	-	-	-	-134.9	-121.1
DEBT REPAYMENT	-	-	-	-	-	-	-115.3	-115.3
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	-	-	-	-	-	-	-71.1	36.7
REAL ROE %	-	-	-	-	-	-	-	-
NOMINAL ROE %	-	-	-	-	-	-	-	-
CPI INDEX (JAN 1982 = 100)	115.4	126.9	139.6	153.6	168.9	185.8	204.4	224.8

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROE)

R O E C A S H F L O W S	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10
CASH OUT								
EQUITY INVESTMENT	-	-	-	-	-	-	-	-
TOTAL CASH OUT	-	-	-	-	-	-	-	-
CASH IN								
OPERATING INCOME	311.5	353.5	401.1	455.2	516.4	585.9	664.7	754.0
INCREASES IN WORKING CAPITAL	-.7	-.8	-.9	-1.0	-1.2	-1.3	-1.5	-1.7
TAXES	-	-	-	-4.0	-37.0	-53.9	-72.7	-94.0
INTEREST	-107.3	-93.4	-79.6	-65.7	-51.9	-38.1	-24.2	-10.4
DEBT REPAYMENT	-115.3	-115.3	-115.3	-115.3	-115.3	-115.3	-115.3	-115.3
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	88.2	143.9	205.3	269.1	311.0	377.3	450.9	532.5
REAL ROE %	-	-	-	-	-	2.22	4.67	6.56
NOMINAL ROE %	-	-	-	4.19	8.92	12.44	15.13	17.22
CPI INDEX (JAN 1982 = 100)	247.3	272.0	299.2	329.2	362.1	398.3	438.1	481.9

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROE)

R O E C A S H F L O W S	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18
CASH OUT								
EQUITY INVESTMENT	-	-	-	-	-	-	-	-
TOTAL CASH OUT	-	-	-	-	-	-	-	-
CASH IN								
OPERATING INCOME	855.2	970.0	1100.1	1247.6	1414.8	1604.4	1819.2	2062.6
INCREASES IN WORKING CAPITAL	-1.9	-2.2	-2.5	-2.9	-3.2	-3.7	-4.2	-4.8
TAXES	-311.2	-353.0	-400.3	-454.0	-514.8	-583.8	-661.9	-750.5
INTEREST	-	-	-	-	-	-	-	-
DEBT REPAYMENT	-	-	-	-	-	-	-	-
RECOVERY OF WORKING CAPITAL	-	-	-	-	-	-	-	-
TOTAL CASH IN	542.0	614.8	697.3	790.8	896.8	1016.9	1153.1	1307.4
REAL ROE %	7.88	8.93	9.78	10.48	11.05	11.53	11.93	12.27
NOMINAL ROE %	18.67	19.82	20.76	21.52	22.16	22.68	23.13	23.50
CPI INDEX (JAN 1982 = 100)	530.1	583.1	641.4	705.6	776.1	853.8	939.1	1033.0

FLUOR

BRAZIL SOUTHERN CONE ENERGY NETWORK
COAL GASIFICATION FOR SNG PRODUCTION AND PIPELINE SYSTEM STUDY
ECONOMIC ANALYSIS
CASE: PIPELINE SYSTEM

(AMOUNTS IN US$ MILLIONS)

CASH FLOW DETAIL REPORT (ROE)

R O E C A S H F L O W S	YEAR 19	YEAR 20
CASH OUT		
EQUITY INVESTMENT	-	-
TOTAL CASH OUT	-	-
CASH IN		
OPERATING INCOME	2338.5	2651.1
INCREASES IN WORKING CAPITAL	-5.4	-6.2
TAXES	-850.8	-964.5
INTEREST	-	-
DEBT REPAYMENT	-	-
RECOVERY OF WORKING CAPITAL	-	51.2
TOTAL CASH IN	1482.3	1731.6
REAL ROE %	12.56	12.82
NOMINAL ROE %	23.82	24.10
CPI INDEX (JAN 1982 = 100)	1136.4	1250.0

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APPENDIX J

DEFINITIONS AND CONVERSION FACTORS

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APPENDIX J

The definition of terms and conversion factors listed below are specific for this project. They have been grouped under major headings. Some of the standard universally used definitions are not presented.

Metric units have been used throughout the report followed by the equivalent English units.

J.1 Metric Units

- Cal = calorie
- G. Cal = gigacalories = calories x 10^9
- m = meters
- km = kilometer (= 0.62137 statute mile)
- kg/sq.cm.-abs = kilogram(force)/square centimeter (absolute) = 14.223 psia
- kg/sq.cm.-g = kilogram (force)/square centimeter (gage)

J.2 Abbreviations

- Nm^3/D = normal cubic meters per day - (at 0°C & 760 millimeters of mercury)
- SCFD = standard cubic feet per day - (at 60°F & 14.696 psia)
- mT/yr = metric tons per year
- MAOP = maximum allowable operating pressure

J.3 Conversion Factors for Calorific Equivalents

The conversion factors listed below are reported as they have been used for this study.

J.3.1 Oil to SNG. 1 metric ton of oil = 1100 Nm^3 (41,200 SCF)* of SNG.

J.3.2 TOE/yr to Nm^3D and SCFD

330 days/yr	365 days/yr
(TOE/yr) x 3.3 = Nm^3D	(TOE/yr) x 3.0 = Nm^3D
(TOE/yr) = 125 = SCFD	(TOE/yr) x 113 = SCFD

J.3.3 Coal to SNG

- 1 metric ton of coal = 251 Nm^3 (9382 SCF)

J.3.4 TOE (energy unit). Metric ton of equivalent oil corresponding to fuel oil similar to Bunker "C", with HHV of 10.4 G cal/mT.

J.3.5

- 1 Nm^3 of SNG = 37,310 BTU (HHV)
- 1 SCF of SNG = 1,000 BTU (HHV)

* All gas volumes are calculated from the base values of

	SCF	Nm^3
Temperature	15°C (288.15k)	0°C
Pressure	14.696 psia	760 millimeters of mercury

1 Atmosphere = 14.696 psia
= 1.0332 kg/sq.cm-abs
= 760 millimeters of mercury

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APPENDIX K

REFERENCE DOCUMENTS

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APPENDIX K

The following reference documents and their abbreviations will be used throughout this report.

- Coal Gasification for SNG Production and Pipeline System - Feasibility Study: Section II (Gas Demand Survey - Brazil Southern Cone Energy Network

- API 5LX - American Petroleum Institute - High Test Line Pipe

- API 6D - American Petroleum Institute - Pipeline Valves

- API RP - 50-American Petroleum Institute - Good operating practices for protection of the environment

- NACE RP-01-69 - National Association of Corrosion Engineers (1972 Revision) - Recommended practice control of external corrosion on underground or submerged metallic piping systems.

- Maps

  Secretaria Do Planejamento

  - FOLHA SF-23
  - FOLHA SG-22
  - FOLHA SG-23
  - FOLHA SH-22

Applicable Standards

American National Standard Institute - ANSI B32-8 (1978) Gas transmission and distribution piping systems.

American Petroleum Institute - API RP 1104 Standard for Field Welding of pipeline and related facilities. API SLX Specification for high test line pipe. API 6D Specification for Pipeline Valves.

Code of Federal Regulations CFR-49, Part 192-5, Transportation