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TAMPA ELECTRIC COMPANY'S POLK POWER STATION INTEGRATED GASIFICATION COMBINED CYCLE PROJECT

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DISCLAIMER

INTRODUCTION

Tampa Electric Company (TEC) is in the construction phase for the new Polk Power Station, Unit #1. This will be the first unit at a new site and will use Integrated Gasification Combined Cycle (IGCC) technology for power generation. The unit will utilize oxygen-blown entrained-flow coal gasification, along with combined cycle technology, to provide nominal net 260MW of generation. As part of the environmental features of this process, the sulfur species in the coal will be recovered as a commercial grade sulfuric acid by-product.

OBJECTIVE

This project is partially funded by the U. S. Department of Energy (DOE) under the Clean Coal Technology Program. Demonstration of this IGCC technology, along with a new hot gas cleanup system, is expected to show significant reduction of SO_2 and NO_x emissions when compared to existing and future conventional coal-fired power plants.

This unit will also be an integral part of TEC's generation expansion plan. Using IGCC technology will meet TEC's objective of providing low cost electric power through the use of coal-based generation.

PROJECT PARTICIPANTS

Tampa Electric Company

Tampa Electric Company (TEC) is an investor-owned electric utility, headquartered in Tampa, Florida. It is the principal, wholly owned subsidiary of TECO Energy, Inc., an energy related holding company heavily involved in coal mining, transportation, and utilization for power generation. TEC has about 3300MW of generating capacity. Approximately 97% of the generation is from the coal-fired units. TEC serves about 485,000 Customers in an area of about 2,000 square miles in west-central Florida, primarily in and around Tampa, Florida. (See Figure 1)

TECO Power Services

TECO Power Services (TPS) is a subsidiary of TECO Energy, Inc., and an affiliate of TEC. This company was formed in the late 1980's to take advantage of the opportunities in the non-utility generation market. TPS operates a 295MW natural gas-fired combined cycle power plant in Hardee County, Florida. Seminole Electric Cooperative and Tampa Electric Company are purchasing the output of this plant under a twenty-year power sales agreement.

TPS is responsible for the overall project management for the IGCC project. TPS will also concentrate on commercialization of this IGCC technology, as part of the Cooperative Agreement with the U. S. Department of Energy.

U. S. Department of Energy

The Department of Energy has entered into a Cooperative Agreement with TEC under Round III of the Clean Coal Technology (CCT) Program. Project Management is based in DOE's Morgantown Energy Technology Center in West Virginia.

Major Project Participants & Responsibilities

Tampa Electric Company - Owner/Operator of Polk Power Station
TECO Power Services Corporation - Overall Project Management & Commercialization
U.S. Department of Energy - Co-funding under Clean Coal Technology Program
Texaco Development Corporation - Licensor of Gasification Technology
General Electric - Supplier of Combustion Turbine/Combined Cycle Equipment
GE Environmental Services, Inc. - Supplier of Hot Gas Cleanup System
Bechtel Power Corp. - Detailed Engineering/Construction Management Services
MAN Gutehoffnungshütte AG - Supplier of Radiant Syngas Cooling System
L&C Steinmüller GmbH - Supplier of Convective Syngas Cooling System
Air Products & Chemicals, Inc. - Turnkey Supplier for Air Separation Unit
Monsanto Enviro-Chem Systems, Inc. - Turnkey Supplier for Sulfuric Acid Plant
Johnson Brothers - Site Development & Reclamation

THE SITE

The Polk Power Station will be built on an inland site in southwestern Polk County, Florida (Figure 2). The site, about 11 miles south of Mulberry, was previously mined for phosphate and is unreclaimed. This site was selected by an independent Community Siting Task Force, commissioned by TEC to locate a site for its future generating units.

The seventeen person group consisted of environmentalists, educators, economists, and community leaders. The study, which began in 1989, considered thirty-five sites in six counties. The Task Force recommended three tracts in southwestern Polk County that had been previously mined for phosphate. These sites had the best overall environmental and economical ratings. Total area for the site is about 4300 acres.

About one-third of the site will be used for the generating facilities (Figure 3). TEC will be responsible for development of the site. As part of this overall plan, the existing mine cuts will be modified and used to form an 850 acre cooling reservoir.

Another one-third of the site will be used for creating a complete ecosystem. It will include uplands, wetlands, and a wildlife corridor. This will provide a protected area for native plants and animals. The final one-third of the site will be unused, primarily used for site access and providing a visual buffer. TEC is also responsible for reclamation and revegetation of the entire site.

THE IGCC PROJECT

Overall Concept

The overall project will integrate two major technologies - coal gasification and combined cycle power generation (See Figure 4). This will combine the ability to use low cost coal with the efficiency of the combined cycle. This is expected to provide a system that is 10-12% more efficient than a conventional coal-fired unit.

Gasification

This unit will utilize commercially available gasification technology under a license provided by Texaco for their oxygen-blown entrained-flow gasifier. A general flow diagram of the entire process is shown in Figure 5. In this arrangement, coal will be ground and slurried in water to the desired concentration (60-70% solids) in rod mills. The unit will be designed to utilize about 2300 tons per day of coal (dry basis). This coal slurry and an oxidant (95% pure oxygen) will then be mixed in the gasifier where the carbon in the coal is partially oxidized at a temperature in excess of 2500°F (1370°C). This produces syngas with a heating value of about 250 BTU/SCF (LHV). The oxygen will be produced from the Air Separation Unit (ASU). The gasifier is expected to achieve greater than 95% carbon conversion in a single pass. The syngas will flow downward into a radiant syngas cooler where the temperature will be reduced from about 2500°F (1370°C) to about 1300°F (700°C). After the radiant syngas cooler, the gas will then be split into two (2) parallel convective coolers, where the temperature will be cooled further to about 900°F (480°C). Syngas from each convective cooler will then enter a gas/gas exchanger, one used for heating clean syngas and one for heating nitrogen. The cooled gas then will go to the Cold Gas Cleanup (CGCU) system for sulfur removal. A slip stream of about 10% of the syngas flow (following one of the convective coolers) will go to the demonstration sized Hot Gas Cleanup (HGCU) system. This flow arrangement was selected to provide assurance to TEC that the IGCC capacity would not be restricted due to the demonstration of the HGCU system. The CGCU system will be a traditional amine scrubber. Sulfur species removed in the HGCU and CGCU systems will be recovered in the form of sulfuric acid.

Most of the ungasified coal exits the bottom of the gasifier/radiant syngas cooler into the slag lockhopper where it is mixed with water. These solids generally consist of slag and unreacted coal. They will exit the slag lockhopper and then be dewatered. This non-leachable by-product is readily saleable for blasting grit, roofing tiles, and construction building products. TEC has been marketing slag from its exiting coal-fired units for such uses for over 25 years.

The water in the slag lockhoppers requires treatment before it can be either discharged or reused. All of the water from the gasification process will be cleaned and reused, thereby creating no requirement for discharging process water from the gasification system.

Air Separation Unit

The Air Separation Unit (ASU) will use ambient air to produce oxygen for use in the gasification system and sulfur recovery unit, and nitrogen which will be sent to the advanced CT. The addition of nitrogen in the CT combustion chamber has dual benefits. First, since syngas has a substantially lower heating value than natural gas, a higher fuel mass flow is needed to maintain heat input. This additional mass flow has the advantage of producing higher CT power output. Second, the nitrogen acts to control potential NO_x in the fuel combustion process.

The ASU will be sized to produce about 2100 tons per day of 95% pure oxygen and 6300 tons per day of nitrogen. The ASU will be designed and constructed as a turnkey project by Air Products and Chemicals, Inc.

HGCU

The HGCU system is being developed by General Electric Environmental Services, Inc. (GEESI). This process is undergoing pilot plant testing at GE's laboratory facilities in Schenectady, NY. The advantage of the HGCU over the CGCU is the ability to use the syngas directly from the gasification system. Instead of having to cool the gas prior to sulfur removal, the HGCU will accept gas at 900-1000°F (480-540°C). The successful demonstration of this technology will provide for higher efficiency IGCC systems.

The slipstream for the HGCU system will come directly after one of the convective syngas coolers (See Figure 6). The HGCU system will be sized to treat about 10% of the syngas. The unit will be able to operate in either the 100% CGCU or 90% CGCU/10% HGCU mode. The metal oxide sorbent used will be zinc titanate or Z-Sorb, a sorbent produced by Phillips Petroleum. GEESI has been conducting tests on both sorbents.

A regeneration system will produce a highly concentrated (about 11%) SO_2 stream. This will feed the sulfuric acid plant, for production of a saleable acid by-product.

Two (2) other support processes will be investigated as improvements to this process. In addition to the high efficiency primary cyclone being provided upstream of the HGCU system, a high temperature barrier filter will be used downstream of the HGCU to protect the combustion turbine.

Sodium bicarbonate, $NaHCO_3$, will be injected for removal of chloride and fluoride species. This will form the stable solids NaCl and NaF, which will be collected in a secondary cyclone and disposed of with other plant solid by-products streams.

<u>Combined Cycle System</u>

The key components of the combined cycle system are the advanced combustion turbine (CT), heat recovery steam generator (HRSG), steam turbine (ST), and generators.

GE is currently optimizing the arrangement for lowering the pressure drop across the fuel inlet control valving. This has a compounding positive effect on cycle efficiency by also allowing a lower pressure in the ASU, requiring less air and nitrogen compressor parasitic power.

The HRSG is installed in the combustion turbine exhaust to complete the traditional combined cycle arrangement and provide steam to the 130MW steam turbine.

No auxiliary firing is proposed within the HRSG system. Hot exhaust from the CT will be channeled through the HRSG to recover the CT exhaust heat energy. The HRSG high pressure steam production will be augmented by high pressure steam production from the coal gasification (CG) plant. All high pressure steam will be superheated in the HRSG before delivery to the high pressure ST.

The ST will be designed as a double flow reheat turbine with low pressure crossover extraction. The ST generator will be designed for highly efficient combined cycle operation with nominal turbine inlet throttle steam conditions of approximately 1,450 psig and 1,000°F (540°C) with 1,000°F (540°C) reheat inlet temperature.

The operation of the combined cycle power plant will be coordinated and integrated with the operation of the CG process plant. The initial start-up of the power plant will be carried out on low-sulfur No. 2 fuel oil. Transfer to syngas will occur upon establishment of fuel production from the CG plant.

Under normal operation, syngas and nitrogen from the ASU will be provided to the CT. The syngas/nitrogen mix at the CT combustion chamber will be regulated by the CT control system to the NO_x emission levels from the unit.

Cold reheat steam from the high pressure turbine exhaust and HRSG intermediate pressure steam will be combined before reheating in the HRSG and subsequent admission to the intermediate pressure ST.

Sulfuric Acid Plant

The original concept for the plant was for a 50% HGCU system, with its own sulfuric acid plant. Since gasification produces a high H_2S - content syngas, a conventional amine type removal system followed by Claus-type sulfur recovery system was planned for the CGCU system. Detailed process, economic, and by-product market studies showed that using a single sulfuric acid plant (versus separate sulfuric acid and sulfur recovery) had many advantages.

In the fall of 1993, bids were requested for a sulfuric acid plant that could treat the H_2S off-gas from the CGCU system or the combination of H_2S from the CGCU system and SO_2 from the HGCU system. Following bid evaluations and negotiations, a contract was signed with Monsanto Enviro-Chem Systems, Inc. (MEC).

As previously indicated, the sulfuric acid plant is designed to take H_2S from the amine CGCU system and SO_2 from the HGCU system. The quantity of each stream will vary depending on the operating rate of the HGCU system. This variation is further amplified by the sulfur content of the coal. In addition, since this is essentially a gas handling process from the gasifier to the sulfuric acid plant, the sulfuric acid plant must be on-stream for the gasifier to be operated continuously. This combination of factors means the sulfuric acid plant must be designed for flexibility and reliability.

A general flow diagram for the sulfuric acid plant is shown in Figure 7. The nominal instantaneous capacity of the plant is 210 STPD (191 MTPD).

The CGCU stream contains about 21% (vol.) H_2S and 73% (vol.) CO_2 with small quantities of H_2O, NH_3, COS, CO and N_2. The H_2S is combusted with ambient air to form SO_2 and H_2O and the heat of combustion is recovered in a waste heat boiler. Steam is produced at a nominal 400 psig. The HGCU SO_2 stream is introduced upstream of the waste heat boiler. The HGCU stream contains about 11% (vol.) SO_2, 88% (vol.) N_2 and 1% (vol.) O_2. The combined gas streams are treated in a DynaWave® system and packed cooling tower to achieve overall water balance. At this point, there is insufficient O_2 in the gas to achieve the required conversion of SO_2 to SO_3. Therefore, O_2 from the Air Separation Unit (ASU) is added to obtain the proper O_2 to SO_2 ratio. The use of ASU O_2 (as compared to ambient air) is an innovation that reduces the gas volume and is beneficial in meeting water balance. It also provides for further process integration of two separate areas into the overall IGCC plant. After the addition of O_2, the water vapor is removed from the process gas in the drying tower that circulates 96% (wt.) sulfuric acid. Acid concentration is maintained by crossflowing 98% acid from the interpass absorbing tower. The drying tower contains Monsanto Enviro-Chem's high efficiency HE mist eliminators to remove sulfuric acid mist and protect downstream equipment. The use of the Dynawave® system and ES mist eliminators eliminates the need for electrostatic mist precipitators. This saves capital cost and reduces maintenance.

The main compressor provides the motive force for the acid plant process gas. Consequently, the upstream equipment operates under a vacuum and the downstream equipment operates under pressure. After the main compressor, the gas is then heated in a series of gas-to-gas heat exchangers to the required catalyst temperature, nominally 800°F (427°C). The gas is heated using heat available from the converter system. Under normal operating conditions, the sulfuric acid plant requires no external fuel, and in fact, there is excess process heat that is recovered as steam. The converter is a multiple pass design with stainless steel materials of construction. The catalyst is a combination of Enviro-Chem type LP 120 and LP 110. Prior to the interpass tower, the gas is cooled in a series of gas-to-gas heat exchangers which also reheat the gas prior to the final converter pass. The interpass absorbing tower removes the SO_3 by circulating 98% (wt.) sulfuric acid. The interpass tower mist eliminators are Enviro-Chem Energy Saver (ES). After the final converter pass, the gas is cooled in a gas-to-gas heat exchanger (heating up the gas from the main compressor). The final absorbing tower removes the remaining SO_3 by circulating 98% (wt.) sulfuric acid. The final tower mist eliminators are also ES type. The ES type mist eliminator assures the plant will meet acid mist emission regulations, particularly at turndown conditions. Special alloy plate heat exchangers are used to cool the acid circulated over the gas cooling tower. Enviro-Chem anodically protected stainless steel shell and tube acid coolers are used to cool the acid circulated over the drying, interpass absorbing, and final absorbing towers.

As stated previously, the reliability of the sulfuric acid plant is a key to the overall operating of the Polk Power Station Unit #1. Therefore, it is a major focus in the design of the plant. First, the amount of equipment, particularly rotating equipment is minimized. For example, for the main acid plant there are only five pieces of rotating equipment, and all of them have installed spares except the main compressor.

Second, premium materials of construction are used throughout the plant. Already mentioned are the stainless steel converter and acid coolers. Other areas include stainless steel ducts for the hot gas ducts around the converter system, and extensive use of FRP in the weak acid and gas systems.

In addition to reliability, there are several other performance requirements that the sulfuric acid plant is expected to meet. These include rated capacity, turndown to one-third rated capacity, emissions, acid quality, steam production, electric power consumption, and oxygen consumption.

Sulfuric Acid Marketing

As noted previously, TEC has always been able to market its coal combustion by-products. This includes slag, bottom ash, flash, and gypsum from a flue gas desulfurization system. In order to continue this trend, TEC contacted phosphate companies and marketers to find a use for the by-product from the sulfuric acid plant.

Since TEC is not a user of the sulfuric acid, and there would only be a few days of storage at the site, it was mandatory that a potential purchaser have the ability to take all of the acid in a timely manner. During the environmental permit process, there was a need to have a contract in place prior to the State Certification hearings. This was to alleviate any concerns for disposal of potentially hazardous wastes.

A contract was entered into between TEC and Sulphuric Acid Trading Company (SATCO). SATCO is a joint venture between Freeport McMoRan Resource Partners, L.P. and Interacid Holdings Ltd. and is involved in buying and selling sulfuric acid in domestic and international markets. Their office is located nearby in Tampa. Pricing terms allow for marketing several grades of acid that may be produced, according to their purity and the market price of sulfur.

A 10,000 gallon storage tank (5 days production at full load) will be on site. Acid will be able to be shipped by either truck or rail. Since the plant is located in Polk County, it is adjacent to the phosphate industry, a large producer and user of sulfuric acid.

Polk County is home to six phosphate companies, with 16 sulfuric acid plants producing about thirteen million tons of sulfuric acid per year. The Polk Power Station expected annual production of 75,000 tons accounts for less than 1%. Therefore, no significant impact to market availability or price are expected to occur due to this additional production.

ENVIRONMENTAL PERFORMANCE

TEC was required to go through both state and federal permit processes. On the state level, a power plant of this size is requires submittal of a Site Certification Application. This provides a "one-stop" permit application process for all state and local agencies, and is administered by the Florida Department of Environmental Protection (FDEP).

The application was submitted in July 1992, and final approval was granted by the Governor and Cabinet in January 1994.

The original application was based on the sulfur plant/sulfuric acid plant concept and was later modified to the present sulfuric acid plant. A Prevention of Significant Deterioration (PSD) air emissions permit was issued by the FDEP on February 24, 1994. Due to minor changes in air emission sources that occurred after the contract was signed for the sulfuric acid plant, a modification to the PSD permit is being processed by the FDEP.

It must be noted that this application was for a power plant unlike any previously seen by these agencies. Therefore, extensive discussions were required to determine the appropriate emissions limitations, since the plant uses coal, burns gas, and includes a sulfuric acid plant.

Subpart H, Standards of Performance for Sulfuric Acid Plants (40 CFR 60.80 et seq.) applies to affected sulfuric acid production plants. It also states that those affected sulfuric acid production units are not "... facilities where conversion to H_2SO_4 is utilized primarily as a means of preventing emissions to the atmosphere of SO_2 or other sulfur compounds" (40 CFR 60.81 [a]). Because the Polk Power Station sulfuric acid plant is used primarily as a means of preventing SO_2 emissions to the atmosphere (sulfur species reduction and removal), it is not regulated under Subpart H.

However, TEC realized that in order to obtain permits for the Polk Power Station, environmental performance at least as good as that in commercially available sulfuric acid plants was required. Even though Subpart H is not applicable to the Polk Power Station sulfuric acid plant, the contract with MEC guarantees that the plant will meet Subpart H emission standards for sulfuric acid mist (0.15 lbs/Ton of 100% H_2SO_4 Product) and SO_2 (4 lbs/Ton of 100% H_2SO_4 Product). As part of the overall power plant, NO_x emission limitations are in place for the sulfuric acid plant stack.

On the federal level, TEC needed to satisfy the requirements of the National Environmental Policy Act (NEPA). Three Federal Agencies were involved in this process as follows: the U.S. Environmental Protection Agency (EPA), due to the need for the water discharge (NPDES) permit, the U. S. Department of Energy due to its co-funding of the project (considered a major Federal action), and the U. S. Army Corps of Engineers, due to the need to obtain a Section 404 permit to dredge and fill in the waters of the U. S. (site development and reclamation of the mined out areas) that had become wetlands. This process began in the summer of 1992 and was completed in July 1994.

DEMONSTRATION

The Cooperative Agreement requires a two year demonstration period. During that time frame, TEC will operate the IGCC plant using four different types of coal. Operation with the HGCU will be a major part of the demonstration program in order to quantify its performance. Depending on the initial success of the HGCU system, an additional two-year period will follow to either continue HGCU testing and enhancement (if HGCU continues to be technically and commercially feasible) or continue with additional overall IGCC plant testing and data collection.

This demonstration period will provide cost and performance data to the DOE. The data will be available to other utilities and will provide another alternative for meeting future generation needs and for repowering existing units to meet upcoming environmental requirements. IGCC will provide these utilities with the benefits of low cost U. S. coal reserves along with efficient, superior environmental performance.

SCHEDULE

Figure 8 presents the project schedule. Site development began in July 1994. Since the sulfuric acid plant is used for complying with air emission limitations, its operation must be concurrent with the balance of the IGCC plant. Checkout will occur in early 1996, with performance testing occurring in late summer of that year. Commercial Operation of the entire IGCC unit is scheduled for October 1996.

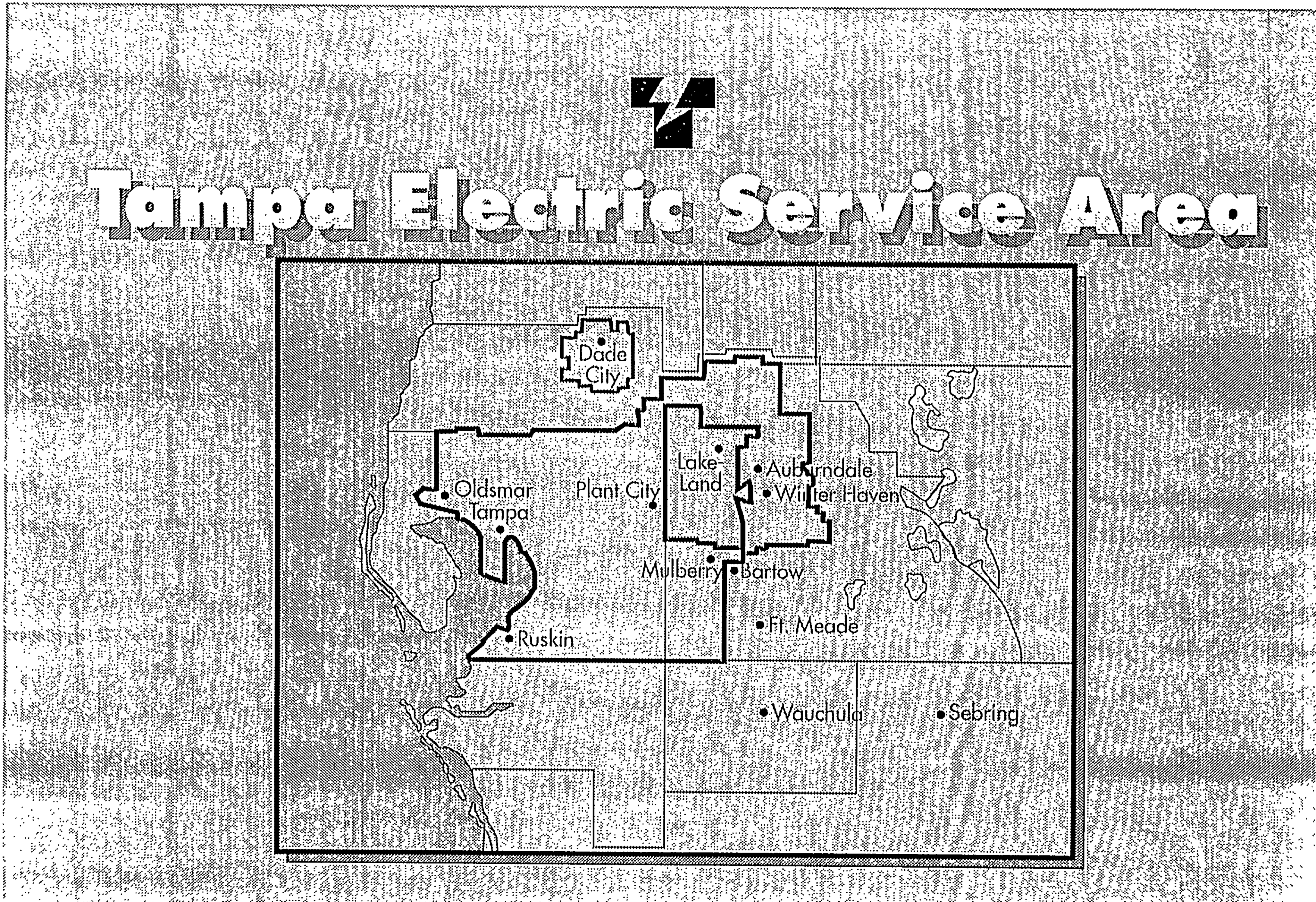
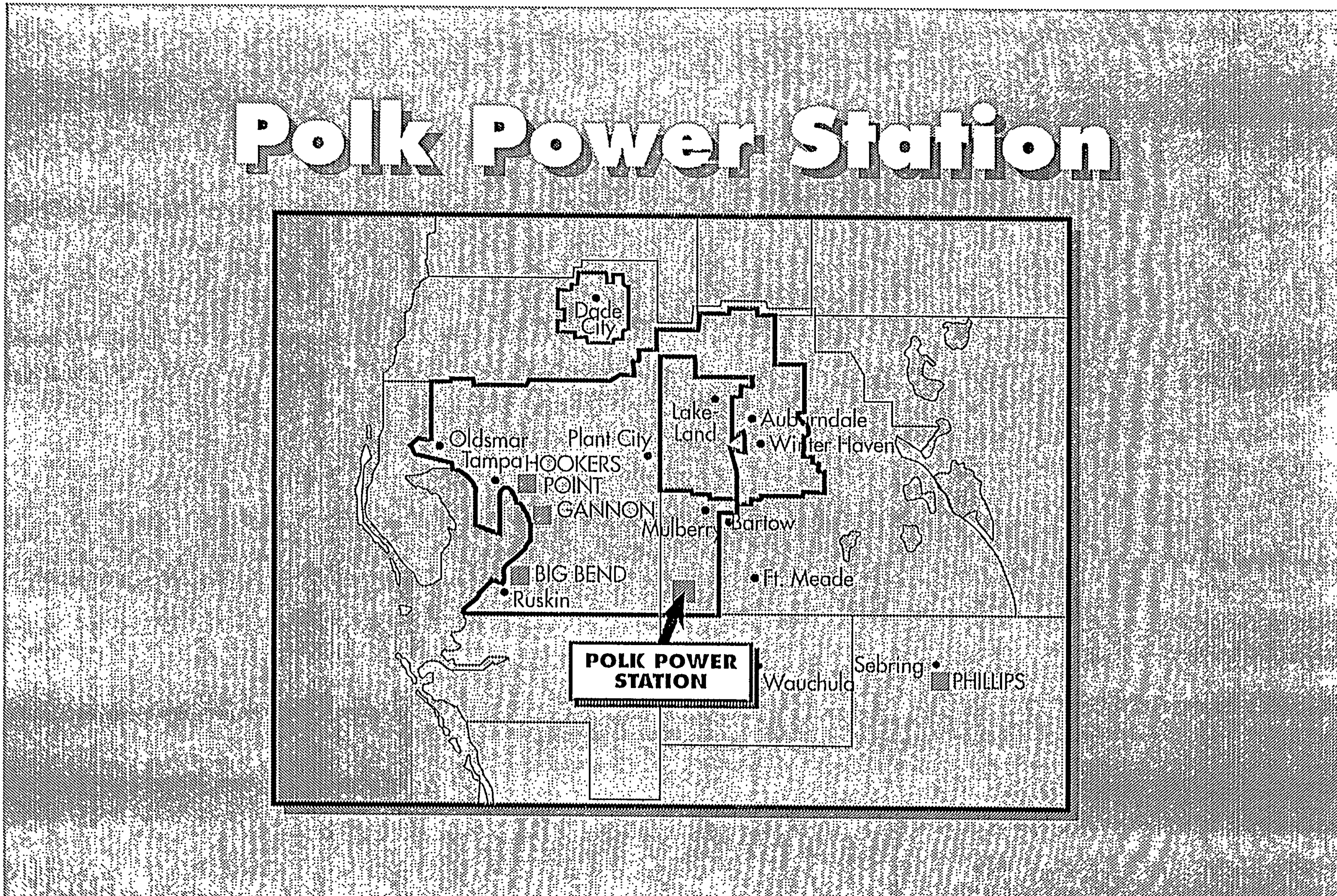

Tampa Electric Service Area
Dade City
Oldsmar
Tampa
Plant City
Lake-Land
Auburndale
Winter Haven
Mulberry
Bartow
Ruskin
Ft. Meade
Wauchula
Sebring

FIGURE 1



Polk Power Station
Dade City
Oldsmar
Tampa
Plant City
HOOKERS POINT
GANNON
BIG BEND
Ruskin
Lake-Land
Auburndale
Winter Haven
Mulberry
Bartow
Ft. Meade
POLK POWER STATION
Wauchula
Sebring
PHILLIPS

FIGURE 2

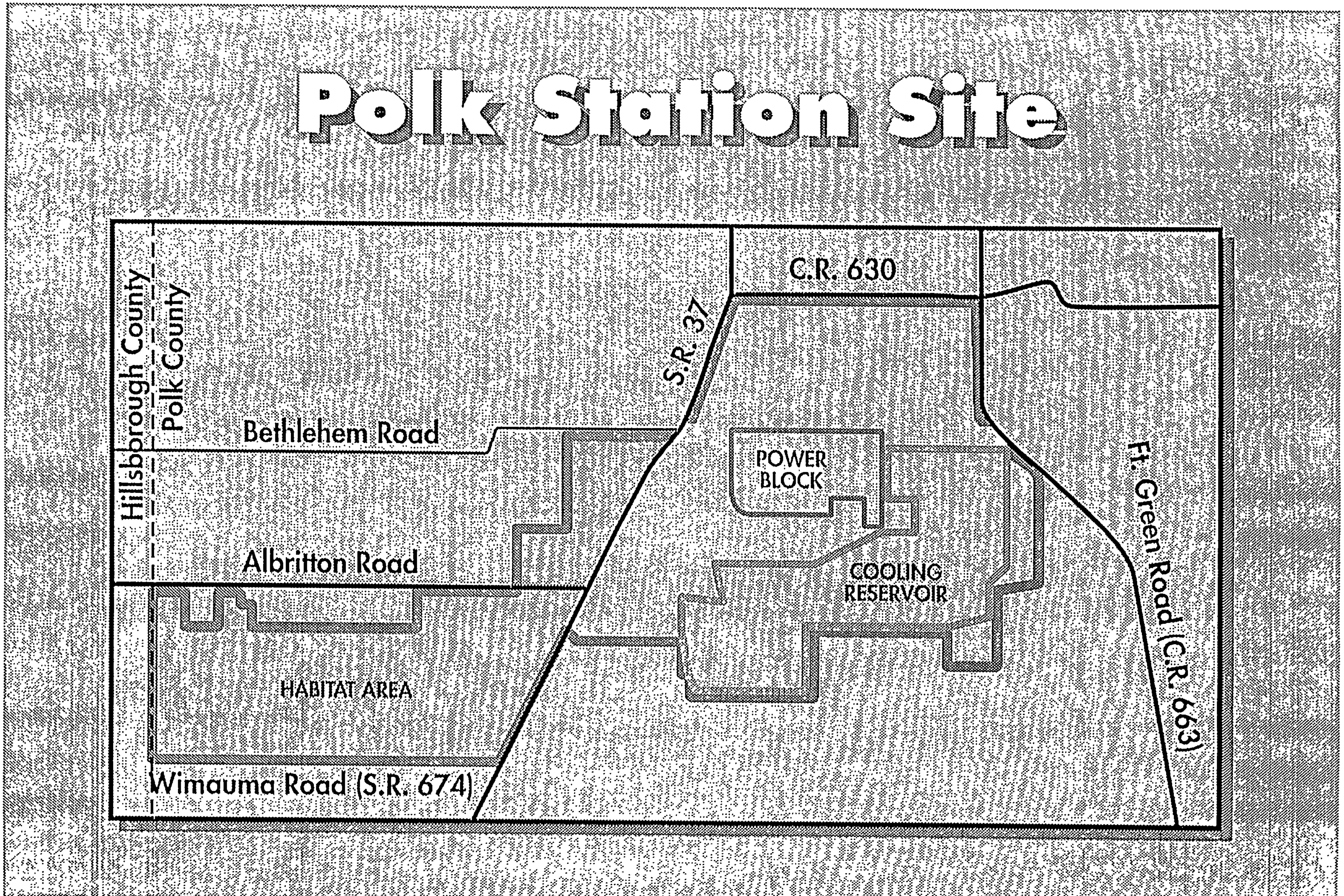

Polk Station Site
Hillsborough County
Polk County
Bethlehem Road
Albritton Road
HABITAT AREA
Wimauma Road (S.R. 674)
S.R. 37
C.R. 630
POWER
BLOCK
COOLING
RESERVOIR
Ft. Green Road (C.R. 663)

FIGURE 3

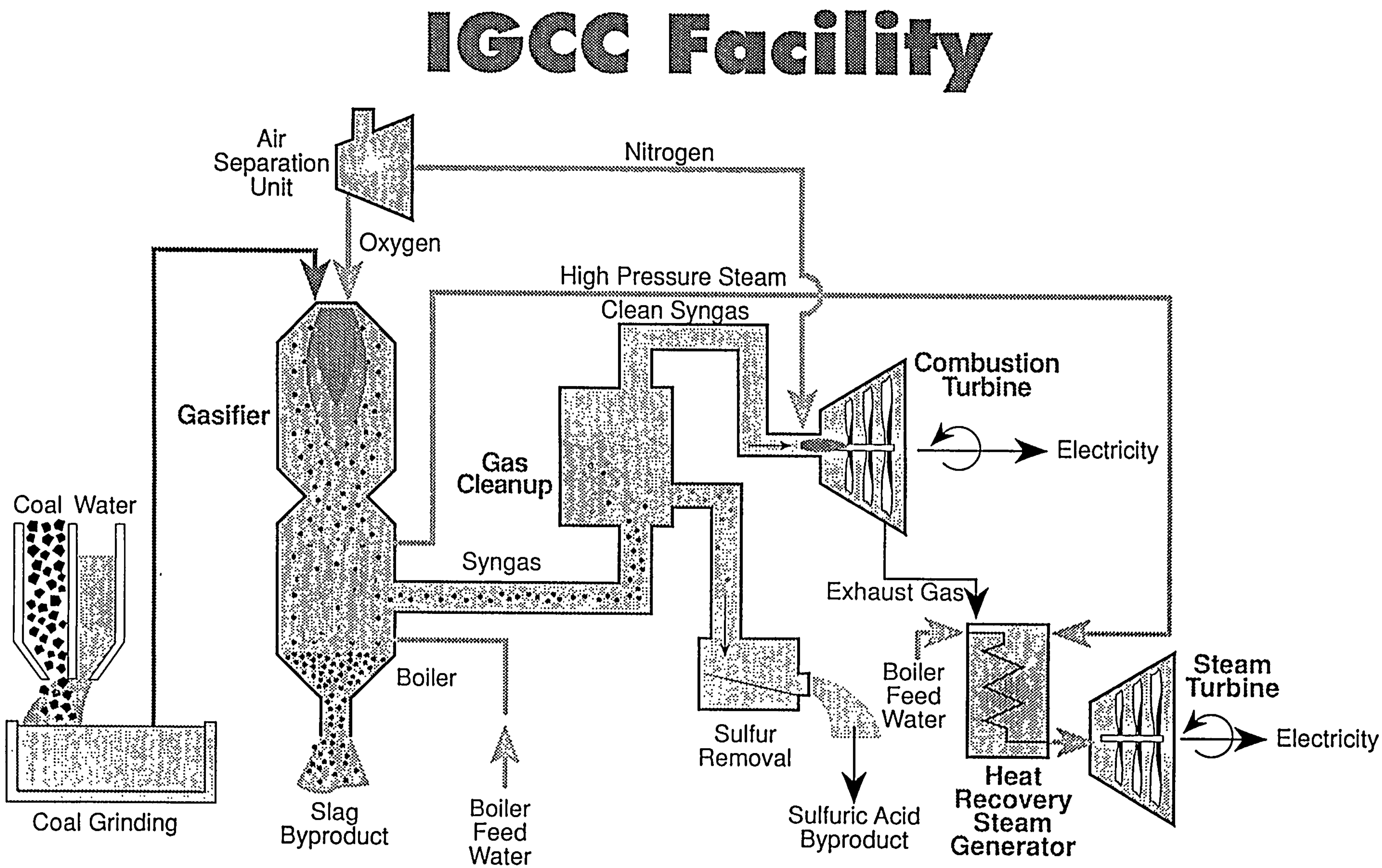
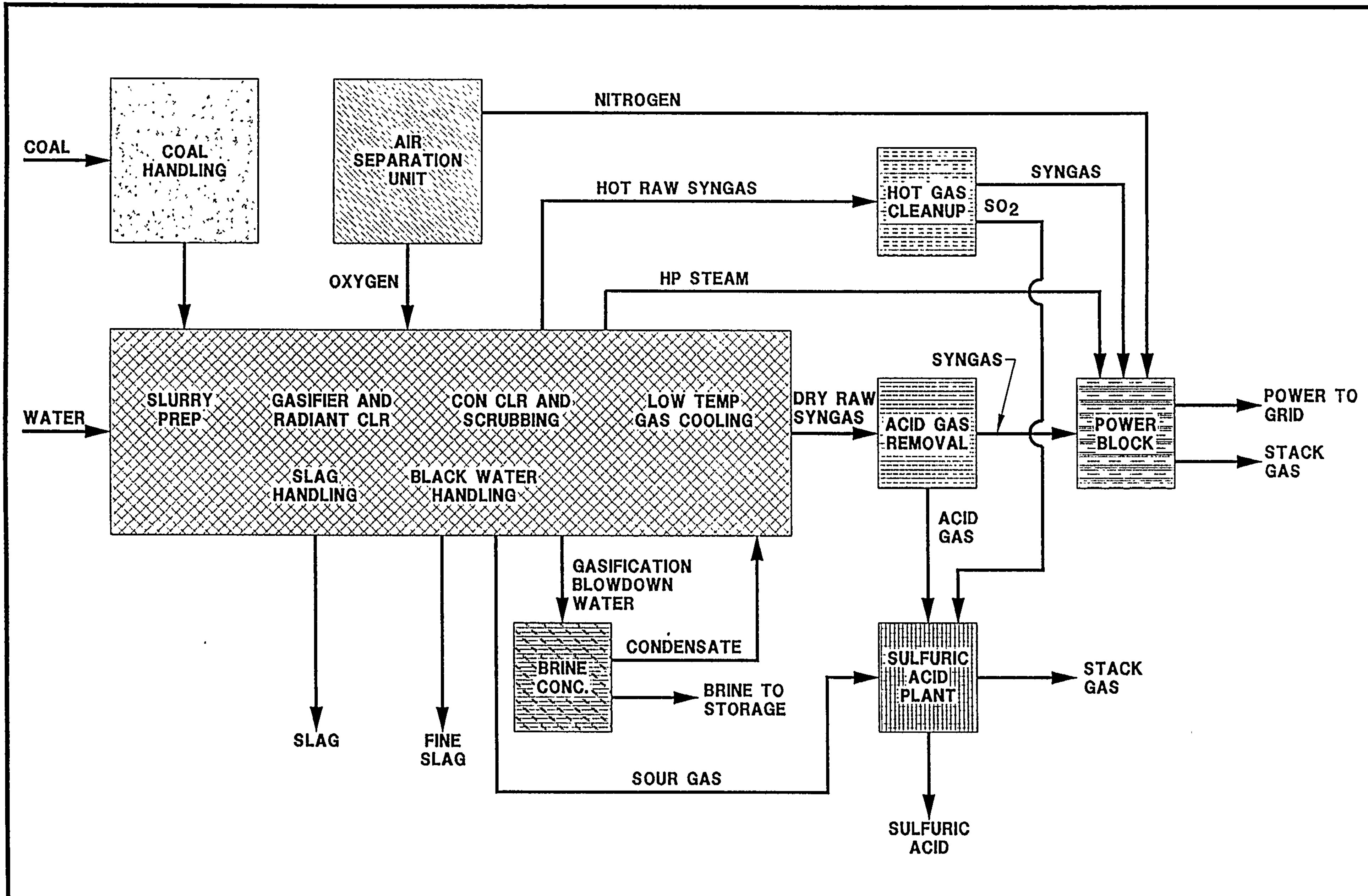

IGCC Facility
Air Separation Unit
Nitrogen
Oxygen
High Pressure Steam
Clean Syngas
Combustion Turbine
Electricity
Gasifier
Gas Cleanup
Coal Water
Syngas
Exhaust Gas
Boiler
Boiler Feed Water
Sulfur Removal
Steam Turbine
Electricity
Coal Grinding
Slag Byproduct
Boiler Feed Water
Sulfuric Acid Byproduct
Heat Recovery Steam Generator

FIGURE 4



TAMPA ELECTRIC
A TECO ENERGY COMPANY

POLK POWER STATION UNIT #1
BLOCK FLOW DIAGRAM

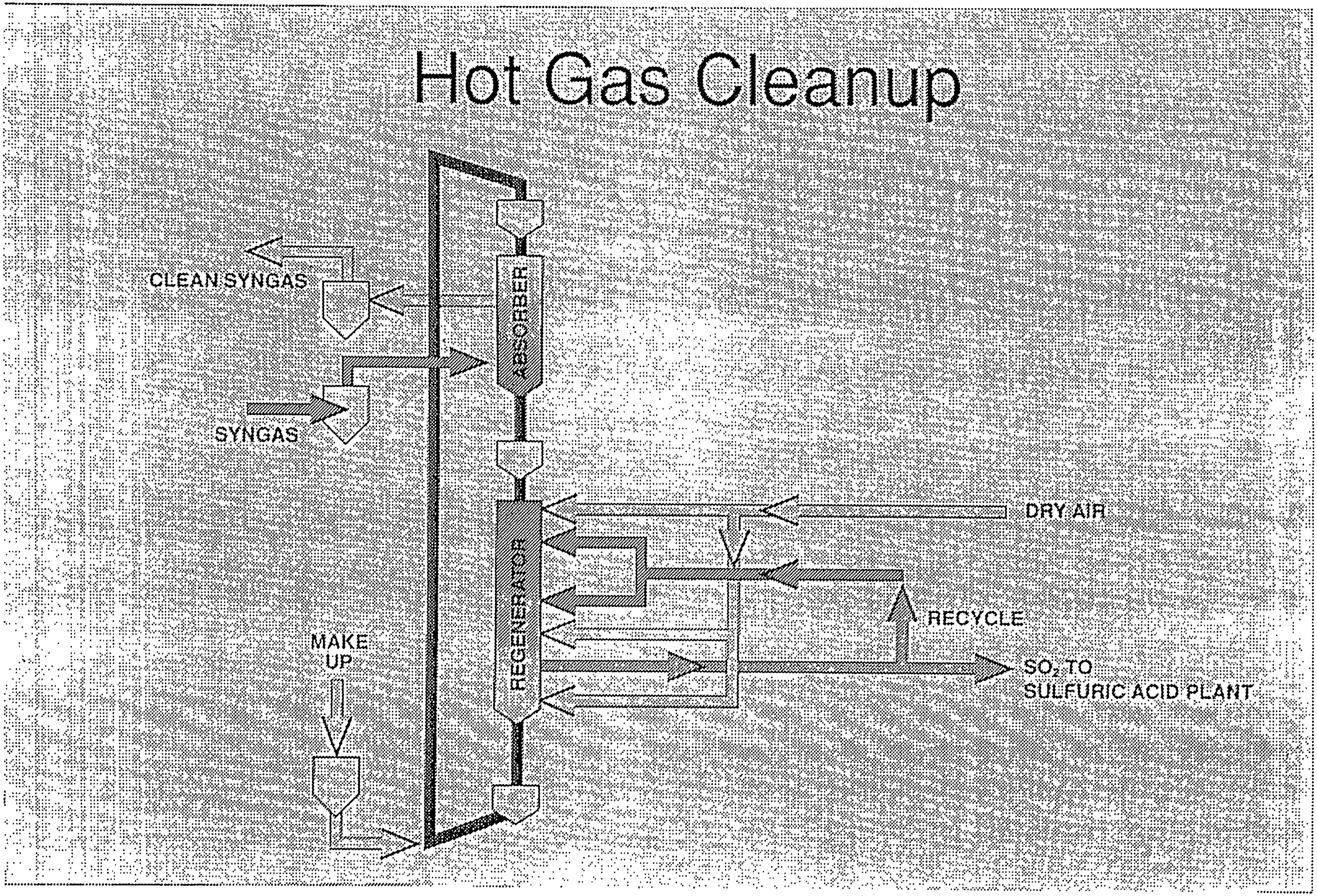

Hot Gas Cleanup
CLEAN SYNGAS
SYNGAS
ABSORBER
REGENERATOR
MAKE
UP
DRY AIR
RECYCLE
SO2 TO
SULFURIC ACID PLANT

FIGURE 6

SULFURIC ACID PLANT

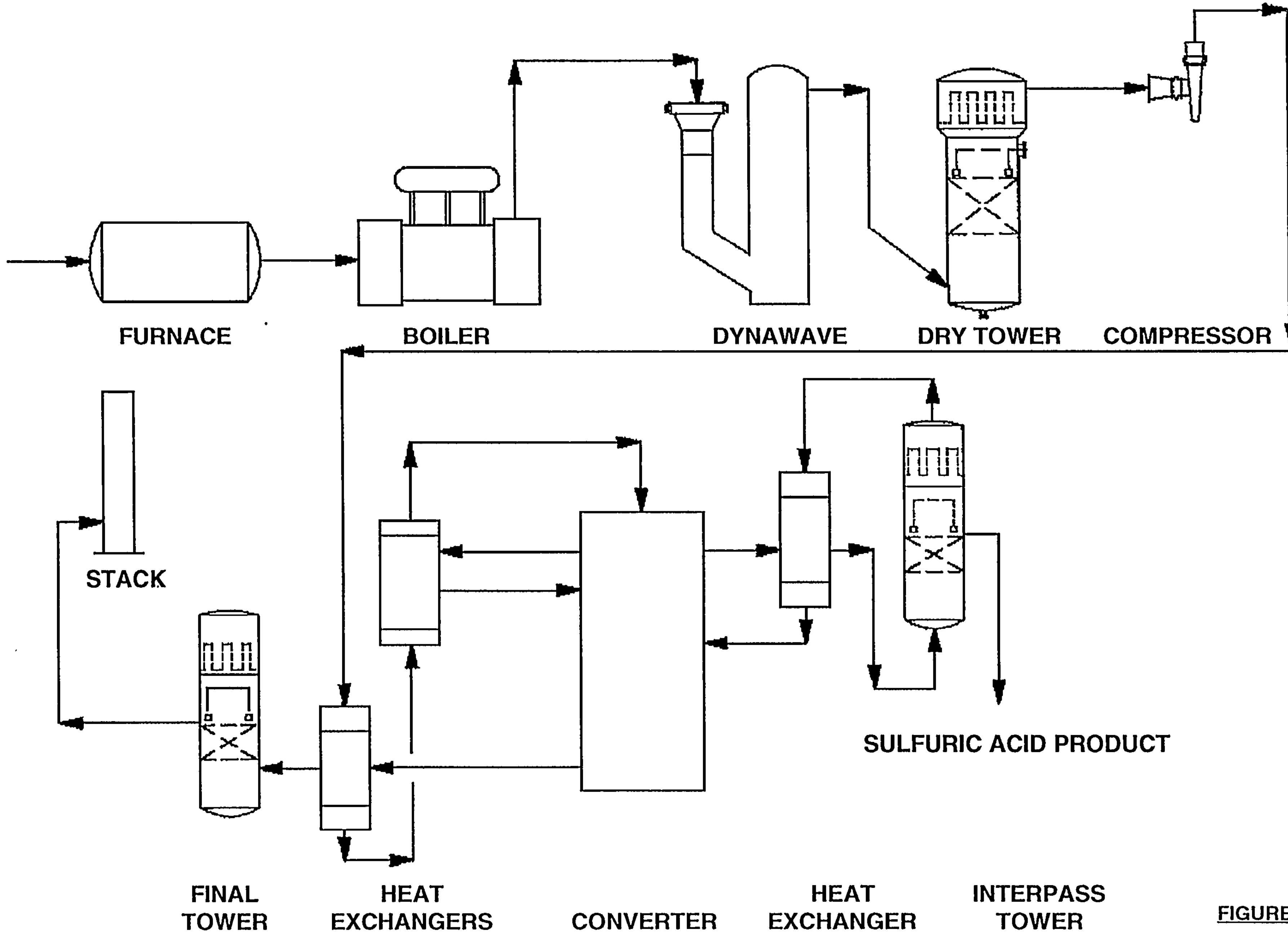


FIGURE 7

POLK POWER STATION PROJECT SCHEDULE

- July 1994 - Start Site Development
- April 1995 - Monsanto Enviro-Chem Site Mobilization
- January 1996 - Start up Combustion Turbine on No. 2 Fuel Oil
- February 1996 - Sulfuric Acid Plant Mechanical Completion
- July 1996 - Production of First Syngas
- September 1996 - Performance Tests Begin for All Plant Systems
- October 1996 - Commercial Operation of Entire IGCC Project

FIGURE 8