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MEMPHIS LIGHT, GAS AND WATER DIVISION
INDUSTRIAL FUEL GAS
DEMONSTRATION PLANT PROGRAM

ENVIRONMENTAL REPORT

VOLUME I

THE PROJECT

MASTER

August 1979

Submitted By
Memphis Light, Gas and Water Division
to
U.S. Department of Energy
Under Contract ET-77-C-01-2582

Prepared By
Energy Impact Associates
for
Foster Wheeler Energy Corporation

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MEMPHIS INDUSTRIAL FUEL GAS

DEMONSTRATION PLANT PROJECT

DEMONSTRATION PLANT ENVIRONMENTAL ANALYSIS - VOLUME I
(Deliverable #27)

NOTICE

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ENVIRONMENTAL REPORT FOR THE MEMPHIS LIGHT, GAS AND WATER DIVISION INDUSTRIAL FUEL GAS DEMONSTRATION PLANT

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FOREWORD

This document is an Environmental Report on the Memphis Light, Gas and Water Division Industrial Fuel Gas Demonstration Plant. This report was prepared for Memphis Light, Gas and Water Division for submission to the U.S. Department of Energy under Contract ET-77-C-01-2582.

This document is Volume I of a three-volume Environmental Report. Volume I consists of the Summary, Introduction and the Description of the Proposed Action. Volume II consists of the Description of the Existing Environment. Volume III contains the Environmental Impacts of the Proposed Action, Mitigating Measures and Alternatives to the Proposed Action.

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CONTENTS

TABLE OF CONTENTS

VOLUME I: THE PROJECT

(Continued)

TABLE OF CONTENTS (Continued)

(Continued)

TABLE OF CONTENTS (Continued)

(Continued)

TABLE OF CONTENTS (Continued)

(Continued)

TABLE OF CONTENTS (Continued)

(Continued)

TABLE OF CONTENTS (Continued)

(Continued)

TABLE OF CONTENTS (Continued)

VOLUME II: THE ENVIRONMENT

(Continued)

TABLE OF CONTENTS (Continued)

(Continued)

TABLE OF CONTENTS (Continued)

(Continued)

TABLE OF CONTENTS (Continued)

(Continued)

TABLE OF CONTENTS (Continued)

(Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

VOLUME III: IMPACTS AND ALTERNATIVES

(Continued)

TABLE OF CONTENTS (Continued)

(Continued)

TABLE OF CONTENTS (Continued)

(Continued)

TABLE OF CONTENTS (Continued)

(Continued)

TABLE OF CONTENTS (Continued)

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TABLE OF CONTENTS (Continued)

LIST OF FIGURES

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LIST OF TABLES (Continued)

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LIST OF TABLES (Continued)

SUMMARY

SECTION S.0
SUMMARY

S.1 INTRODUCTION

This environmental report describes the proposed action to construct, test and operate a coal gasification demonstration plant in Memphis, Tennessee, under the co-sponsorship of the Memphis Light, Gas and Water Division (MLGW) and the U.S. Department of Energy (DOE).

The plant, designated the Industrial Fuel Gas Demonstration Plant (IFGDP), will convert high-sulfur eastern bituminous coal into approximately 171 million R
standard cubic feet per day of environmentally clean medium-Btu gas having a heating value of 300 ± 30 Btu per standard cubic foot. This gas will be usable by industrial customers in the Memphis area as combustible fuel in place of natural gas and fuel oil. The IFGDP will also produce elemental sulfur as a commercial by-product.

The IFGDP will incorporate a "credit generation" system to assure reliability of gas supply to customers. A portion of the industrial fuel gas (IFG) produced will be normally converted into pipeline gas having a heating value
of 950 Btu per standard cubic foot and a composition nearly identical to R
natural gas. The "credit generation" system will convert approximately 16.7 R
million standard cubic feet per day of IFG into approximately 4.3 million R
standard cubic feet per day of pipeline gas. This pipeline gas will be R
supplied to the Memphis natural-gas distribution system to generate credits which can be withdrawn later as required.

Figure S-1 is a pictorial schematic of the overall plant showing the major material inputs to the plant (coal, steam, air) and the major products and by-products (IFG, pipeline gas, elemental sulfur). The rates of material supply and production for the plant under normal conditions with three gasifiers operating at full capacity are also shown.

It is planned that the IFGDP will begin operating in 1984 for a period of demonstration testing to be followed by commercial operation of the plant. The project life is estimated to include 4 years for detailed engineering

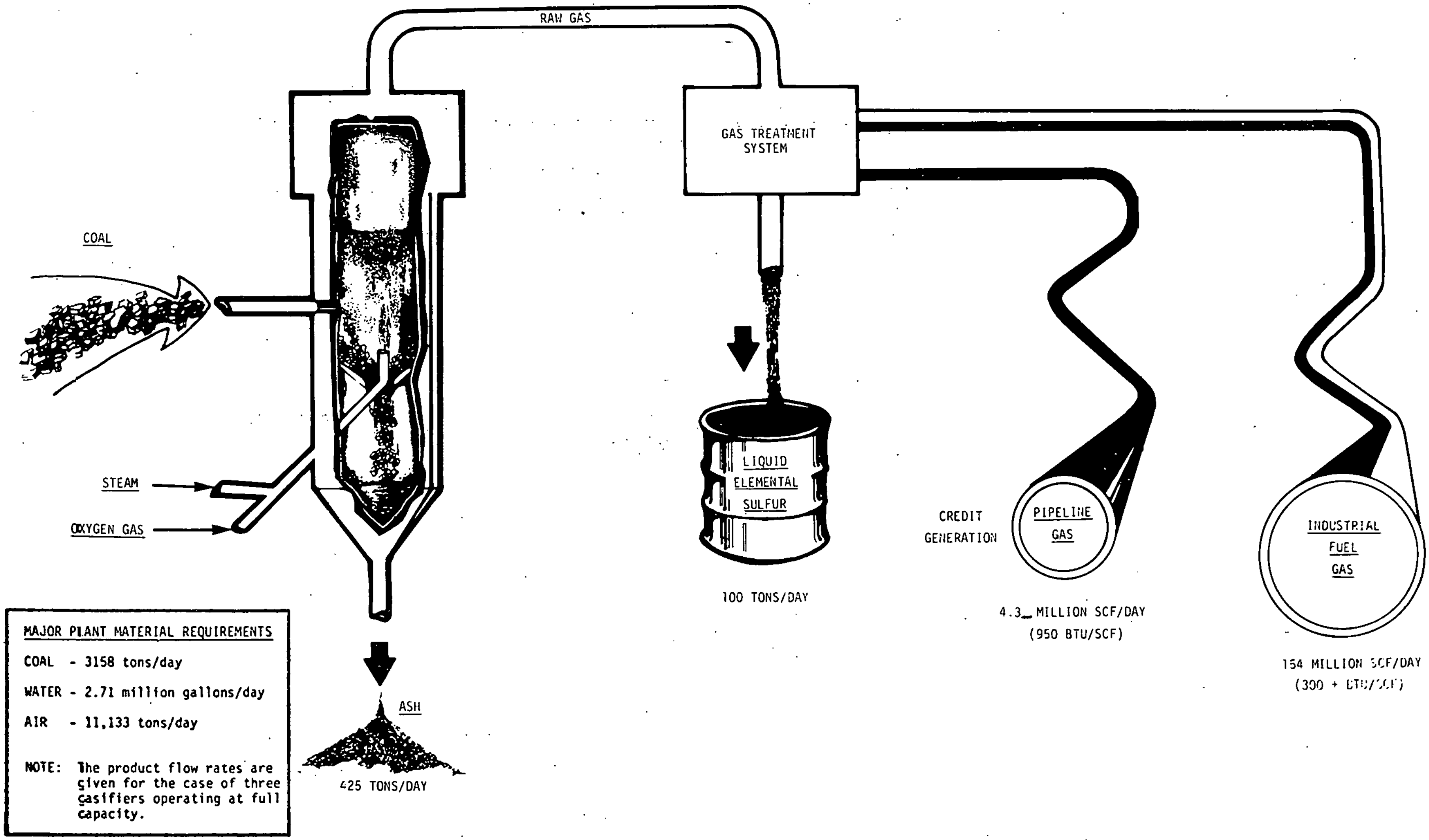

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Figure S-1. Pictorial Schematic of the Memphis Industrial Fuel Gas Demonstration Plant Showing Material Requirements and End Products

REVISED
November 1979

design and construction, 2 years for demonstration testing and 20 years for commercial operation of the plant.

The plant as proposed will meet all presently applicable federal, state and local environmental regulations.

S.2 PROJECT BACKGROUND

In 1976, the U.S. Department of Energy (DOE), which at the time was the U.S. Energy Research and Development Administration, announced it would co-sponsor a series of coal gasification demonstration plants to encourage the development of practical technology for converting coal into a useable gaseous fuel as a means of encouraging the country's energy self-sufficiency. A request for proposal, RFP E-(49-18)-2043, was issued, and MLGW responded with a proposal in May 1976.

In 1977, MLGW and the W. R. Grace Company were selected by DOE to conduct a design competition which could lead to the construction and operation of a demonstration plant for industrial fuel gas. The programs are being conducted in phases with costs during each phase borne by DOE and the participants in varying proportions. The information contained in this environmental report has been developed and prepared entirely during Phase I of the MLGW program, which is totally financed by DOE.

The overall need for this project is based both on DOE's objectives to demonstrate the technical, economic and environmental feasibility of producing synthetic gas from coal for industrial applications and on MLGW's desire to alleviate the natural gas supply shortage in the Memphis area.

Beginning in 1975, MLGW, as distributor of natural gas in the Memphis area, experienced sharp seasonal curtailments of natural gas from its pipeline supplier, Texas Gas Transmission Corporation. These seasonal curtailments were passed on to industrial customers under contracts with them for interruptable supply. Present usage of natural gas by industry is about 30 percent below 1974 levels, and projected supply levels of natural gas will continue to leave a shortage. The curtailments have hampered the economic development of the area. Therefore, MLGW has actively sought alternate sources of gaseous fuel for its customers.

Most industries that have been curtailed in their gas usage have switched to low-sulfur distillate fuel as their alternate energy source, resulting in increased dependence on foreign energy resources. These industries are potential IFG customers. Availability of coal-derived IFG will, in most cases, directly displace the use of fuel oil and natural gas, benefitting the general economy of the Memphis area as well as that of the United States in the long run.

S.3 DESCRIPTION OF THE PROPOSED PLANT SITE AND ENVIRONS

The proposed site for the plant is located approximately 13 kilometers (8 miles) west-southwest of downtown Memphis, Tennessee and is within the limits of both Shelby County and the City of Memphis (see Figure S-2). The site is on a peninsula extending into Lake McKellar situated approximately 1.2 kilometers (4000 feet) east of the Mississippi River. The site boundaries encompass 0.54 square kilometer (134 acres) of land. The site is zoned for heavy industry, but industrial activity is currently limited to using parts of the area to receive dredged material from Lake McKellar.

Elevation -- Figure S-3 is an aerial photograph of the site and surrounding area. Much of the site is presently at an elevation around 62.5 meters (205 feet) above mean sea level. Portions of the site are periodically flooded, particularly following spring snowmelt in the Mississippi River basin. As a result, the site area will be elevated prior to construction of the IFGDP to protect it from flooding. Embankments rising to an elevation of 71 meters (233 feet) above mean sea level will surround the site. This elevation exceeds the U.S. Army Corps of Engineers recommendation for the project-design flood. The 100-year flood level at the site is about 68.5 meters (224.9 feet) above mean sea level. The Presidents Island industrial complex across Lake McKellar is built at an elevation of 70.1 meters (230 feet) above mean sea level. Fill material for the purpose of raising the site will be obtained from near-by dredging operations in the Mississippi River and will be sandy in composition.

Socioeconomics -- The site area is located within the three-county Memphis Standard Metropolitan Statistical Area (SMSA). This is a major and growing metropolitan area with strengths in wholesale and retail trade, manufacturing, services and government. Land use is predominantly urban, although there is a significant amount of agricultural land remaining. All the facilities and amenities of comparably-sized SMSA's in other parts of the country are found here, especially transportation facilities, educational systems and medical and public health facilities. Housing construction is expanding to meet

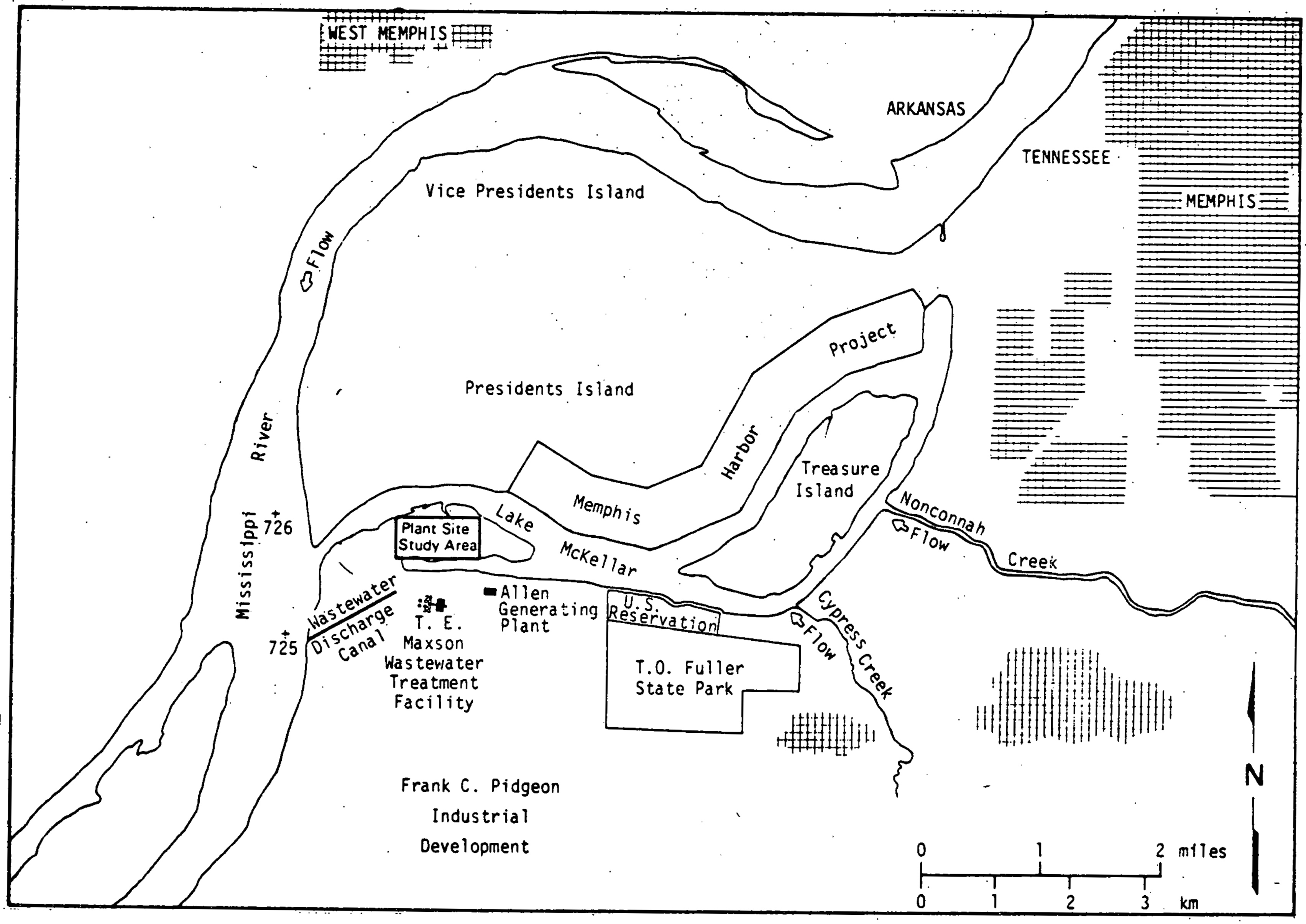

Figure S-2. Proposed Site for the Memphis Industrial Fuel Gas Demonstration Plant

Figure S-3. Aerial Photograph of the Region Surrounding the Site of the Proposed Memphis Industrial Fuel Gas Demonstration Plant current and projected growth. Population in the SMSA is increasing, as is the local labor force. This assures an adequate pool of local workers for construction and operation of the IFGDP.

Land Use -- The region around the proposed plant site is rural in nature and also zoned for industrial use. A large area (Frank C. Pidgeon Industrial Development) being held for future development is close-by, as is the T. E. Maxson Wastewater Treatment Facility and a large electrical generating station (TVA's Allen Generating Plant). The closest community development and housing of any significant extent is about 5 kilometers (3 miles) from the site, west of Fuller State Park. A portion of the land on Presidents Island and in the Pidgeon Development area is currently under agricultural production.

Seismology -- The proposed site is in Seismic Risk Zone 3. A regional earthquake risk study prepared for the Mississippi-Arkansas-Tennessee Council of Governments indicated that a seismic event of magnitude VI on the Mercalli scale would occur six times per one hundred years on the average and would result primarily from seismic events centered near New Madrid, Missouri, approximately 165 kilometers (102 miles) north-northeast of the site. This study stated: " ... the maximum credible earthquake expected to occur in the [plant] area will have a Richter Magnitude of 7.4 (epicentral Mercalli Intensity of X) and will have a repetitive occurrence about every 500 to 700 years." The IFGDP will be built to withstand such a risk.

Water Resources -- The two major surface water bodies adjacent to the site area are the Mississippi River and Lake McKellar. Very little surface water is used for domestic, industrial or agricultural purposes in the Memphis area within 4.8 kilometers (3 miles) of the IFGDP site. The Memphis public water system derives its supplies from two artesian aquifers identified according to their depths as the "500-foot" and "1400-foot" sands. A shallow groundwater aquifer exists beneath the site area.

Water Quality -- Water quality in Lake McKellar, the Mississippi River and the shallow groundwater aquifer beneath the site is generally good, although it is possible to discern the accumulated results of urban, industrial, and agricultural discharges from the vast watershed area. Some EPA water quality criteria are exceeded. Manganese and iron are at high levels in local water bodies during all seasons. This condition is most pronounced in groundwater, indicating that natural geochemical sources are responsible. Heavy metals, nutrients and organic loading are generally in a low to medium range, except for phenol, which often exceeds criteria. During the summer months when Lake McKellar is stratified, dissolved oxygen concentrations become depleted in the deeper water layers. Bottom sediments are considered to be mostly nonpolluted and are of a higher quality in the river than in the lake. Groundwater is highly buffered and of a similar water quality as the surface waters.

Climatology -- The existing climate of the southwestern Tennessee area in the vicinity of Memphis is typical of the low-elevation region of the mid-southern United States. Summers are generally warm and humid, while winters are generally mild. Rainfall is abundant and reasonably well distributed throughout the year. During most months of the year, the prevailing direction of the wind is north-to-northwest, although it often blows toward the south during the winter months.

Air Quality -- The existing air quality at the plant site meets the National Ambient Air Quality Standards for all pollutants except ozone. However, the site is close to a portion of Shelby County, i.e., Presidents Island, that is presently classified as being in nonattainment of the Standards for particulate matter.

Noise -- Ambient noise levels in the vicinity of the plant site are higher than in a normal rural environment. Insects are the most significant contributor to these high levels, with additional contributions from the nearby TVA Allen Generating Plant, the Maxson Wastewater Treatment Facility and occasionally from airplanes and barges.

Geology -- Much of the site is covered by a silty dredge spoil to a depth of 0.6 to 1.5 meters (2 to 5 feet). Beneath this is a series of layers consisting of sands and gravels to a depth of about 44 meters (145 feet). Below this is a very dense clay ranging in thickness from about 30 to 43 meters (100 to 140 feet) which extends to the beginning of the so-called Memphis or "500-foot" sands. The silty clay is essentially impermeable and acts as a confining layer for the Memphis sands. About ninety-five percent of the drinking water for the City of Memphis comes from these sands, with the remainder coming from the "1400-foot" sands.

Terrestrial Ecology -- The soil on the site is primarily sand with small amounts of topsoil. Terrestrial ecology within 3 kilometers (1.8 miles) is typical of the Mississippi River floodplain. Vegetation on the site consists mostly of (a) successional bottomland forest with black willow trees predominating and (b) meadowland. No plant species listed by the U.S. Department of Interior or the state of Tennessee as threatened or endangered were observed on the site during the 1978-79 field surveys.

Wildlife species, especially birds and reptiles, are locally abundant in the vicinity of the site and include six classified species -- (a) bobcat, listed as threatened by the U.S. Department of Interior, (b) marsh hawk and sharp-shinned hawk, listed as threatened by the state of Tennessee, (c) Mississippi kite, listed as endangered by the state of Tennessee, and (d) swamp rabbit and six-lined racerunner, listed as special by the state of Tennessee. As expected on a floodplain, portions of the local region are classified as wetland and are habitat for these species.

Use of the site by wildlife has been limited by the annual late fall dredging of the Memphis harbor channel which deposits muddy water on the site. Previous nearby clearing of floodplain forests for soybean fields and industrial developments along the harbor shoreline have also limited wildlife value. However, soybean fields and meadow vegetation provide a significant resource for native and introduced wildlife species, and they supplement forest and open water habitat.

Aquatic Ecology -- Aquatic species in the Mississippi River near the site are characterized by the following: the fish community is a warmwater type dominated by rough and forage species such as gizzard shad, carpsuckers, buffalo and carp; the community of benthic macroinvertebrates (bottom dwelling organisms) is poorly developed; plankton (free-floating microscopic plants and animals) is diverse but relatively sparse; periphyton (attached microscopic plants) is fairly diverse and abundant; and macrophytes (larger aquatic plants) are absent. Biological communities found near the site are not unique to the middle Mississippi River.

Aquatic species in Lake McKellar near the site are characteristic of warm backwaters, with regular dredging having affected some components of the eco-system. The fish community is a varied, warmwater type dominated by rough and forage fish such as gizzard and threadfin shad, although a number of sportfish, e.g., sauger, largemouth bass and catfish, are present. Lower water velocities allow more abundant and diverse bottom dwelling organisms and zooplankton (microscopic animals) assemblages than found in the Mississippi River. However, all types of vegetation are restricted by reduced light penetration due to high turbidity.

No aquatic species included on either the U.S. Fish and Wildlife Service or the Tennessee Wildlife Resource Agency list of threatened or endangered species were encountered in Lake McKellar or the Mississippi River during the 1978-79 field surveys, nor were any noted in other studies reviewed.

S.4 DESCRIPTION OF THE PLANT AND PROCESS

S.4.1 PLANT DESCRIPTION

The proposed placement of major plant facilities on the site is indicated in the preliminary plot plan, Figure S-4. Major areas include access roads, process and support facilities, coal and ash storage areas and barge unloading facilities. The process and support facilities consist of coal storage, coal and coke handling, coal gasification, gas cleanup, cooling towers, gas treatment, credit generation, wastewater treatment and solid waste disposal.

Most of these facilities will be constructed at an elevation of approximately 71 meters (233 feet) above mean sea level. Short-term ash storage and long-term coal storage will be at an elevation of approximately 68.6 meters (225 feet). Long-term ash storage will start at an elevation of 64 to 68.6 meters (210 to 225) feet above mean sea level and will be surrounded by a levee at the 71 meter mean sea level elevation. These elevations will be attained by filling the site with a sandy material hydraulicly dredged and deposited on the site. The exterior of the elevated area will be covered with rip-rap where necessary.

Several off-site facilities associated with the IFGDP will be constructed. These include water supply and wastewater discharge pipelines, electric transmission lines, telephone lines, a natural gas pipeline and an IFG distribution system. Most of these off-site facilities will be constructed along existing rights-of-way.

S.4.2 PROCESS DESCRIPTION

The IFGDP will produce industrial fuel gas (IFG) and pipeline gas as its main products. All waste products will be treated or handled so that they may be disposed of without significant environmental impact.

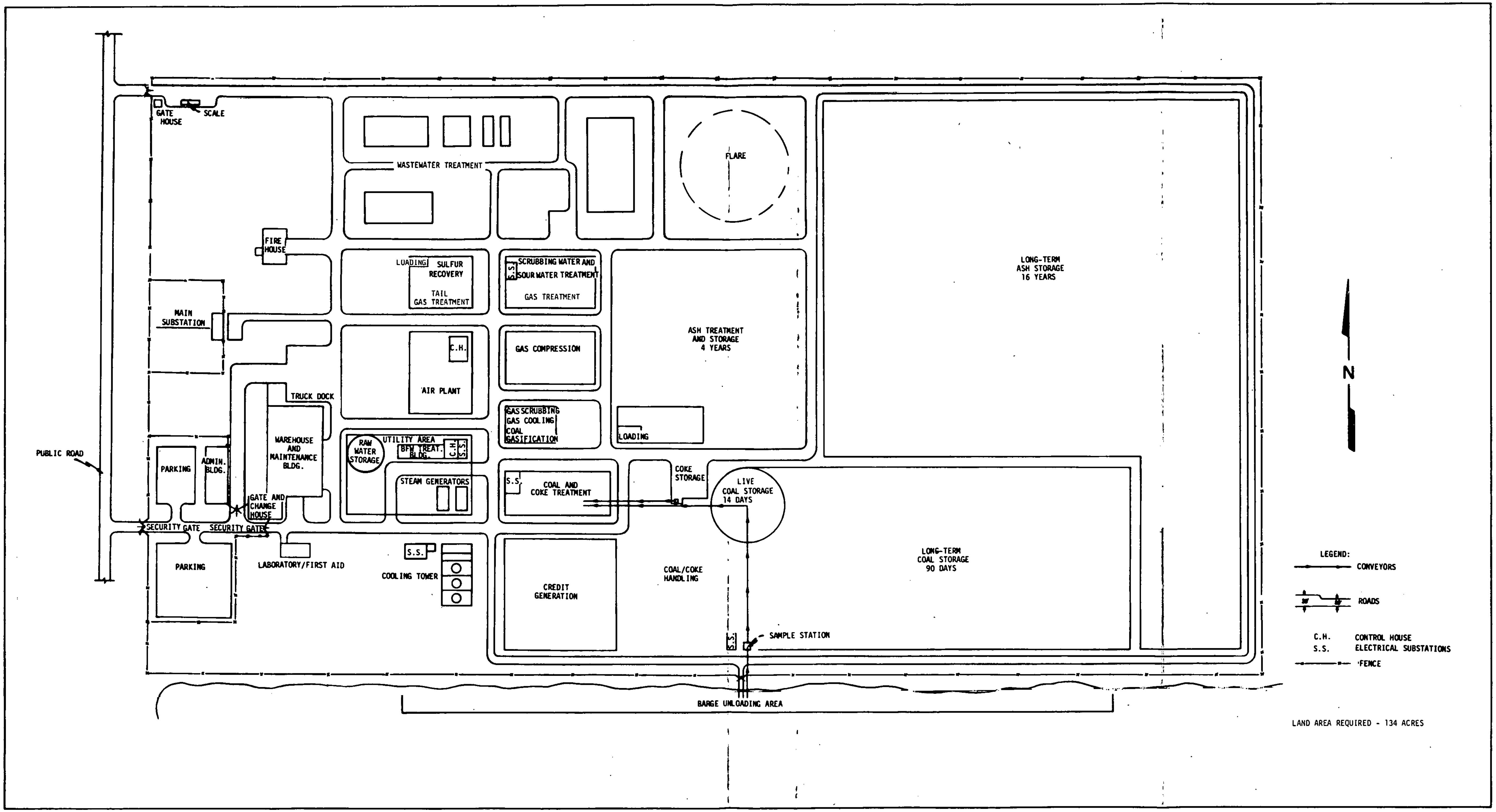

Figure S-4. Preliminary Plot Plan Showing the Location of Major Facilities

The overall process consumes coal, atmospheric oxygen and water (steam) in a gasifier at high temperature. Figure S-5 is a simplified flow diagram that shows the major process units, their interconnections and the major input and output materials.

Crushed coal, oxygen and steam are combined in a gasifier at high temperature to form the "raw" fuel gas. The gasifier is a fluidized-bed unit using the U-GAS™ process developed by the Institute of Gas Technology. Gas from the gasifier is processed by cooling and scrubbing to remove particulates and water soluble material. After scrubbing, the gas is compressed and treated to remove unwanted gases. Hydrogen sulfide, resulting from sulfur in the input coal, and a portion of the carbon dioxide are removed. Cleaned IFG then flows to the IFG distribution pipeline and to the Credit Generation unit, where it is processed to pipeline gas quality that is comparable to natural gas. Sulfur compounds removed during Gas Treatment are converted to elemental sulfur which is recovered for sale as a by-product.

A portion of the steam for the gasifier and other process units is produced in the Steam Generation unit by burning coal. Particulate matter and sulfur dioxide from burning coal are reduced to acceptable levels prior to being discharged into the atmosphere. Other gaseous streams containing particulate matter and sulfur compounds are also treated to acceptable levels before emission. Table S-1 gives the emission rate and composition of the major gases released to the atmosphere under the conditions of maximum plant operations with four gasifiers operating at 75 percent capacity. Normally, the plant operates with three gasifiers running at 100 percent capacity, and the emissions will be lower than shown. Table S-1 includes gaseous emissions from other process units not shown in Figure S-5.

Wastewater from various process units and rainfall collected at the IFGDP site is treated before being discharged to the Mississippi River. This treatment includes removal of suspended particulate matter, organic materials (including oils) and metals such as chromium and zinc. Sanitary sewage is piped to the nearby Maxson Wastewater Treatment Facility. Composition and flow rates for the wastewater stream are given in Table S-2.

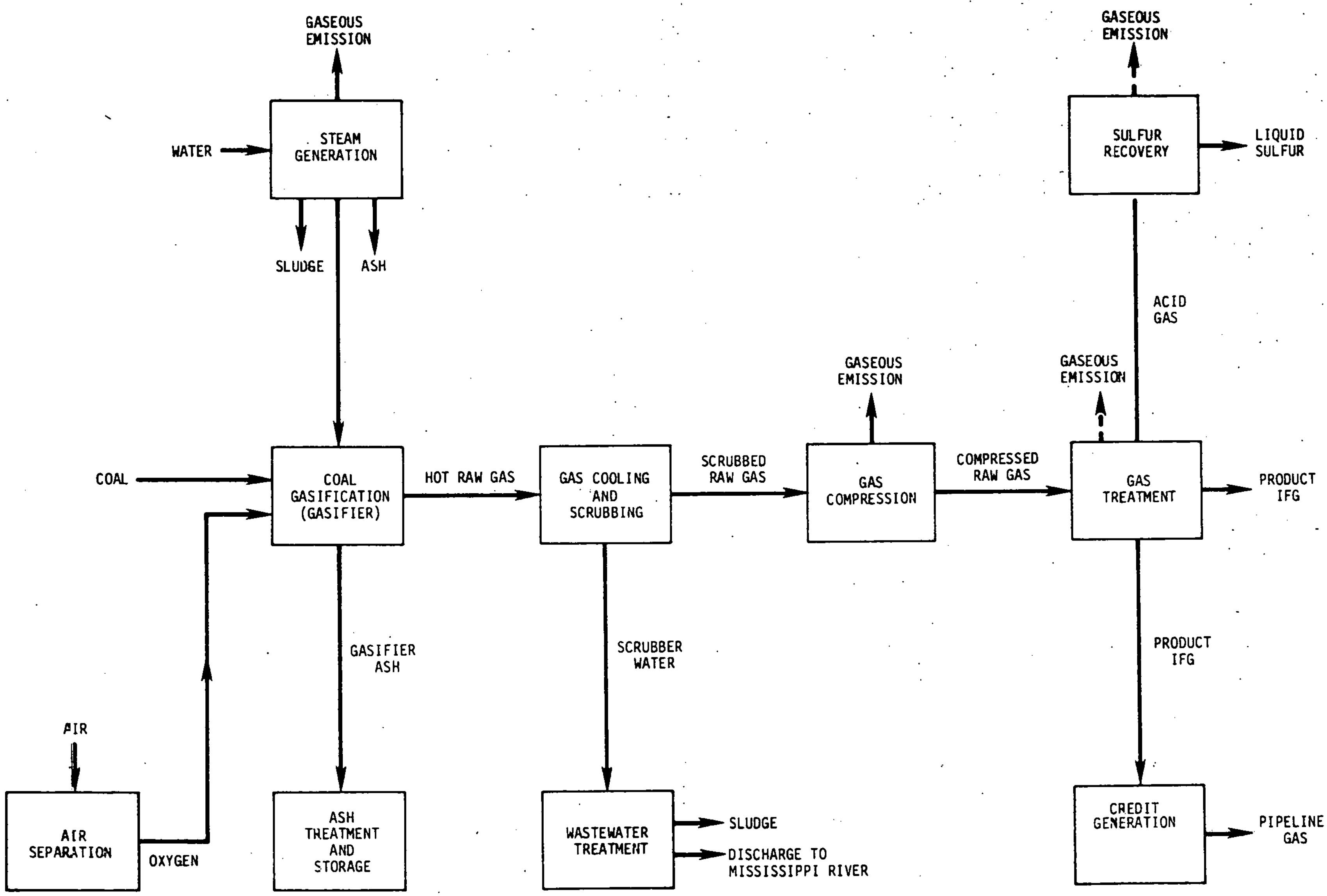

Figure S-5. Simplified Block Flow Diagram of the IFGDP

TABLE S-1

MAJOR GASEOUS EMISSIONS FROM THE MEMPHIS INDUSTRIAL FUEL GAS DEMONSTRATION PLANT

Constituents	Tail Gas Treating Vent Gas	Stack Gas to Atmosphere	Cooling Tower Evaporation	Flare Flue Gas	
Nitrogen (N_2)	19,400*	393,580	--	76,210	
Carbon Dioxide (CO_2)	31,800	248,080	--	60	
Water Vapor (H_2O)	1,500	66,765	459,500	1,045	
Oxygen (O_2)	--	24,320	--	40	
Hydrogen (H_2)	12	--	--	--	
Sulfur Dioxide (SO_2)	--	295	--	Less than 0.001	R
Particulates	--	35	--	Less than 0.01	
Nitrogen Oxides (NO_x)	13	460	--	Less than 0.01	
Ammonia (NH_3)	1	--	--	--	
Hydrocarbons (as Methane, CH_4)	--	6	--	Less than 0.01	
Carbon Monoxide (CO)	20	27	--	Less than 0.01	
Hydrogen Sulfide (H_2S)	10 ppm max	--	--	--	
Carbonyl Sulfide (COS)	2	--	--	--	
Carbon DiSulfide (CS_2)	0.1	--	--	--	
Ozone (O_3)	--	Less than 0.1	--	--	
TOTAL	52,748 lb/hr	733,588 lb/hr	459,500 lb/hr	77,355 lb/hr	

* Emission rates given in terms of pounds per hour for maximum plant operation (i.e., four gasifiers running at 75 percent capacity).

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November 1979

TABLE S-2

COMPOSITION OF WASTEWATER EMISSION FROM THE MEMPHIS INDUSTRIAL FUEL GAS DEMONSTRATION PLANT

Flow, lb/hr	450,000
pH	6-9
Constituents (milligrams/liter)	
TDS	1200-2400
TSS	20-30
COD	25-65
TOC	5-20
BOD_5	20-30
Oil & Grease	5-15
Phenol	<0.1
NH_3-N	0.5-3
CN-	<0.05
SCN-	<0.3
H_2S	<0.1
Ag	0.005
As	0.03
Be	0.005
Cd	0.05
Cr	0.06
Mg	0.03
Ni	0.03
Pb	0.5
Sb	0.03
Se	0.10
Tl	0.03
Zn	0.3
Others	<1
Priority Organics	<0.5

* Abbreviations are TDS (total dissolved solids), TSS (total suspended solids), COD (chemical oxygen demand), BOC_5 (five-day biological oxygen demand), and TOC (total organic carbon).

Solid wastes generated by the IFGDP include ash from the Coal Gasification and Steam Generation units, sludge from the removal of sulfur dioxide from Steam Generation unit gases and sludge from the Wastewater Treatment unit. Solid wastes are stored on the IFGDP site, which has provisions for up to 4 years production of ash in a short-term disposal area and sufficient additional space for storage of 16 more years production if necessary in a long-term disposal area. Should markets for gasifier ash and sulfur-removal sludge be developed, these materials will be sold and removed from the IFGDP plant site.

S.5 PLANT ENVIRONMENTAL IMPACTS

Some environmental impacts to the plant area are expected to occur as a result of both the construction and operation phases of the project. The following is a summary of the impacts expected after the planned mitigating measures are implemented.

S.5.1 CONSTRUCTION

Site Buildup -- Construction phase impacts are expected to be minimal. Elevation of the site with dredged material from the Mississippi River is not expected to constitute a long-term adverse physiographic or geological impact. The design and placement of the embankment will conform with the flood control objectives of the U.S. Army Corps of Engineers and not pose an additional problem to nearby areas.

Terrestrial Ecology -- Construction will temporarily disturb about 75 hectares (185 acres). A little over 20 hectares (49 acres) will be allowed to return to preconstruction vegetation. About 28 hectares (69 acres) of low to medium quality wetland will be removed, resulting in only minor impact since the area is flooded naturally every year and portions are also used as a wasting area for dredge spoils.

Mobile wildlife including birds and large mammals will be displaced from the site peninsula during plant construction and from pipeline corridors during pipeline installation. A recovery by these populations to approximately 95 percent of baseline levels during operation is expected as portions of the disturbed land develop into successional forest. Selected species will be affected to a greater or lesser extent depending on their sensitivity to disturbance, food preference and species-specific behavior.

Species populations of special concern that are within 3 kilometers (1.8 miles) of the site center listed as threatened by the U.S. Fish and Wildlife Service or as endangered by the Tennessee Wildlife Resources Agency (for example, the bobcat and the Mississippi kite) will decline during construction and recover during operation as food becomes more available on disturbed land. Nesting habitat of threatened and endangered species will not be disturbed by site activities.

Water Quality -- The buildup phase of construction will increase the total dissolved solids concentration in the surface runoff from the site. However, this addition is not expected to significantly increase the overall total dissolved solids concentration in Lake McKellar. A holding pond, used to allow suspended solids in the runoff to settle, may allow seepage into the shallow groundwater aquifer beneath the site. However, due to the poor quality of this aquifer and the fact that it is not used for drinking, no adverse impacts are expected.

Aquatic Ecology -- Dredging in the Mississippi River will potentially disturb a large volume of bottom sediment, but is not expected to add any significant long-term impact, since the sediment is of a sandy nature. The dredging may temporarily increase total dissolved solids content and may affect areas of bottom habitat and bottom-dwelling organisms. However, the sandy areas to be disturbed are poor habitats for organisms and have been subject to previous dredging. Rapid recolonization of the area by organisms should follow reestablishment of the habitat after dredging.

Two small areas of Lake McKellar will be dredged for: (1) installation of the product IFG and water pipelines and (2) preparation of the barge unloading area. Since the areas affected are small and the lake sediments do not release substantial amounts of trace elements or organic materials on disturbance, only a minor and temporary water quality impact is expected. Rapid recolonization by affected organisms is expected. Stabilization of site shorelines with rip-rap where necessary will destroy some existing soft-bottom habitats and produce new rocky bottoms, but these areas may be suitable for many invertebrates, as well as the spawning of channel catfish, sauger and perhaps white bass.

Air Quality -- During the construction phase, potential air quality impacts are associated with traffic movement, equipment exhaust and fugitive dust from debris. Particulates from traffic movement and debris are expected to cause negligible impacts since debris will be regularly removed and roadways will be either paved or watered down. Equipment exhaust is not expected to impact the ambient pollutant levels since most emissions are expected from diesel construction vehicles.

Noise -- Virtually all noise associated with construction will be inaudible at noise sensitive locations within a 3.2 kilometer (2 mile) radius of the plant site. Any additional noise audible at these locations will be barely perceptible to the human ear. All equipment to be used during construction and operation will meet Occupational Safety and Health Administration specifications for noise. As a result, neither workers nor wildlife are expected to be adversely impacted.

Land Use -- Construction of the pipeline distribution system for the product IFG will take place mainly in industrial areas along existing road rights-of-way and is not expected to affect any residential or recreational areas. No adverse land use, cultural or visual impacts are expected. The current industrial nature of the neighboring area will not be affected by development.

Socioeconomics -- Work on the site is expected to cause several socioeconomic impacts. The construction period will increase vehicular traffic by approximately 1000 vehicles per day along Mitchell Road. Traffic noise through Fuller State Park and the nearby community will increase at travel times, but this is a small fraction (about 18 percent) of the present traffic flow on the road. It is expected to have only a small impact since the traffic will occur during the work week when use of Fuller Park is low. Schools along the route will be unaffected since traffic will occur before school begins in the morning and after dismissal in the afternoon. Also, the direction of traffic flow in the morning and afternoon will generally be opposite to that of most residents travelling to work in the greater Memphis area. Several mitigating measures, such as staggered work hours, car pooling, use of alternate routes and delivery of much equipment by barge will reduce the periodic traffic noise levels in the community.

Construction will generate on-site employment of up to 703 workers and secondary employment of 570 workers in the Memphis economy. Purchases are expected to contribute about $70 million to the area.

S.5.2 OPERATION

Terrestrial Ecology -- Plant operation is not expected to cause any adverse impacts to either vegetation or wildlife. Disturbances resulting from vehicle exhaust fumes, fugitive dust, vehicle movements and human disturbance will continue, but their effects should be minor. Gaseous and particulate emissions will be very low from the plant. Cooling tower drift and stack effluents will cause some deposition of dissolved solids and particulates, but the low deposition rates should not affect the soil.

Water Quality and Aquatic Ecology -- The discharge of wastewater effluent to the Mississippi River will cause only minor impacts to the water quality and aquatic ecology in the local area adjacent to the outfall. The flow of the river will rapidly dilute the concentrations in the discharge, thereby limiting the amount of downstream distance over which Tennessee or EPA Criteria will be exceeded to less than 50 meters (164 feet) in most cases, even under 20-year low flow conditions.

Although mercury and cyanide concentrations in the discharge plume exceed EPA Criteria for fish and aquatic life, the ambient concentration of these species in the river already exceeds these Criteria during the highest seasons. Drinking water standards are still met. Signficiant bioaccumulation of mercury in fish and effects on human consumers of fish is unlikely.

Barge movement and coal spillage in Lake McKellar could have some potential impact under conditions of thermal stratification. Likely effects of barge movement would be disruption of the thermal gradient which is a benefit. Coal spillage can release trace elements from the coal deposits. These impacts are considered to be minor.

Surface water runoff during operation will be collected in a settling basin and released as part of the total effluent to the Mississippi River. Any impact is expected to be minor.

Ashes and scrubber sludges will be placed in the proposed short-term and long-term disposal site. The sites will be lined as necessary with an impermeable plastic liner. Leaching tests conducted on ash representative of that to be produced by the plant indicate it is highly resistent to leaching and would not be classified as a toxic material under the proposed (December 1978) regulations of the Resource Conservation and Recovery Act. No degradation of local water quality resources should occur from disposing of these wastes on the plant site. Potential leachates could enter only the shallow aquifer below the site, which is not used for human consumption. Under the site, the "500-foot" sand aquifer that serves as the main water supply for the City of Memphis is separated from the shallow aquifer by a thick layer of impermeable clay varying in thickness from about 30 to 43 meters (100 to 140 feet). This will preclude any leachate from flowing into the "500-foot" sand.

Coal storage areas are expected to cause no adverse impacts due to runoff since all coal pile runoff will be collected and treated before discharge. This will minimize any water quality impact.

Air Quality -- There are expected to be no adverse effects of gaseous emissions from the plant on the air quality of the surrounding area. Atmospheric dispersion modeling of plant emissions indicates that in most cases, the maximum pollutant concentrations at ground level from the plant will be about 2.0 to 5.0 kilometers (1.2 to 3 miles) north of the proposed site, which places it on the uninhabited portions of Presidents Island.

For normal plant operation, the highest sulfur dioxide concentrations for the annual, 24-hour and 3-hour averaging times are well below half the Prevention of Significant Deterioration Class II Increments which apply to new sources in attainment areas. Furthermore, when sulfur dioxide concentrations from the IFGDP are added to the maximum sulfur dioxide concentrations observed by TVA monitors in the vicinity of the plant, total sulfur dioxide concentrations are still below the National Ambient Air Quality Standards (NAAQS). Similarly, annual nitrogen dioxide concentrations from the IFDGP combined with existing sources are well below the Standards.

For both particulate matter and carbon monoxide, the observed concentrations expected from the plant are below U.S. EPA levels of significance in the present nonattainment areas (Presidents Island and metropolitan Memphis, respectively). The best available control practices will be used to minimize fugitive emissions so that the air quality impacts will be minimized.

Noise -- Virtually all noise associated with operation of the IFGDP will be barely perceptible at all noise sensitive locations within a 3.2 kilometer (2 mile) radius of the plant site.

Socioeconomics -- Operation of the IFGDP is not expected to cause any adverse land use, cultural or visual impacts, although there will be some socioeconomic impacts. Operation will cause an increase in vehicular traffic of approximately 400 vehicles per day through Fuller State Park and the adjoining community. This is expected to have only a minor impact since it is less than 10 percent of the current traffic flow, and the traffic will occur during the work week at times when use of the park is at a minimum. Use of alternate access routes through the neighboring community will be encouraged. Schools are expected to be unaffected since the traffic will occur before school begins in the morning and after dismissal in the afternoons.

Plant operation will generate inside employment of about 270 workers and secondary employment of about 580 workers in the Memphis economy. Annual payments in lieu of taxes could be paid to the general funds of the City of Memphis.

S.6 ALTERNATIVES TO THE PROPOSED PROJECT

MLGW has identified and evaluated a number of alternative means within its sphere of influence to fulfill the need for increased gas energy in the Memphis area. Additionally, alternatives dealing with the gasification process, project location, project size, effluent control processes and plant water sources have been considered.

<u>Alternative Solutions to MLGW's Long-Term Natural Gas Shortage</u> -- The following alternatives were considered:

- No action
- Conservation
- Additional purchase and production of natural gas
- Direct coal use by industry
- Cogeneration/Steam production
- Coal gasification

While a program involving several positive actions is required to resolve a shortage problem of the present magnitude, production of IFG by coal gasification is considered an attractive means to help resolve the natural gas shortage in a major way because it:

- Depends upon coal, a widely available domestic resource that can be readily transported to the Memphis area.

- Produces a gaseous product that present industrial users of natural gas can easily adapt to.

- Provides energy costs that compare favorably to projected (mid-1980's) costs of natural gas and low-sulfur distillate oil.

- Can generate sufficient gaseous energy to supply a significant portion of Memphis industry's energy needs.

- Increases the long-term economic stability and growth potential of the Memphis area.

- Provides the opportunity to demonstrate a domestically-based technology that can reduce the country's dependence on foreign oil.

Coal Gasification -- Various coal gasification processes were evaluated prior to the initial stages of this project. These included fixed-bed gasifiers, entrained-bed gasifiers and fluidized-bed gasifiers with various operating pressures. The Institute of Gas Technology's U-GAS™ process was judged to be the most appropriate for the needs of DOE and MLGW on this project. It is applicable to high-sulfur bituminous coals having a high Free Swelling Index and can produce a fuel gas at an elevated pressure with the desired heating value.

Project Location -- Five candidate sites in Shelby County were identified by MLGW and evaluated on a set of criteria that included economic, environmental, social and engineering considerations. Ratings for the environmental acceptability of using each site for the plant were developed. Relative economic costs for each site were also computed and compared. Considerations were given to recent Executive Orders covering the construction of federal projects in floodplains and on wetlands. The Allen Site was chosen as the most practicable site among the five candidates based on all the factors included.

Project Size -- Based upon the projected market in Shelby County for IFG and the investment cost for the plant, the plant's design capacity of approximately R
50×10^9 Btu per day was determined as best to allow MLGW to economically and reliably supply the IFG market demand in Shelby County beginning in 1984.

Cooling System -- Mechanical draft cooling towers were considered to be the most economical and environmentally compatible cooling system with the available cooling water resources and the heat rejection rate of the IFGDP.

Alternative Plant Water Source -- The City of Memphis water disbribution system can easily accommodate the needs of the IFGDP and was considered to be the most desirable water supply source for the plant. The economic cost and environmental impact of withdrawing water from the Mississippi River, which would require the construction and operation of a treatment system, is not justifiable.

1.0 INTRODUCTION

SECTION 1.0
INTRODUCTION

The Memphis Light, Gas and Water Division (MLGW), in co-sponsorship with the U.S. Department of Energy (DOE), proposes to construct, test and operate a coal gasification demonstration plant in Memphis, Tennessee. The overall objective of this cooperative venture is to demonstrate the technical, economic and environmental feasibility of converting agglomerating, high-sulfur bituminous coal to a clean-burning medium-Btu industrial fuel gas by the U-GAS™ process and to use this gas in a commercial application.

Construction and operation of the plant will: (1) advance the state of the art in the field of industrial fuel gas production from coal, (2) permit detailed evaluation of the costs and benefits of the expanded technology and (3) allow further identification of environmental and social impacts and regional and national economic benefits. Construction and operation activities are considered to be the primary action of this project and are the subject of this environmental report.

The following sections of the Introduction provide a brief description of the proposed plant, explain the background of the project and discuss the need for the plant.

1.1 BRIEF DESCRIPTION OF THE INDUSTRIAL FUEL GAS DEMONSTRATION PLANT

Site -- The proposed plant site is on a peninsula of land located near the confluence of the Mississippi River and Lake McKellar, within both Shelby County and the city boundaries of Memphis (see Figure 1-1). The 134-acre site is approximately 13 kilometers (8 miles) west southwest of downtown Memphis. The land is owned by MLGW, but the Tennessee Valley Authority (TVA) currently holds rights for ash disposal on part of the area. As of August 1979, MLGW and TVA were in the final stages of negotiating a release on this easement. The northern boundary of the site is Lake McKellar, providing easy access to the Mississippi River, which lies approximately 1.2 kilometers (0.7 mile) to the west. The southern channel bordering the site is used as a barge-turning basin.

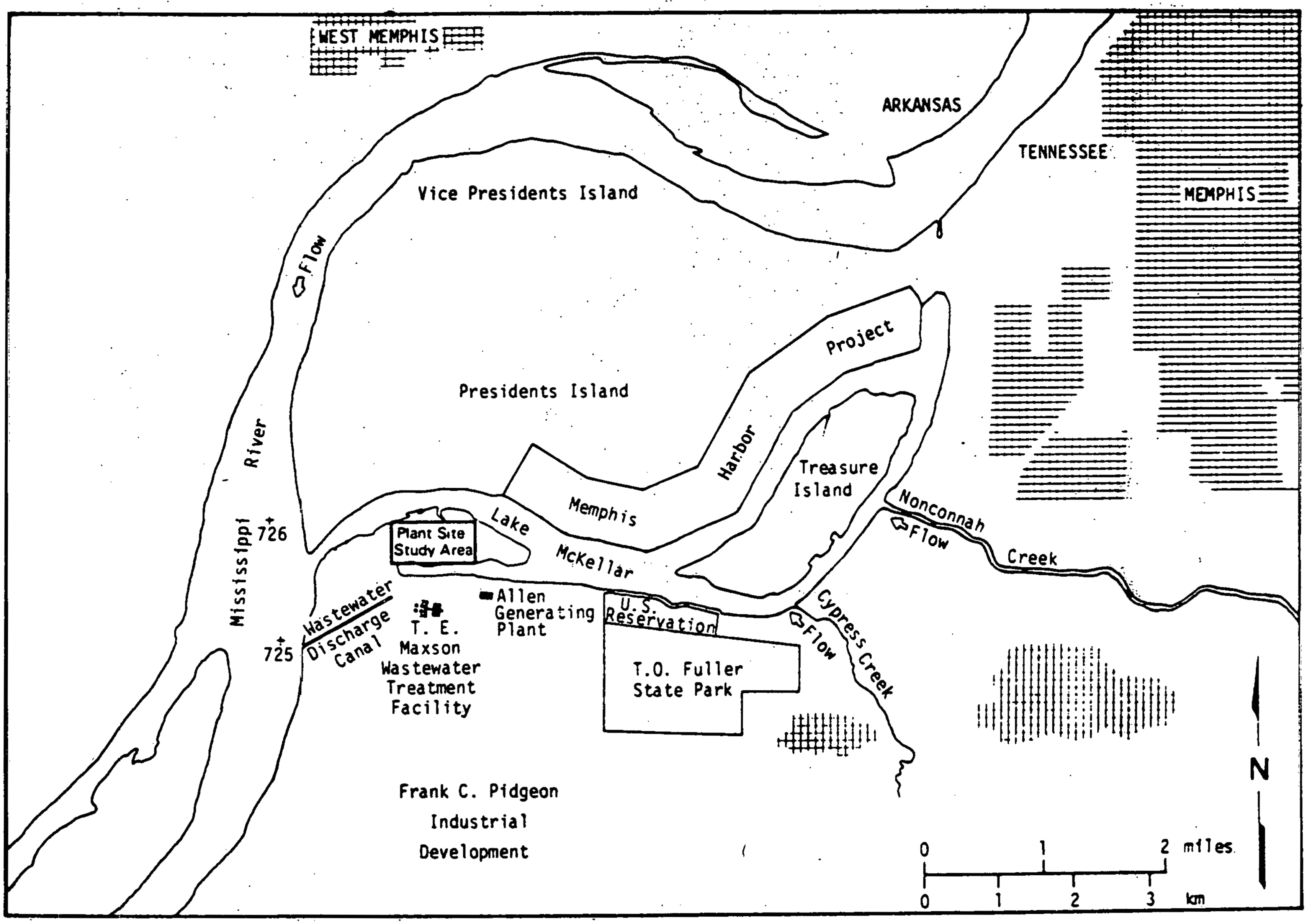

Figure 1-1. Proposed Site for the Memphis Industrial Fuel Gas Demonstration Plant

The site will be elevated with clean fill material from a sand bar in the Mississippi River to a height of 71 meters (233 feet) above mean sea level (msl) to protect the plant from periodic flooding. This location was selected as the best practicable site in Shelby County for the plant considering all environmental, economic, social and time schedule factors. Chapter 381 of the Private Acts of 1939, State of Tennessee, restricts construction by MLGW as a municipal facility to Shelby County.

Plant Description -- The industrial fuel gas demonstration plant (IFGDP) will produce approximately 171 million standard cubic feet per day of medium-Btu R
gas having a heating value of 300 ± 30 Btu per standard cubic foot (scf). A portion of this output will be used for the "credit system" which will be R
highlighted in subsequent paragraphs. Following a work phase to complete R
detailed design and construction, the IFGDP will begin operating in 1984 for demonstration testing, which will be followed by commercial operation. The project life is estimated to include 4 years for engineering and construction, 2 years for demonstration testing and 20 years for commercial operation.

The engineering and design data contained in this environmental report represent the information available as of August 1979. The description is consistent with the conceptual design produced by Foster Wheeler Energy Corporation, the plant designers. It is recognized that detailed design efforts scheduled to begin in 1980 could change some of the information presented here. In any case, however, the IFGDP will be designed, constructed and operated to meet all applicable environmental permits and laws.

The IFGDP will utilize 3158 tons per day of high-sulfur eastern bituminous coal to produce its industrial fuel gas (IFG). This coal will be transported by barge to the plant site. The plant design is based on washed Kentucky No. 9 coal, which is available in substantial commercial quantities, but other eastern bituminous coals could also be used. Sufficient reserves of eastern bituminous coal are already developed that no new mine is specifically required to supply this project. The product IFG will be transported by pipeline beneath Lake McKellar into a separate and independent piping network that will supply a number of industrial customers. This network will be placed along existing rights-of-way. Approximately 100 tons per day of liquid elemental sulfur will also be produced for sale as a by-product from the plant.

Water requirements for the project will be met by deliveries from the Memphis city water supply system, which has both ample reserves and capacity to meet the needs of the plant.

Process Description -- The IFGDP will use the Institute of Gas Technology's (IGT) U-GAS™ coal gasification process to generate the medium-Btu fuel gas. This process is a second-generation coal gasification process that uses a single-stage, fluidized-bed reactor incorporating simple control, reliable operation and ability to use coal fines. The U-GAS™ process has evolved from years of coal-utilization research and development. A pilot plant was constructed in Chicago, Illinois, in 1973 to support development and testing of this process. Since early 1974, the unit has been operated for over 5600 hours for a variety of technical projects and purposes. However, during 1978 and 1979, the pilot plant was operated in direct support of the present project.

Sized coal is fed through a series of lock hoppers to the gasifier where it is fluidized by a flow of oxygen gas and steam. A portion of the coal is oxidized to provide some of the heat required for reaction, while the remainder is converted to "raw" gas. The process uses elevated pressure (90 pounds per square inch absolute) fluidized-bed, agglomerating ash, gasifier operating at 1875°F. This temperature is sufficiently high to cause the ash to soften and agglomerate. The unit contains conical internals near its bottom. Softened ash is agglomerated within the gasifier into small solid pellets and is removed from the bottom of the gasifier and quenched.

Provisions have been made on-site for storage of the initial 4 years' production of ash from the gasifier in an environmentally safe manner. Sufficient area is also provided on-site for storage of an additional 16 years' production of ash. This larger area will be treated as required to provide for storage of the ash in an environmentally acceptable manner. However, it is possible that the ash produced by the plant may eventually be sold for some commercial purpose. If future demands should require expansion of the plant, a portion of the long-term ash storage area could be used for this purpose.

The hot, raw gas emerging from the gasifier is subjected to a series of cooling, cleanup and purification steps designed to remove sulfur and other impurities from the gas stream. Commercially available gas treatment equipment is used. The composition of the final product gas is approximately 42 percent hydrogen (H_2), 34 percent carbon monoxide (CO), 18 percent carbon dioxide (CO_2), 5 percent methane (CH_4) and 1 percent nitrogen (N_2). The gas will be usable by industries in the Memphis area as a combustible fuel.

Credit System -- In order to increase the attractiveness of this fuel gas to potential industrial customers, the reliability of supply must be ensured, even during periods of plant shut-down for repair or maintenance. The plant is designed to enhance reliability by the use of modular gasifier trains and several back-up systems, but it is not cost-effective to build complete redundancy into the plant. For the present project, reliability is of special concern because only one plant, rather than several independent plants as would be the case for an already-developed system, will be available to produce gas for customers. Therefore, the IFGDP will also incorporate a "credit system" to assure customers of a continuous fuel supply. During operation, from 10 to 30 percent of the product gas from the IFGDP will be methanated to natural gas quality and introduced into the existing Memphis gas system, thereby accruing "credits" against periods of time when the plant is not operating. During these periods, the "credited" natural gas will be withdrawn, adjusted with air to the proper medium-Btu heating value and distributed to the industrial customers.

Economic Factors -- The facility will be constructed at a capital cost of about $200 million based on 1979 dollars. The on-site construction work force will consist of about 3.0 million job site hours over 36 months, with a peak level of about 703 workers. This will represent a payroll of over $50 million. The vast majority of the workers required to build the plant are expected to come from the Memphis area work force. The capabilities and skills required are presently available in sufficient numbers from the metropolitan area.

The annual operating staff for the IFGDP will be about 270 persons, involving an annual payroll of $6.4 million. While many of these workers are expected to be drawn from the Memphis area, the specialized requirements of some jobs are likely to result in about 25 percent of the operating staff coming from outside the area.

Under Shelby County law, real property owned by governments is exempt from property taxation. Following completion of the demonstration testing period, the IFGDP will be owned by MLGW, which can make payments in lieu of tax to the city.

1.2 PROJECT BACKGROUND

In 1976, the U.S. Department of Energy (DOE), which at that time was the U.S. Energy Research and Development Administration, announced that it would co-sponsor a series of coal gasification demonstration plants to encourage the development of practical technology for converting coal into a usable gaseous fuel as a means of encouraging the country's energy self-sufficiency. A request for proposal, RFP E-(49-18)-2043, was issued, and MLGW submitted a responding proposal in May 1976.

To perform this work, MLGW established an industrial team with the following members and responsibilities:

- MLGW -- Memphis Light, Gas and Water Division, Memphis, Tennessee. The prime contractor and distributor of the industrial fuel gas.
- FWEC -- Foster Wheeler Energy Corporation, Livingston, New Jersey. The engineer-construction manager.
- IGT -- Institute of Gas Technology, Chicago, Illinois. The process developer.
- DRC -- Delta Refining Company, Memphis, Tennessee. To provide operating experience.

In 1977, MLGW and W. R. Grace Company were selected by DOE from among the proposals received to conduct a design competition that could lead to the construction and operation of a demonstration plant for industrial fuel gas. Contracts were negotiated with both parties in late 1977. MLGW's work was carried forward under contract ET-77-C-01-2582. The MLGW and Grace contracts specify that the work is to be conducted in three phases. Phase I costs are financed entirely by DOE. Costs for Phases II and III are to be shared by DOE and the industrial partner.

The phases are:

- o Phase I -- Program Development and Conceptual Design
- o Phase II -- Demonstration Plant Final Design, Procurement and Construction
- o Phase III -- Demonstration Plant Operation

The MLGW plant is intended to produce industrial fuel gas in Memphis, Tennessee, while the Grace plant is intended for ammonia production in Baskett, Kentucky.

The information contained in this environmental report has been developed and prepared entirely during Phase I of the MLGW program.

1.3 NEED FOR ACTION

The proposed project is a joint venture between DOE and MLGW. Each participant has its own objectives and needs which the proposed IFGDP will meet.

The overall need for this project is based primarily on: (1) DOE's objectives to demonstrate the technical, economic and environmental feasibility of producing synthetic gas from coal for industrial applications, and (2) MLGW's requirements to bridge the gap between customer demand and natural gas supply in the Memphis area and to provide a reliable energy supply in support of the stability and growth of the local economy. This dual need for the proposed action provides strong rationale for locating a medium-Btu coal gasification plant in the Memphis area.

The national energy policy of the United States involves the encouragement of energy self-sufficiency for the country. This includes reducing our dependence on foreign oil and developing technologies based on national energy resources that can replace requirements for imported oil. Industries and utilities using oil and natural gas as fuel sources are being encouraged to convert to coal and other abundant fuels. The increase in the natural gas supply currently being experienced by the United States, which started in 1978, has slowed the conversion away from natural gas. However, this is expected to be only a transient circumstance. The availability of natural gas is expected to continue its long-term decline in supply after the next few years.

In the meantime the nation is pursuing a vigorous research and development program to demonstrate practical alternative technologies for producing energy from more abundant resources in ways that are technically and economically promising as well as environmentally acceptable. One of DOE's prime goals is the development of energy-related technologies that make use of domestic coal resources and have the capability of reducing our oil needs. The proposed IFGDP is aimed at meeting these objectives. Coal gasification is one of the techniques that allows use of coal for industrial application with lower environmental impact than other methods of using coal such as electric power generation in coal-fired boilers.

DOE has also recently expressed interest in the development of processes for the production of liquid synthetic fuels ("synfuels") from coal. This objective can be greatly enhanced by the commercial demonstration of medium-Btu gas production in Memphis. The technology for large-scale production of IFG is a major required processing step in the production of synthetic gasoline from coal via the "indirect" liquefaction process scheme. Also, "direct" liquefaction technologies require char gasification for hydrogen gas production, and this step, too, is medium-Btu gasification. Moreover, the development of other advanced energy technologies, such as fuel cell power plants running on coal-derived fuel, also depend on this gasification technology.

MLGW's need for this project is to assist resolution of a natural gas supply and demand imbalance which exists in the Memphis area and to support a stable and growing industrial base. MLGW has been interested for some time in acquiring an energy source alternative to natural gas for selected industrial customers. These industrial customers use natural gas mostly for generating steam and as gaseous fuel. Their needs, therefore, do not necessarily require natural gas but could be met by other clean-burning fuels. Use of medium-Btu gas will, in effect, allow MLGW to preserve natural gas for higher priority usages and hence have the effect of extending natural gas supplies in the best interests of the United States.

Availability of IFG will enable industry in Memphis to rely on energy needed to maintain current operations and to grow. Most industries identified as potential IFG customers have been curtailed from natural gas and are using low-sulfur distillate fuel as their energy source, either full- or part-time, resulting in increased dependence on foreign energy resources. Availability of coal-derived IFG will, in most cases, directly displace the use of fuel oil, as well as natural gas.

The remainder of this section presents details of MLGW's need for the proposed action. Further details of DOE's objectives can be obtained from DOE's Fossil Energy Program Plan, DOE/ET-0087, March 1979.

1.3.1 MLGW NATURAL GAS SUPPLY AND DEMAND IMBALANCE

MLGW, as distributor of natural gas in the Memphis area, has experienced seasonal curtailments of natural gas from its pipeline supplier, Texas Gas Transmission Corporation, since 1975. These seasonal curtailments have been passed on to industrial customers under contract for interruptible supply. On occasion, MLGW has also had to curtail commercial customers. From April 1974 until mid-1979, gas-main extensions were restricted for all gas customers. Therefore, MLGW has actively sought alternate sources of gaseous fuel for its customers. The recent availability of additional supplies is viewed as only a temporary solution to the problem. Long-term solutions are still required.

Memphis has a diversified industrial economy. Major industrial categories include chemicals, oil refining, wood products, farm machinery, heavy manufacturing, foods, beverages, paper and rubber products, pharmaceuticals, soybean and cotton oil derivatives and fertilizers. Manufacturing firms numbered 9550 in 1975 and employed 63,700 people. Memphis also has a strong commercial sector. Nationally, it ranked eighteenth in 1972 as a wholesale and distribution center; sales volume was well over $7 billion.

Table 1-1 presents historical information on use of natural gas in the Memphis area for both industrial and total customers. It can be noted that industrial consumption of gas peaked in 1974, the year before curtailments began, and that industrial customers have borne the heaviest burden in the supply loss because their consumption decrease accounts for virtually the entire decrease in gas use since 1974.

The increases in gas supply to the industrial and total sectors brought about by decontrol of gas prices are evident in Table 1-1 by comparing the 1977 and 1978 usage data. This is commonly referred to as the "gas bubble" because the increased supplies are not expected to last indefinitely. These additional supplies have not significantly alleviated the long-term reduction in industrial allocation experienced since 1974. In addition, the supplies have not allowed for any growth from the 1974 figures.

TABLE 1-1

ANNUAL NATURAL GAS USE IN MEMPHIS*

(mcf)

Year	Industrial	Total
1968	35,538,824	93,676,358
1969	38,036,892	93,465,695
1970	37,672,941	92,703,430
1971	36,314,586	90,374,996
1972	40,665,734	93,087,422
1973	40,001,452	88,295,021
1974	42,985,982	77,354,212
1975	36,510,622	70,674,561
1976	31,340,799	65,679,453
1977	25,942,867	58,530,059
1978	27,619,463	62,866,275

* MLGW data

Some understanding of the extent of the supply shortage can be obtained from the following analysis. By assuming an unrestrained 2.5 percent per year industrial growth rate from the 1973 supply figures, based on the average yearly historical growth of nonagricultural employment in the Memphis area, the 1978 supply would have been 45,257,971 mcf,* which is substantially over the actual supply figures (27,619,463 mcf) for 1978. A summary of these figures follows:

	Gas Supply (mcf)
1973 Actual Supply to Industry	40,001,452
1978 Projected Supply to Industry (based on 2-1/2 percent unrestrained growth)	45,257,971
1978 Actual Supply to Industry	27,619,463
Estimated Supply Shortfall to Industry for 1978	17,638,508

The estimated supply shortfall of nearly 18 million mcf in 1978 represents an energy demand requirement that industry in the Memphis area has had to satisfy by turning to other sources. As a result, many industrial customers have turned to fuel oil, which has increased the demand for foreign oil.

Figure 1-2 portrays the overall gas supply and demand situation for MLGW through 1980. By that year, overall supply is expected to be around 75 billion cubic feet per year, while unconstrained demand, based on an assumed annual growth rate of 2-1/2 percent, could rise to nearly 120 billion cubic feet. Beyond 1980, the Texas Gas Transmission Corporation foresees decreases in its ability to supply gas to the Memphis area.

At the present time, MLGW has once again begun to accept new gas customers of all types, residential, commercial and industrial. However, new industrial customers are being given no guarantee of future supply. No curtailments are expected for the 1979-80 heating season, except those that are weather-related due to the system's daily allocations from the interstate pipeline.

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* mcf = thousand cubic feet

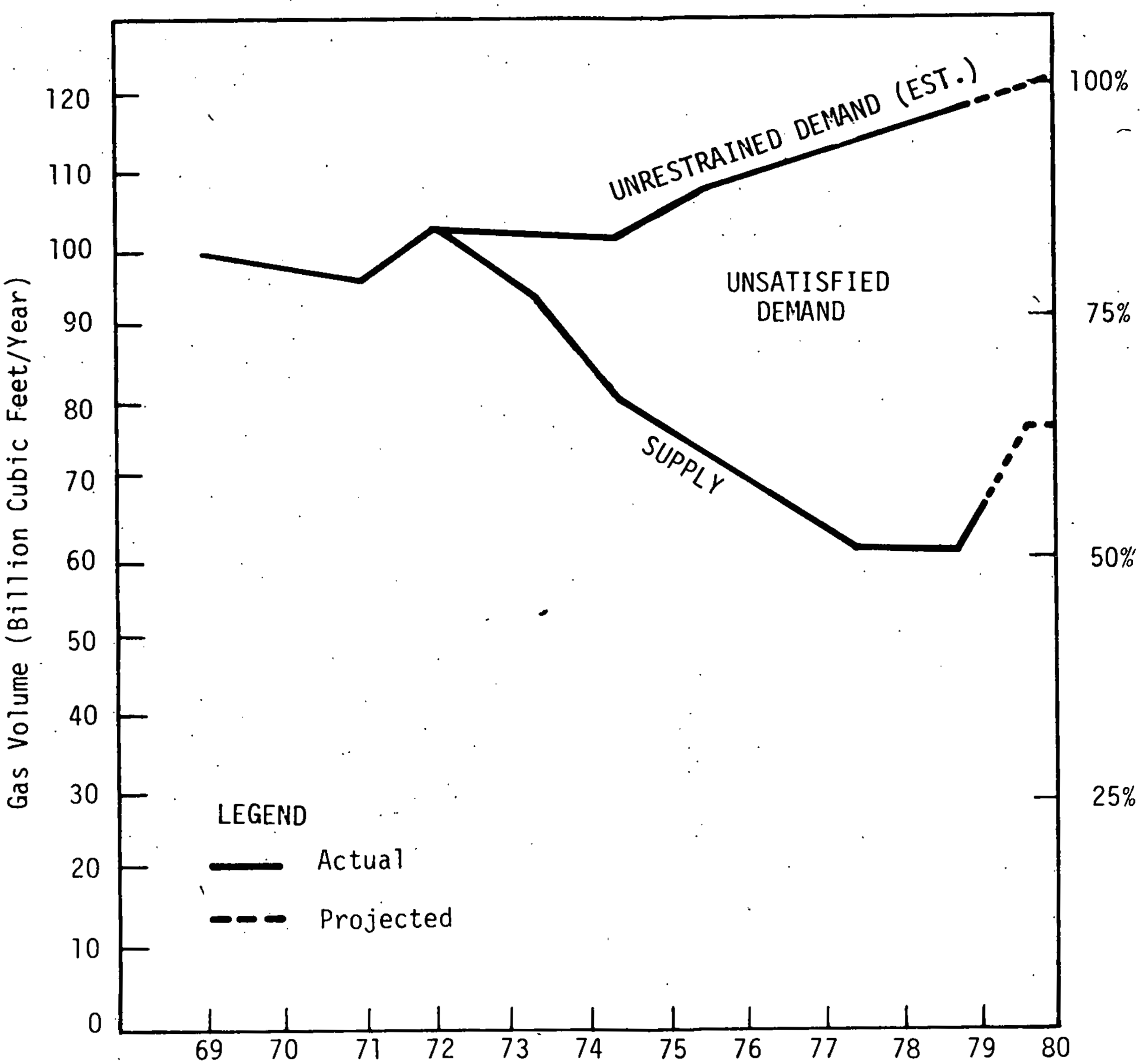

Figure 1-2. MLGW Natural Gas Supply and Estimated Demand

MLGW has several active programs underway in the Memphis area (some in conjunction with TVA) to promote energy conservation, efficient energy utilization or use of other energy sources. These programs include the following:

- o Home insulation
- o Solar water heating
- o Electric heat pump financing plan
- o Consumer education

In August 1977, MLGW took possession of the rights and properties known as the Bayou Galion Gas Field located near Monroe, Louisiana. This action was taken to improve the supply capabilities for industrial customers and to supplement gas purchases on the spot market that MLGW had previously made. The 18,000-acre field is only partially developed now, and it is expected that production levels can be increased with time.

MLGW has purchased supplemental gas and promoted conservation as a means of decreasing the long-term supply and demand imbalance. However, most of the shortfall to date has been bridged by curtailment of low-priority industrial users. This method is effective in controlling demand, but in the long run is inconsistent with MLGW's responsibility to the community.

Natural gas demand in the Memphis area is expected to continue to grow through the 1980's, based on projected growth of the real gross national product and business activity in the Memphis area. Nonagricultural employment in the Memphis metropolitan area has experienced an average annual historical growth rate of 2.5 percent, slowed only by the recession and lack of energy from 1974 to 1976. Continuing actions will be required to assure that Memphis has sufficient energy resources available to maintain its present industrial base and attract new industry.

1.3.2 RELATIONSHIP OF PROPOSED PROJECT TO MLGW AND DOE GOALS

Production of IFG by the proposed project will:

- Demonstrate the U-GAS™ coal gasification process in terms of technology, economics and environmental compatibility
- Be consistent with the Fuel Use Act of 1978 and the National Energy Act of 1978 by providing an alternative fuel, which is not dependent on foreign oil or domestic natural gas, to industry in the Memphis area
- Displace the use of natural gas and low-sulfur fuel oil by Memphis industry
- Benefit the general economy of the Memphis area by supplying existing industry and promoting industrial growth through access to a reliable long-term energy source
- Diversify MLGW's energy base, because it would be based on coal, an ample, independent, noncurtailable source.
- Protect local jobs and industries, because it would be a local undertaking not subject to curtailments associated with interstate natural gas
- Increase domestic energy utilization in the Shelby County area and displace imported fuel oil.
- Provide additional work and income in the Memphis area

As part of its overall energy supply responsibilities, MLGW is also actively seeking alternate sources of natural gas supply and is encouraging measures to conserve available supplies. The IFG from the proposed project will have the primary effect of resolving a major part of the present imbalance between natural gas supply and possible demand.

1.4 CONSEQUENCES OF DELAY

Few potential IFG customers in the Memphis area have the physical, economic and/or technical capability to convert directly to coal for their energy needs. In addition, there are regulatory constraints that pose further problems to potential coal users. These potential customers, then, will continue to rely on natural gas and fuel oil for their operations unless there is a suitable alternative that can provide a reliable, long-term energy supply. Reliance on either natural gas, which is subject to potential availability and curtailment problems over the long-term, or fuel oil, much of which comes from imported sources, poses supply concerns for the future. Alternative energy resources for Memphis and for the United States must clearly be developed and proven. Failure to expeditiously provide IFG in the Memphis area will, therefore, result in greater fuel oil use, the possible suspension of business activity by some industries in the event of curtailments and/or the lack of reliable energy availability for stimulating the growth of the Memphis economy.

2.0 DESCRIPTION OF THE PROPOSED ACTION

SECTION 2.0
DESCRIPTION OF THE PROPOSED ACTION

This section provides a detailed description of the proposed Industrial Fuel Gas Demonstration Plant (IFGDP). Discussions of the plant location, layout, construction program, gasification process, fault and failure analysis, health and safety program, toxicology program and decommissioning are presented in the following sections. Details of plant design, construction and operation reported in this document are those of the Phase I conceptual design as of August 1979. Details may be changed and/or refined as a result of the final design work of Phase II, which is expected to begin in 1980. In many places, numerical values are reported in metric units followed in parentheses by U.S. equivalents.

2.1 PROJECT LOCATION

The proposed plant site is located approximately 13 kilometers (8 miles) west-southwest of downtown Memphis, Tennessee. The location of the plant in relation to the city is indicated in Figure 2-1. The site is within both the Shelby County and Memphis city limits.

A more detailed map of the site vicinity, including the plant site study area, is presented in Figure 2-2. The area is on a peninsula extending into Lake McKellar, a man-made lake formed when a channel of the Mississippi River was closed by the U.S. Army Corps of Engineers (U.S. COE). Presidents Island, an industrial and agricultural area, is to the north across the lake. The western boundary of the plant site lies 1.2 kilometers (4000 feet) east of the Mississippi River. The southern boundary consists of the shoreline along a barge-turning basin in Lake McKellar. Important nearby facilities include the TVA Allen Generating Plant and the T. E. Maxson Wastewater Treatment Facility.

The area which was studied for this report measures 1158 meters (3800 feet) along the north and south boundaries and 564 meters (1850 feet) along the east and west boundaries, encompassing 0.65 square kilometer (162 acres). The

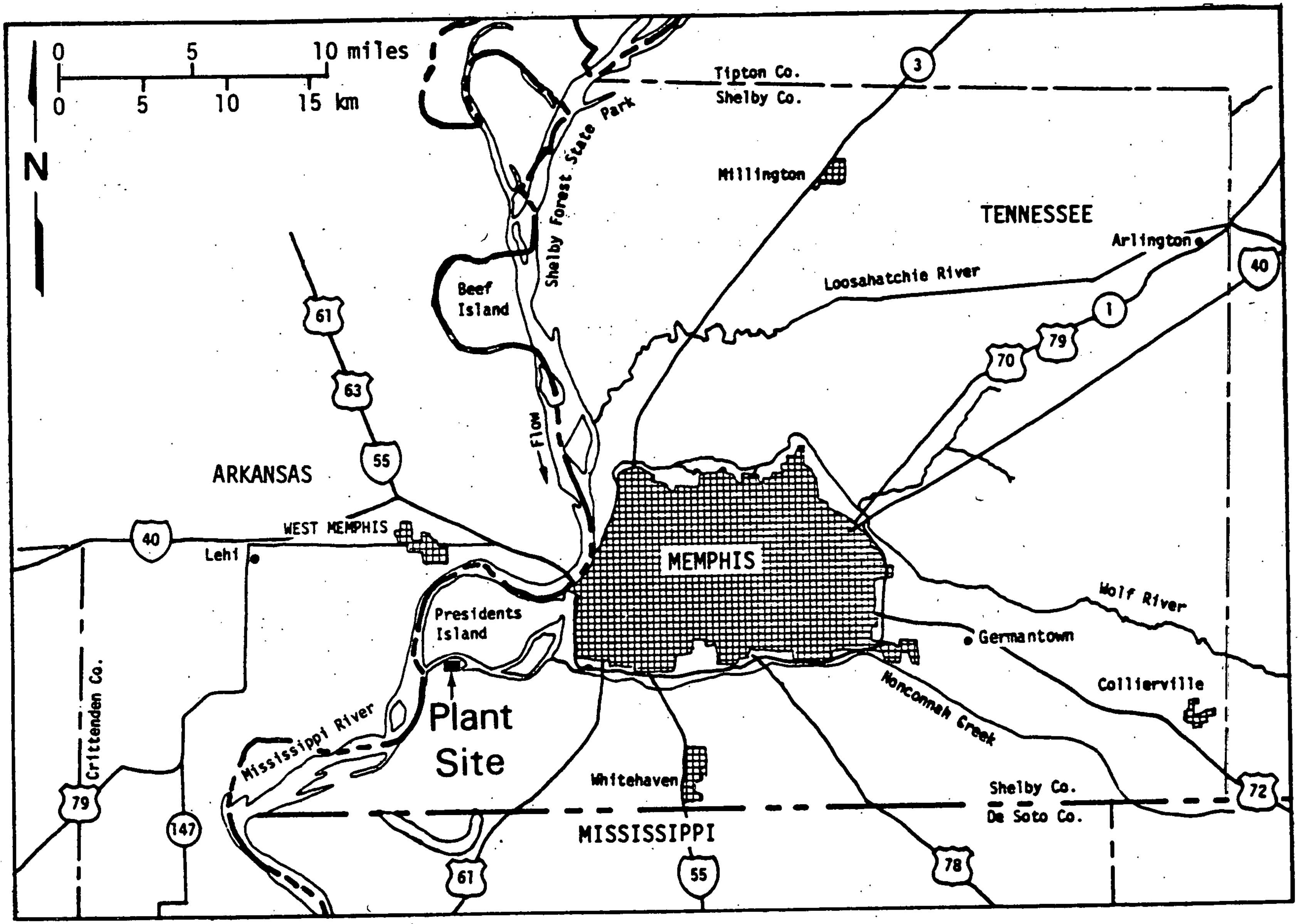

Figure 2-1. Plant Site Location

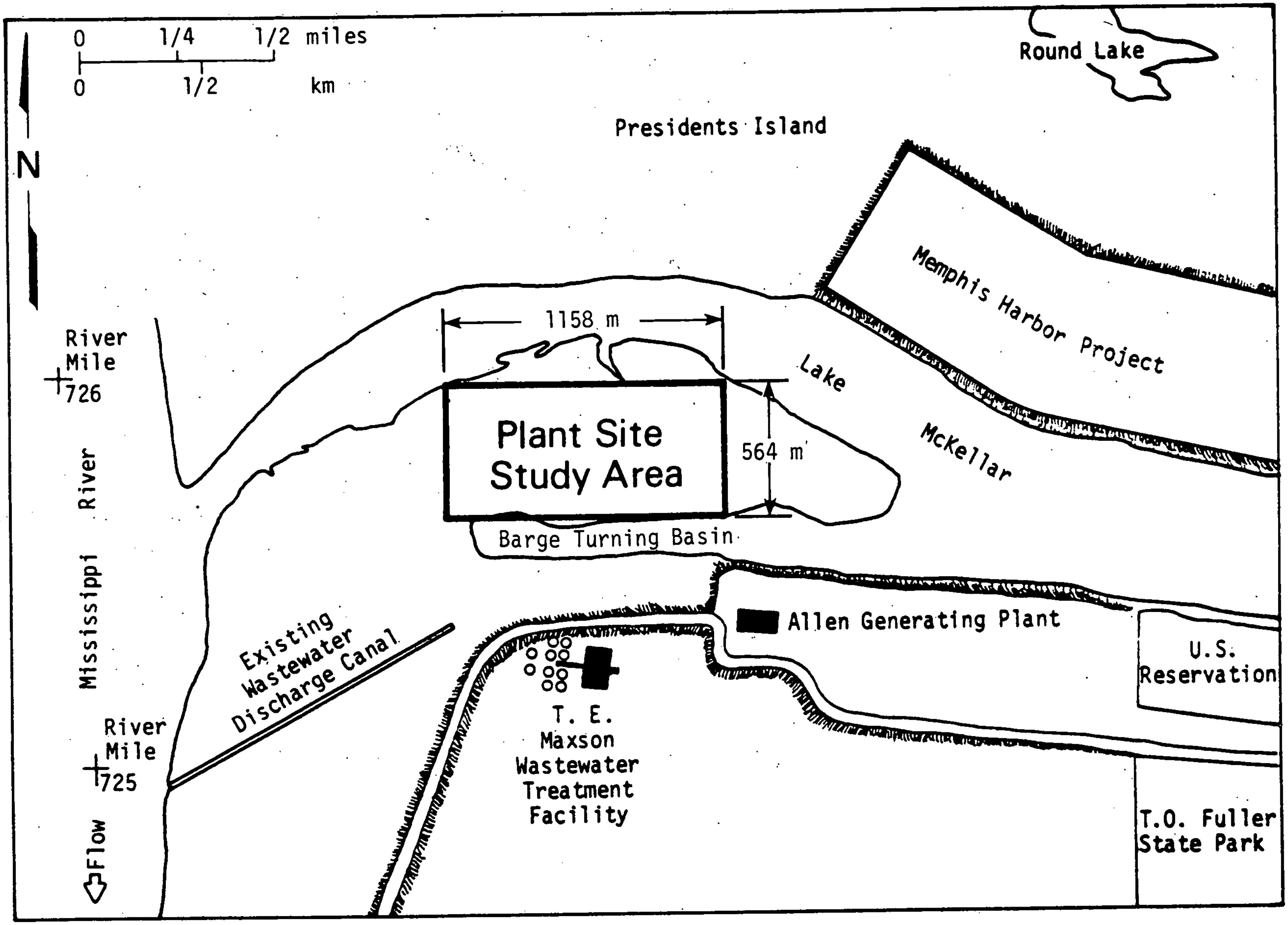

Figure 2-2. Plant Site Study Area and Vicinity

existing elevation of the site is 61 to 62.5 meters (200 to 205 feet) above mean sea level (msl). Portions of the site are frequently flooded, particularly following spring snowmelt in the Mississippi River basin. Several levees have been constructed on the site at an elevation of 62.5 to 64 meters (205 to 210 feet) above mean sea level, but are unable to control any significant flooding. This potential for flooding necessitates the buildup of the site to an elevation of 71 meters (233 feet) above mean sea level to accommodate the project. This elevation exceeds the U.S. Army Corps of Engineers recommendation for the project design flood.

The proposed plant site is located entirely within the study area, measuring 960 meters (3150 feet) along the north and south boundaries and 564 meters (1850 feet) along the east and west boundaries. The site encompasses 0.54 square kilometer (134 acres) and is outlined in Figure 2-3.

For the most part, the surface soil at the site consists of sand and gravel. A surface layer of clayey silt is located in the southwestern portion. This silt is a result of the deposition of dredge spoil during annual U.S. Army Corps of Engineers dredging operations in Lake McKellar. Vegetation on the site consists primarily of successional bottomland forest and meadowland.

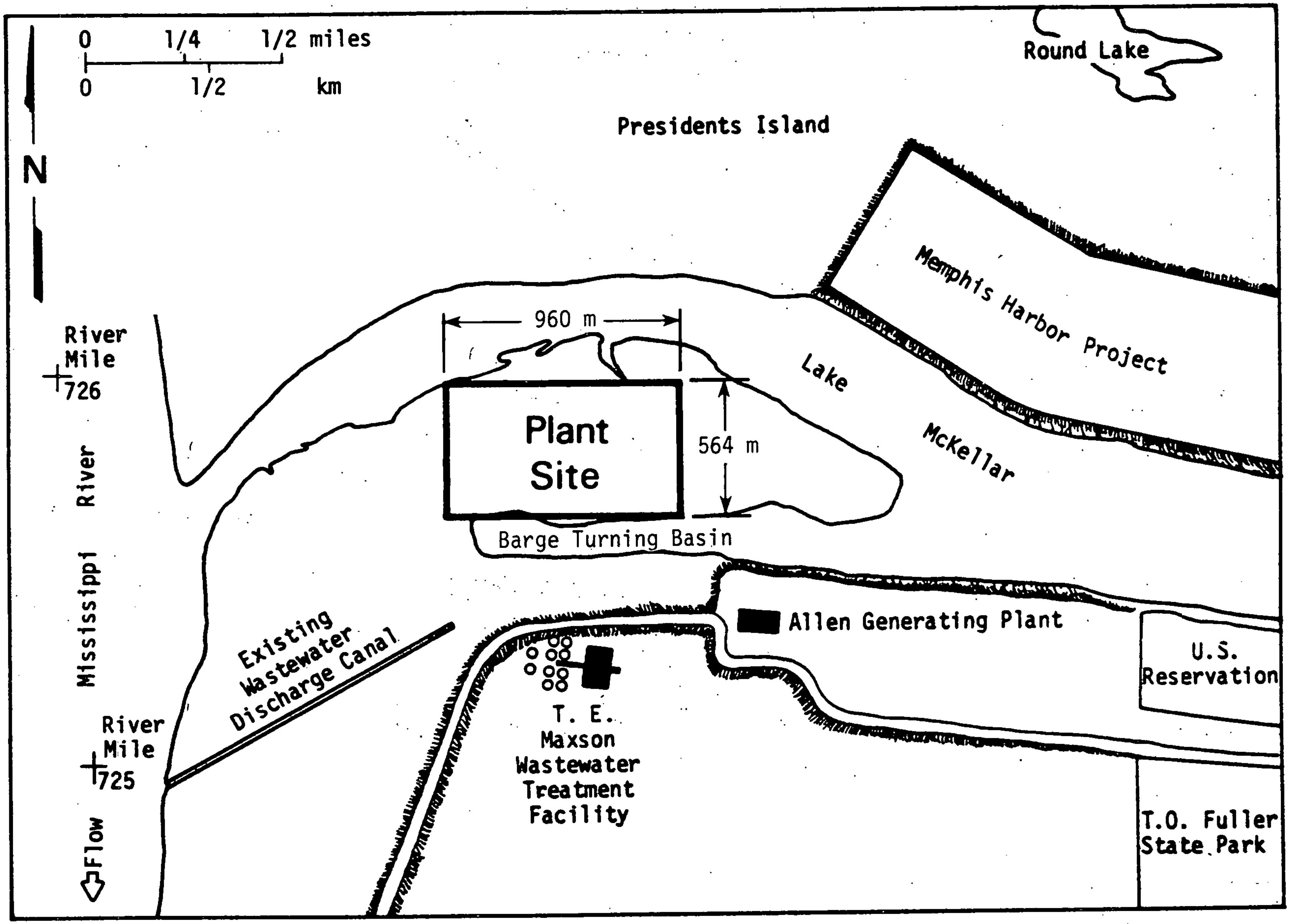

Figure 2-3. Proposed Plant Site

2.2 PLANT DESCRIPTION

Locations of all facilities required for the IFGDP are discussed in this section. The project consists of the elevated plant site and access road, barge unloading area and off-site utilities. Utilities include pipelines for product industrial fuel gas (IFG), natural gas, water supply, sanitary sewage and wastewater as well as power and telephone lines. Details of facilities and layout are those of the Phase I conceptual design as of August 1979. Details may be changed and/or refined as a result of final design work of Phase II, which is expected to begin in 1980.

2.2.1 PLANT LAYOUT

This section presents a description of the layout of all plant facilities, including access roads, process facilities, storage areas, barge unloading facilities, off-site facilities and the IFG distribution system.

2.2.1.1 ACCESS ROAD

Access to the site will be made along a public road which will extend west from the Allen Generating Plant on top of an existing levee. The road will curve north at the T. E. Maxson Wastewater Treatment Facility discharge channel and extend north along the western plant site boundary. The access road will be elevated to the project design elevation (Section 2.2.2) and will provide routing for power and telephone lines and water, natural gas and sewer pipelines. The location of this road is indicated in Figure 2-4.

2.2.1.2 PROCESS AND SUPPORT FACILITIES

A plot plan detailing the location of all process and control facilities and all storage areas for the IFGDP is presented in Figure 2-5. A detailed engineering description of each process is presented in Section 2.4.

Several support facilities will be located along the western plant site boundary. These will include an administration building, a laboratory/first

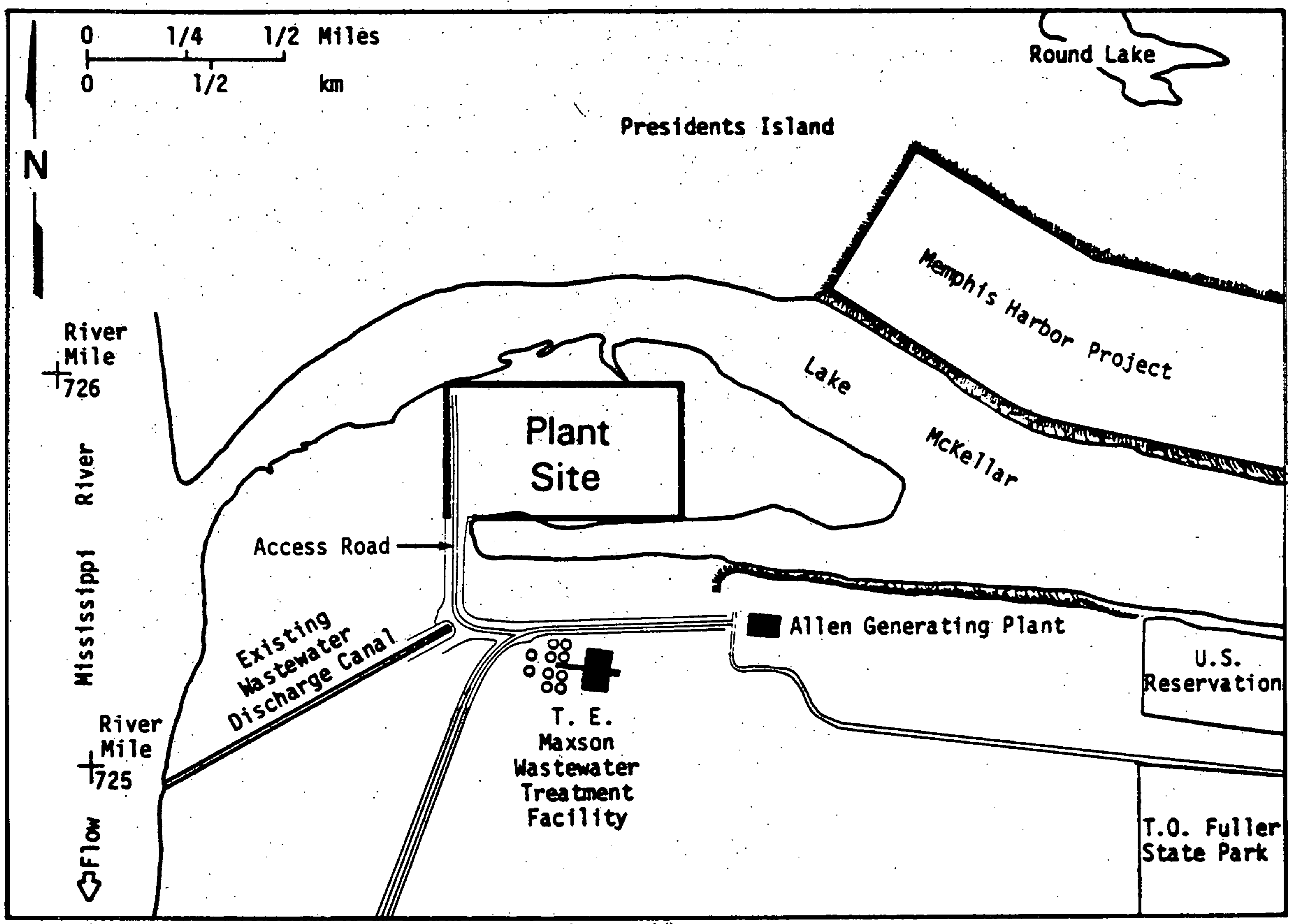

Figure 2-4. Location of Access Road

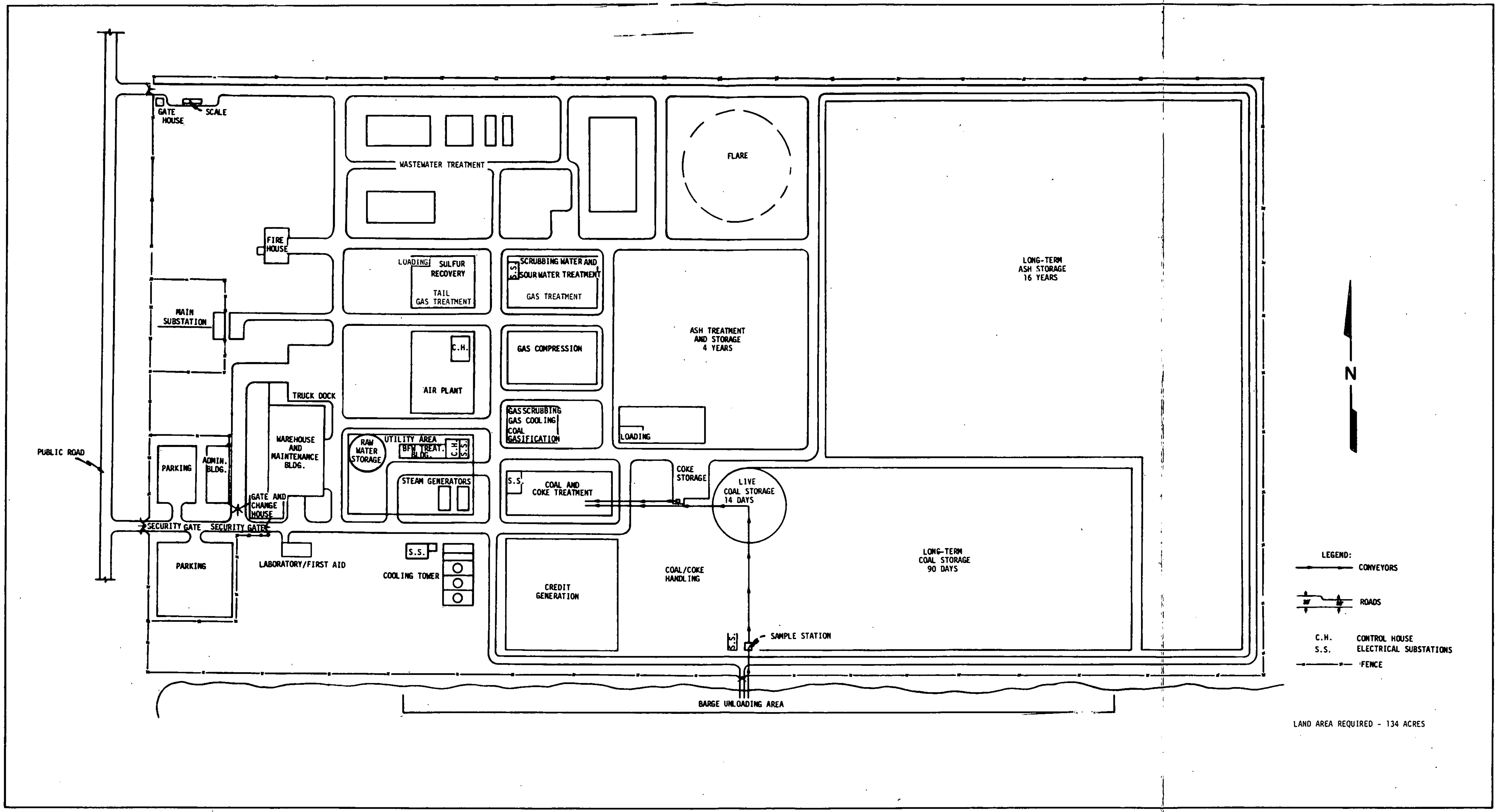

Figure 2-5. Facility Plot Plan

aid facility, a warehouse and maintenance building, a firehouse and parking areas. The main electric substation will also be situated in this area. For security purposes, a fence will surround the entire plant site, with security gates at all entrances to the plant.

The plant contains four gasifier units. Normal operation of the plant involves using three of the gasifiers at 100 percent capacity with one gasifier in reserve. The plant can also operate with four units running at 75 percent capacity. Under these conditions, the plant generates its maximum environmental emissions.

All Coal Gasification process facilities will be located east of the facilities described above, along a north-south roadway. These facilities include Coal/Coke Receiving and Handling, Coal Gasification, Gas Cooling and Scrubbing, Gas Compression, Gas Treatment, Scrubbing Water and Sour Water Stripping, Sulfur Recovery, Tail Gas Treatment, Air Plant, Raw Water Storage, Steam Generators, Cooling Towers, Credit Generation, Wastewater Treatment and Flare.

2.2.1.3 STORAGE AREAS

Short-term (4-year) and long-term (16-year) ash storage areas will be provided. Scrubber sludge will also be stored in these areas. Short-term (14-day) and long-term (90-day) coal storage areas will be located in the southeastern quarter of the site. The location of these areas is indicated in Figure 2-5.

Leaching studies on ash from the IGT pilot plant have indicated that the ash produced by the U-GAS^{TM} process can be classified as nontoxic. MLGW desires eventually to make the ash available for some commercial purpose and will keep the ash separate from the scrubber sludge during the first 4 years of operation. Additionally, sludge from Flue Gas Desulfurization will be stored in a separate section of the Ash Treatment and storage area.

The short-term ash storage area and the short- and long-term coal storage areas will be lined with a commercially available plastic, which will prevent any leachate from stored materials from reaching the groundwater. The long-term ash storage area will be unused during the first 4 years of operation and will be covered with grass. At the end of that period, if a buyer for the ash has not been found, the long-term storage area will also be used for ash as well as scrubber sludge.

2.2.1.4 BARGE UNLOADING FACILITIES

Barge unloading facilities will be situated along the southern boundary of the site (Figure 2-5). Mooring facilities will be on the south bank of the site. The unloading facilities consist of unloading equipment and a covered conveyor which will be used to deliver coal from a barge unloading platform to the live coal pile. Also, facilities will be constructed to enable the transportation of large loads from barges to the plant. These temporary facilities may not be co-located with the coal barge unloading system.

2.2.1.5 OFF-SITE FACILITIES

Locations of all off-site facilities, with the exception of the IFG distribution system, are described in this section. The facilities include all water supply and wastewater discharge, natural gas and IFG pipelines and the electric transmission line.

2.2.1.5.1 WATER SUPPLY PIPELINES

Water will be supplied to the IFGDP from the Memphis municipal water supply system. Two pipeline routes will be used for the water supply, as is indicated in Figure 2-6. Each pipeline will have independent capacity to supply the plant to a rate of 4 million gallons per day and will tie into existing dead ends in the Memphis distribution system. A detailed description of flows required for the plant is presented in Section 2.4.5.16.1.

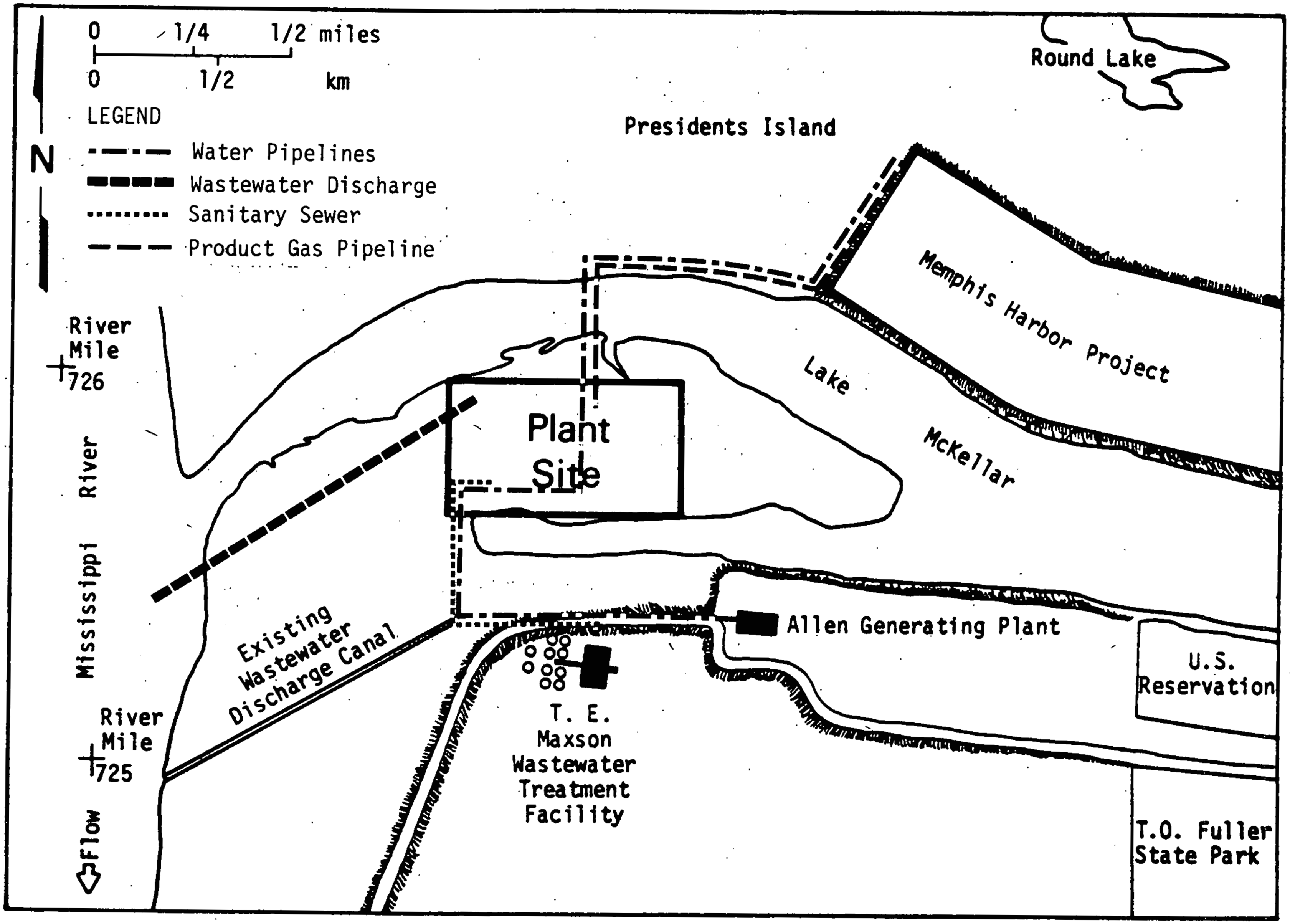

Figure 2-6. Location of Off-Site Water, Wastewater and Sanitary Sewer Pipelines and Product Gas Pipeline

One water pipeline will connect to an existing line on Presidents Island and will follow the right-of-way to be used for the IFG pipeline (discussed in detail in (Section 2.2.1.5.5). This line will have a diameter of 41 centimeters (16 inches) and will be able to carry a maximum flow of 3700 gallons per minute. The other pipeline will connect/to a line at the Allen Generating Plant and will extend along the access road to the site. It will have a diameter of 41 centimeters (16 inches) and will carry a maximum flow of 2200 gallons per minute. These capacities are ample for plant requirements.

2.2.1.5.2 WASTEWATER DISCHARGE PIPELINES

A sanitary sewer pipeline will extend from the plant to the T. E. Maxson Wastewater Treatment Facility. This pipeline will be 20 centimeters (8 inches) in diameter and will also extend along the access road, as is indicated in Figure 2-6. All other wastewater, including process wastewater and rainfall runoff from process units, will be treated on-site and discharged through a 46 centimeter (18 inch) pipeline into the Mississippi River. The location of this pipeline is indicated in Figure 2-6. An analysis of wastewater flows is provided in Section 2.4.5.13.

The wastewater pipeline will be placed in a dredged trench extending to a submerged outfall. The outfall will be located 1.8 meters below the 20-year low water reference plane in the Mississippi River (as specified by Appendix 4A, Figure 4A-1) and 1.8 meters from the low flow shoreline. The water line will discharge into the river at a downward angle in the vertical plane of 45 degrees.

2.2.1.5.3 TRANSMISSION LINE

Electricity will be provided to the plant from the TVA system. The expected power usage during operation is 45 megawatts. An overhead 161-kilovolt transmission line with a capacity of 100 megavolt-ampere will extend along the access road from the Allen Generating Plant to the main substation on the site, as indicated in Figure 2-7. Telephone lines will also reach the plant by a routing along the access road.

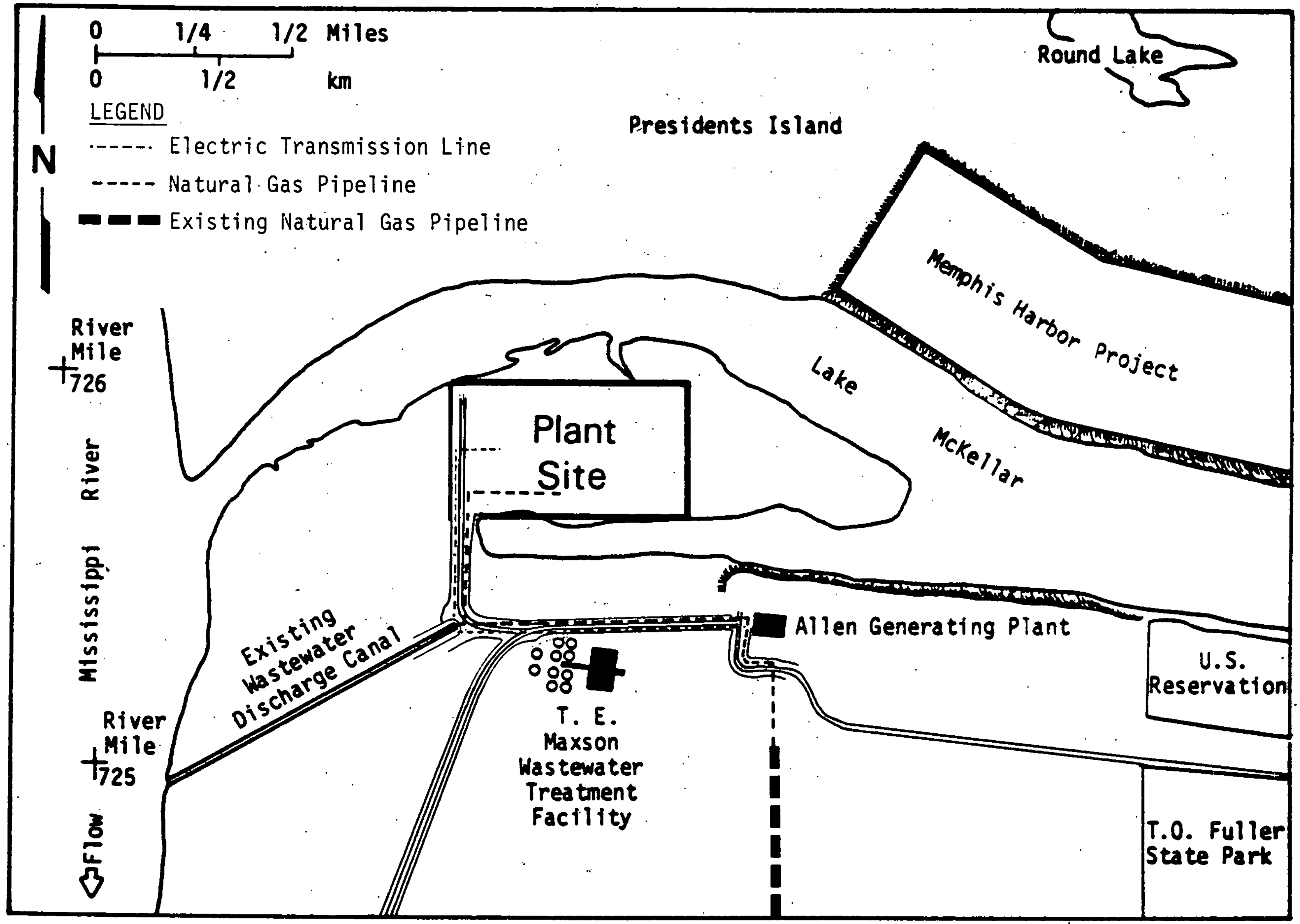

Figure 2-7. Location of Transmission Line and Natural Gas Pipeline

2.2.1.5.4 NATURAL GAS PIPELINE

Pipeline quality gas will be generated at the proposed IFGDP from a portion of the plant IFG output and fed into a natural gas pipeline operated by MLGW. The purpose of this generation is to create credits in the natural gas system so that whenever the IFGDP undergoes maintenance and repair operations, natural gas may be withdrawn from the city system, adjusted and distributed to IFG users to assure reliability of supply. This Credit Generation system is described in more detail in Section 2.4.5.11.

Figure 2-7 shows the locations of the existing natural gas pipeline and the proposed extension required to connect to the IFGDP. The pipeline will be approximately 41 centimeters (16 inches) in diameter and will be built on an easement. This pipeline will be buried 1.5 meters (5 feet) underground. Back filling will be accomplished using previously removed topsoil at the top of the fill so that crop growth can be continued.

2.2.1.5.5 IFG PIPELINE

A conceptual IFG distribution system developed by MLGW is presented in Figure 2-8. Final system design will be completed after all IFG customers have been determined.

The conceptual distribution system is 41.9 kilometers (26 miles) in length. It extends north from the plant across Lake McKellar to Presidents Island, and along the island to Channel Avenue. A 9.1 meter by 1920.2 meter (30 feet by 6300 feet) right-of-way must be obtained along that route. This routing will be a common corridor with the city water pipeline. Both the IFG distribution and water pipelines will be constructed in the same time period. On Presidents Island, the pipeline will extend east along the south shore then north along the built up area to an existing city street. The remainder of the distribution system will follow existing city streets, as is shown in Figure 2-8. As a result, no further rights-of-way need be obtained.

An engineering description of the IFG distribution system is provided in Section 2.2.3.

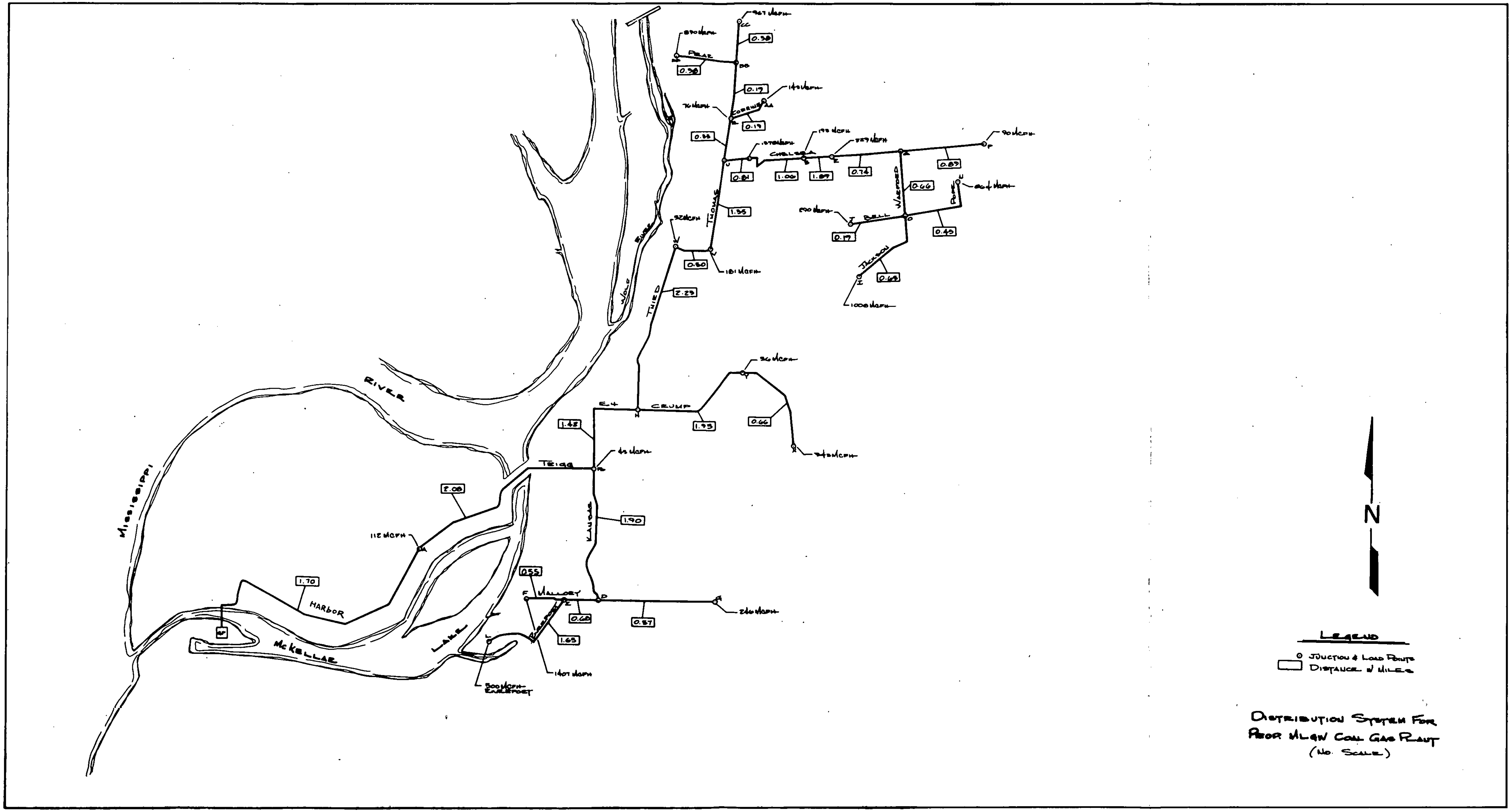

Figure 2-8. IFG Distribution System

2.2.2 SITE TOPOGRAPHY

The U.S. Army Corps of Engineers has determined that the required project flood elevation for the IFGDP is 70.9 meters (232.8 feet) above mean sea level. This elevation is higher than the 100-year flood level, which has been determined to be 68.6 meters (225 feet) above mean sea level. The project design elevation will be 71 meters (233 feet) above mean sea level, which complies with U.S. COE recommendations.

The elevation of the site is currently 61 to 62.5 meters (200 to 205 feet) above mean sea level. The site will be built up to the project design elevation using filling procedures described in Section 2.3.1.1.4.

All process and support facilities, with the exception of the short-term ash storage area, the long-term coal storage area and the long-term ash disposal area will be constructed at the design elevation. The short-term ash storage and long-term coal storage areas will be constructed at the 68.6 meter (225 feet) elevation and will be surrounded by a levee with a top elevation of 71 meters (233 feet). The long-term ash disposal area will be raised to an elevation of 64 to 68.6 meters (210 to 225 feet) above mean sea level and will also be surrounded by a levee at the 71 meter mean sea level elevation. The banks surrounding the Wastewater Treatment ponds may be at an elevation of 71.9 meters (236 feet) above mean sea level.

2.2.3 IFG DISTRIBUTION SYSTEM

This section presents an engineering description of the IFG distribution system, existing underground lines and estimated costs of construction.

2.2.3.1 ENGINEERING DESCRIPTION

The IFG distribution system will be operated as a one pressure system between the limits of 150 pounds per square inch gage at the plant to approximately 80 pounds per square inch gage at the lowest point. A pressure drop of 2.9

pounds per square inch per mile of gas transport will occur. Pressure reduction will occur at each customer's metering facilities. The system can deliver 50 billion Btu per day of product IFG. The system will be protected from over-pressure at the outlet of the compressor at the plant and at individual customer's facilities. No gas will be vented to the atmosphere unless the relief valve is forced to operate at abnormally high pressure.

The gas will be odorized at the plant by a variable speed pump with the output proportional to the flow. Thiophane (Tetrahydrothiophene or THT) will be used as the odorant. Odorizing is a normal procedure to facilitate detection of any pipeline leaks. Coated welded steel pipe and cathodic protection will be used for corrosion control.

An access road will be constructed within the right-of-way between Channel Avenue and Lake McKellar on Presidents Island (see Figure 2-8). It will be 9.1 meters (30 feet) in width and will allow for easy access to the pipeline. No access roads will be necessary for the remainder of the distribution system, since the system follows city streets.

2.2.3.2 EXISTING LINES

All streets in the present Memphis distribution system contain existing gas, water and sewer lines. Approximately 50 percent contain underground electric lines. A minimum clearance of 0.9 meter (3 feet) for parallel lines and 0.3 meter (1 foot) for crossing lines will be maintained between existing lines and the IFG pipeline.

2.2.3.3 PIPELINE COSTS

Table 2-1 presents estimated total distribution system material and labor costs on a dollar per mile basis for the IFG pipeline. Estimated total cost of the pipeline will be \$9.62 million. Material costs will be \$7.22 million, and labor costs will be \$2.40 million, based on 1978 dollars.

TABLE 2-1

ESTIMATED PIPE MATERIAL AND LABOR COST
(1978 Dollars)

Pipe Diameter (inches)	Length (miles)	Total Material Cost	Total Labor Cost
6	2.31	$222,000	$ 89,000
8	2.12	266,000	88,000
10	2.41	261,000	109,000
12	1.87	279,000	123,000
16	2.88	761,000	221,000
18	0.66	195,000	54,000
22	4.50	1,528,000	495,000
26	5.50	2,100,000	726,000
30	3.78	1,613,000	498,000
	TOTALS	$7,225,000	$2,403,000

2.3 CONSTRUCTION PROGRAM DESCRIPTION

This section presents a summary of the construction program for the IFGDP. A brief description of each construction activity and measures to be taken to reduce the environmental impact of the activity are provided along with a discussion of the construction labor force and construction expenditures. Details on construction are those of the Phase I conceptual design as of August 1979. Details may be changed and/or refined as a result of the final design work of Phase II, which is expected to begin in 1980.

2.3.1 CONSTRUCTION ACTIVITIES

Major activities during construction of the IFGDP will consist of site preparation, followed by the construction of foundations, warehouses and shops, underground piping and electrical systems, barge unloading facilities, on-site facilities and the IFG distribution system. Site preparation includes the construction of the access road and construction facilities, site clearing, site buildup and site grading. All major construction activities are described in the following sections.

2.3.1.1 SITE PREPARATION

The following is a brief description of all construction activities to be performed during site preparation.

2.3.1.1.1 ACCESS ROAD

Access to the construction site will be made along an existing road which extends along the top of the levee west of the Allen Generating Plant to the T. E. Maxson Wastewater Treatment Facility discharge canal, then north to the site (Figure 2-4). The road will require temporary modification in order to transport heavy earthmoving equipment onto the site. These modifications will include widening and leveling. During site filling (Section 2.3.1.1.4) the access road will be elevated to 71 meters (233 feet). All permanent modifications to the road will be made at that time. This access road will provide the right-of-way for all utilities entering and leaving the site from the south.

2.3.1.1.2 CONSTRUCTION FACILITIES

Construction facilities required during site preparation will be set up on existing builtup areas, including the access road and areas near the Allen Generating Plant and the T. E. Maxson Wastewater Treatment Facility.

Water will be trucked to the site until permanent pipeline facilities are available. The maximum potable and construction process water demand during construction will be approximately 14,000 gallons per day, of which 25 percent will be for personnel use and the remainder for construction.

During site preparation, temporary sanitary facilities will be used, consisting of portable toilets that use chemicals or small volumes of water. These will be emptied by a pumper tank truck and discharged to the Memphis sewage treatment system.

A temporary electric transmission line will deliver electricity to the construction facilities. The location of this line is identical to that of the permanent line along the access road and is shown in Figure 2-7. This line will have a capacity of 1200 kilovolt-amperes.

All construction debris will be collected and removed to an approved sanitary landfill. Containers will be located in several areas on the site to be used as collection points.

2.3.1.1.3 SITE CLEARING

The plant site will be cleared of all vegetation. The contract for clearing the site will require the contractor to sell to the maximum extent possible wood that is salvaged. Slash will be chipped and sold to the maximum extent possible rather than burned.

2.3.1.1.4 SITE BUILDUP

Site buildup will involve raising the elevation of the site to the project design elevation using dredged material obtained from the Mississippi River.

DREDGING OPERATIONS

Fill will be obtained from the Mississippi River. The most probable dredging location is the western side of the barge channel in the vicinity of river mile 725. It may also be possible to dredge the eastern side of the river near the same river mile. The number of dredge barges and the amount of river traffic will be used to determine exact locations. On the western side of the channel, possible dredge locations extend south from the vicinity of river mile 725. Use of the eastern side of the river south of that mile may be restricted because of the proximity to the existing revetment and the barge channel. The location of these areas is indicated in Figure 2-9.

Based upon previous dredging experience in the area, it may be possible to obtain the required 6 million (approximate) cubic yards of fill without moving the dredge barge(s). However, if barge movement is required, a total impacted area of no more than 0.15 square kilometer (0.06 square mile) will be impacted. (The total dredged area will not exceed 0.5 mile in length and 200 yards in width).

The dredged material will be pumped to the site through a 61- to 76-centimeter (24- to 30-inch) flexible discharge pipe. The dredge pipeline route is shown in Figure 2-9. While crossing the river, the pipeline will be anchored onto the riverbed to avoid obstruction of river traffic and to prevent any movement upstream or downstream. The length of the submerged pipeline will be approximately 1.25 kilometers. Upon leaving the Mississippi River, the pipeline will go overland following either the sewage treatment plant outfall channel or the route of the wastewater pipeline or will possibly float out of the barge channel along the Lake McKellar shoreline. These locations are indicated in Figure 2-9.

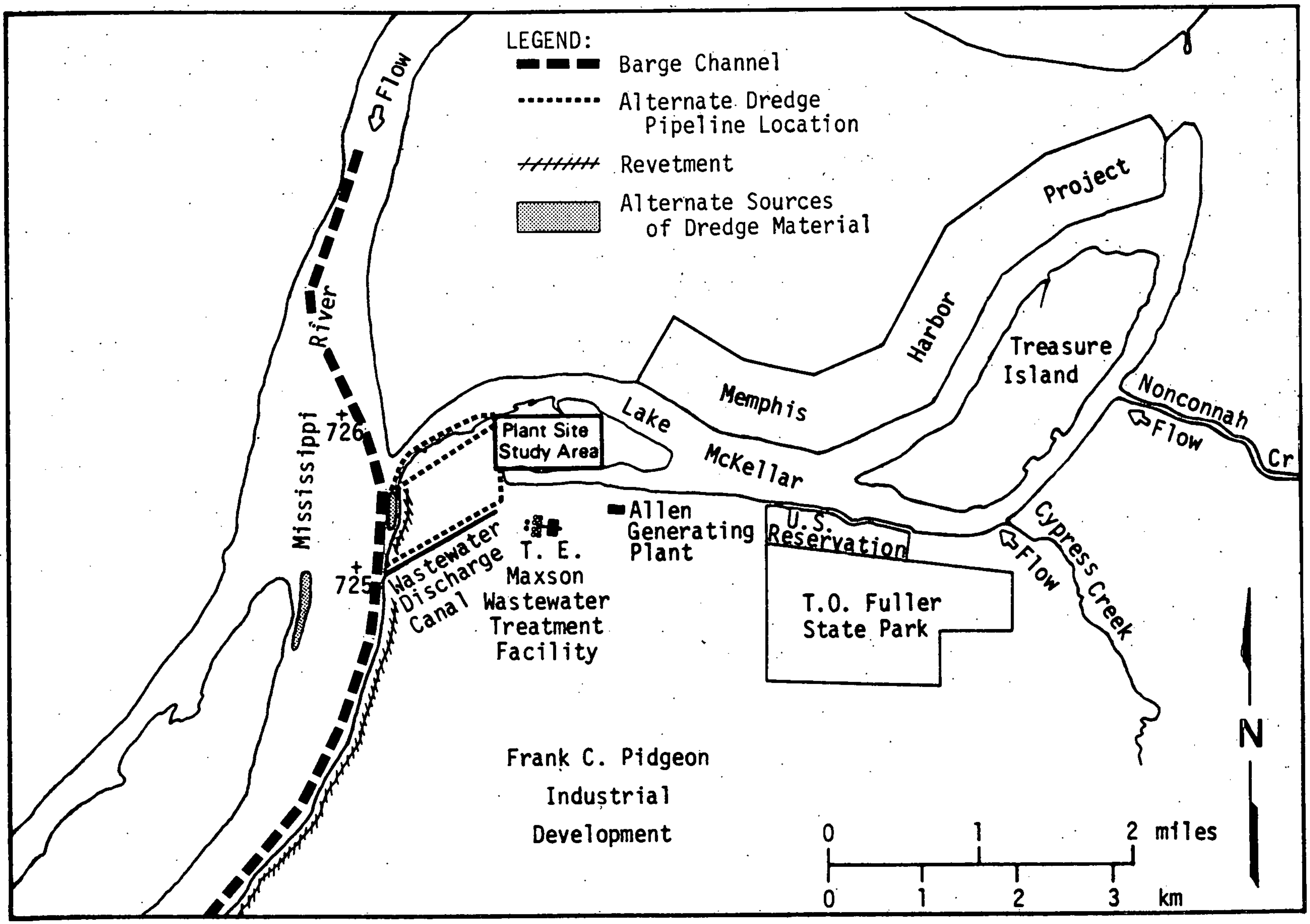

Figure 2-9. Location of Dredging Operations

Up to three dredgers will operate approximately 22 hours per day during dredging operations, which are estimated to last for 250 calendar days. The exact number and size of dredgers is dependent on the contractor involved. Three 24-inch, one to two 27-inch or one 30-inch dredger may be used, each resulting in the same schedule.

SITE FILLING

Details of site filling are dependent on details to be agreed upon between the contractor and MLGW. Following are two possible methods of site filling.

Dredge material will first be pumped onto the east end of the site. This material will be used to build a temporary dike around a small area, most probably in the location of the ash disposal area (Figure 2-5). Additional dredge material will then be deposited and allowed to drain through a weir into Lake McKellar. Subsequently, more dredge material will be placed on the central and western portions of the site to accomplish the site buildup. Any silt that does not settle will flow into Lake McKellar. Because of the high sand content of this fill, little silt is expected.

During the buildup, a series of temporary dikes will be constructed. This will allow the pumping of dredged material into the temporarily diked areas for drainage simultaneous with placement of drained material on the site.

The fill to be used for the process and Steam Generation units and the live coal pile will be compacted to 95 percent of Modified Proctor Density (ASTM D 1557). The vibratory compaction method will be used. All other fill will be placed by the dredge discharge pipe and spread by bulldozers. Adequate compaction will be achieved by water drainage downward during the filling operation.

An alternate method of site filling would be to clear the site and provide temporary diking around the entire site to a presently undetermined elevation no greater than 71 meters (233 feet) above sea level. This dike would probably be constructed of a combination of materials from the site and some dredge fill. A weir would be located on the north side leading to Lake McKellar. The dredger would then fill the site generally from south to north. Water would rise inside the dike and overflow the weir to the lake. The entire site would serve as a sedimentation pond. Silt that does not settle in the fill would eventually overflow into the lake.

The specific method of filling will be dependent on the contractor selected, equipment available, contractual terms and other considerations. The end result, however, will be the same.

The site will be filled to an elevation of 71 meters (233 feet) above mean sea level for the process and support facilities and the live coal pile. The remainder of the site will be built to the elevations described in Section 2.2.2.

Grading and ditching will be provided during construction to convey rainfall runoff to a holding pond in the northeastern end of the site. The runoff diversion will serve as a method of erosion control. The water will then be allowed to flow into Lake McKellar. If the alternate scheme is used, rainfall would flow through the weir to the lake.

All roadways and construction areas will be sprinkled with water as necessary to minimize fugitive dust.

2.3.1.1.5 SITE GRADING

Site grading will begin as site buildup nears completion or as soon as possible thereafter. The site will be graded to above project flood level to an elevation of 71 meters (233 feet) above mean sea level for the process and Steam Generation units and for the live coal pile. Other process and storage areas (see Section 2.2.2) will be graded to an elevation of 68.6 meters (225 feet) and will be surrounded by a levee at the 71 meters above mean sea level elevation.

All roadways and construction areas will be sprinkled with water as required to minimize fugitive dust concentrations. Rip-rap will be placed on the outside slopes of the plant site and access road where required to reduce any erosion caused by wave action along the shore. All open areas where no construction will occur (such as the inside of the dike and the long-term ash disposal area) will be seeded with grass to prevent erosion due to rainfall runoff.

2.3.1.2 FOUNDATIONS

The construction of foundations will occur simultaneously with site grading. All structures will be supported on spread footings with an allowable net soil bearing value of 3000 pounds per square foot. To compensate for the fact that the site is located in Zone 3 of the U.S. Seismic Risk Map (as discussed in Section 3.2.5 and 3.11), a factor of safety will be incorporated so that the net soil bearing value will increase to a maximum of 4000 pounds per square foot. Soil liquefaction during seismic activity is also discussed in Section 3.11.4.

The minimum foundation depth will be about 1 meter (3 feet) below final grade to ensure frost protection and to provide for adequate confinement of the bearing soils. The minimum foundation width will be about 0.5 meter (18 inches) for continuous footings and 24 inches for individual footings. The bottom of the footings will be compacted to densities equivalent to 95 percent of the Modified Proctor density (ASTM Specification D-1557). The footing excavations will not extend below the groundwater table. The construction of foundations will begin approximately 2 to 6 months following completion of the filling or as soon as possible.

The foundation design criteria mentioned above are considered preliminary and are subject to change pending further soils investigations during Phase II of this project. It may be necessary to use piles for the gasifier structure and live coal pile structure. All changes, as well as the above specifications, will be in accordance with the ACI 318 "Building Code Requirements for Reinforced Concrete."

2.3.1.3 WAREHOUSES AND SHOPS

Various temporary construction shops, warehouses and auxiliary buildings will be constructed in the locations shown in Figure 2-10. A concrete batch plant and a materials testing laboratory will also be located in this area. These temporary facilities will be prefabricated corrugated metal structures or trailers. Approximately 9 acres are available for these facilities.

The permanent warehouse and maintenance building, laboratory/first aid building and firehouse will be constructed at this time and will be in use during the remainder of the construction program. The security fence will also be constructed along the 71 meter (233 feet) elevation. The location of these facilities is also indicated in Figure 2-10.

2.3.1.4 UNDERGROUND PIPING AND ELECTRICAL SYSTEM

Following site grading, and concurrent with the construction of warehouses and shops, the electric transmission line, main substation, water supply pipelines, sanitary sewage line and wastewater discharge pipeline will be constructed. The location of these structures is indicated in Figures 2-6 and 2-7.

During the remainder of the construction program, the sanitary sewer system will consist of both a standard flush toilet system and portable toilets that use chemicals or small volumes of water. When the water supply and wastewater discharge pipes have been installed, the temporary and permanent facilities shown in Figure 2-10 will use flush toilets. Portable facilities will remain at various locations on the site.

Potable and construction process water will be provided through the Memphis municipal system to the site when all hookups to the existing lines have been completed. The tops of the water supply pipelines, sanitary sewage line and wastewater discharge pipeline will be 0.9 meter (3 feet) below the surface to protect against potential freezing.

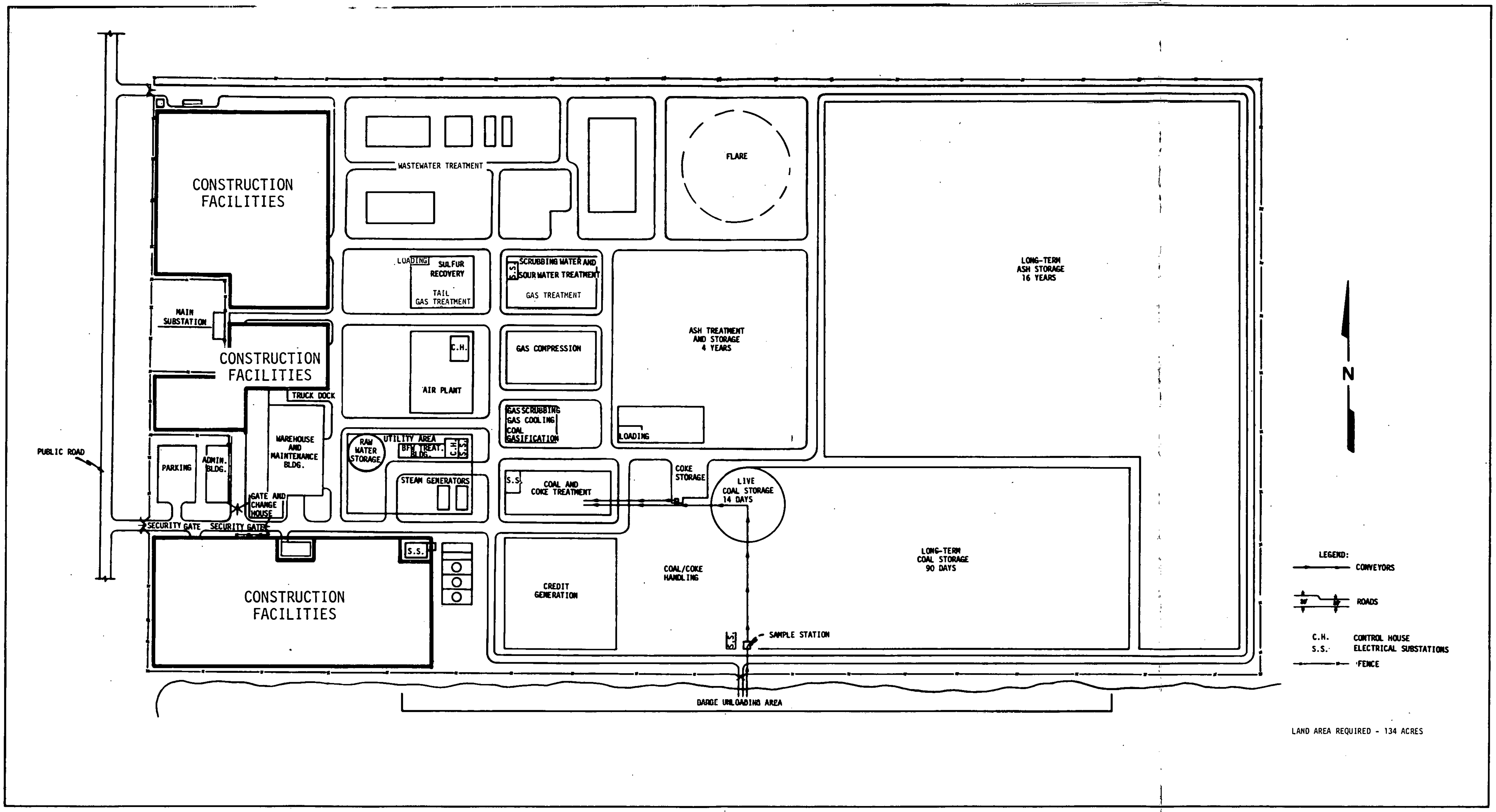

Figure 2-10. Location of On-Site Construction Facilities

2.3.1.5 BARGE UNLOADING FACILITIES

Much of the equipment to be used during permanent facilities construction will be transported to the site by barge. Maximizing barge delivery will reduce the amount of construction traffic on city streets. As a result, the barge unloading facilities will be constructed concurrently with site grading and installation of warehouses, shops, underground piping and the electrical transmission system.

Dredging and filling may occur along the north bank of the channel in order to provide a uniform bank, as shown in Figure 2-5. The maximum anticipated dredging is approximately 1160 meters (3800 feet) in length, 15.2 meters (50 feet) in width and 2 meters (6 feet) in depth. All dredged material from the unloading channel will be disposed of in the existing dredge spoil area at the eastern end of the peninsula, and all fill material will be obtained from dredging operations described in Section 2.3.1.1.4.

Mooring stations will be located south of the site (Figure 2-5). Each station will be made up of one to four separately driven piles. Barge mounted pile driving equipment will be used for this activity. The main support deck for the barge unloader will be pile supported.

2.3.1.6 ON-SITE FACILITIES

The equipment for all control facilities will be set in place and the structural steel erected. All vessels in the gasification process (Gasifiers; Steam Generators; Air Plant; Gas Cooling, Scrubbing, Compression and Treatment facilities; and Sulfur Recovery Tail Gas Treatment facilities) will be erected, as well as the Cooling Towers, Flare Stack, storage tanks and Credit Generation facilities. All above-ground piping and electrical equipment will be installed. The Wastewater Treatment facilities will be constructed, and the short-term ash storage pond will be lined. All instrumentation will be installed. The facilities will be painted, insulated and fireproofed, and the facility will be ready for preoperational testing.

During construction, wastewater and rainfall runoff will be stored in the long-term ash disposal area, as mentioned in Section 2.3.1.1.4. Suspended particulates will be allowed to settle out. The water will then be allowed to flow to Lake McKellar.

All construction equipment will meet OSHA-specified noise standards.

2.3.1.7 IFG DISTRIBUTION SYSTEM

The section of the IFG distribution system under Lake McKellar will be installed by dredging in a right-of-way across the lake (Figure 2-8). The pipeline will be anchored with concrete weights at specified intervals to counteract buoyancy. The top of the pipe will be at a maximum elevation of about 47 meters (155 feet) above mean sea level, which conforms to U.S. Army Corps of Engineers requirements. The dredge spoil will be discharged to an existing fill area near to the plant site. A 9.1 meter (30-foot) wide right-of-way will be obtained both across Lake McKellar and on President Island where the pipeline is not located in street rights-of-way. Crossing Lake McKellar will require dredging a length of approximately 270 meters (885 feet) to a depth of approximately 1.5 meter (5 feet) below the lake bed. The maximum width of dredging for both the IFG and city-water pipelines is 3 meters (10 feet). The water pipeline has a diameter of 40.6 centimeters (16 inches) and the IFG pipeline has a diameter of 76 centimeters (30 inches) or less.

Coated welded steel gas pipe will be used in the construction of the distribution system. For quality assurance, each weld will be inspected and/or x-rayed. The top of the pipe will be located at a minimum of about 1.1 meters (3.5 feet) below the ground surface. The existing storage area at the MLGW service center will be used as a staging and warehouse area for construction.

2.3.2 CONSTRUCTION TERMINATION

Upon commencement of operation, the construction program will be terminated. This will include landscaping and the removal of all temporary facilities. The temporary facilities will be demolished or relocated by their owners.

Landscaping will include finish grading, topsoiling with reclaimed topsoil, fertilizing and planting.

2.3.3 CONSTRUCTION SCHEDULE

A construction activity schedule is provided in Table 2-2. Construction is scheduled to begin on October 1, 1980 with the commencement of site preparation and will require 45 months to complete. This schedule may be reduced by 6 months if site grading and construction of warehouses and shops can occur simultaneously with site filling.

2.3.4 CONSTRUCTION LABOR FORCE

The construction labor force, divided into labor categories, is summarized on a quarterly basis in Table 2-3. The maximum number of workers for any quarter is expected to be 703. These workers are expected to be available from the Memphis area. This will minimize the need for temporary housing due to the construction program. Additionally, the construction manager will maintain approximately 40 people on-site throughout the construction period, a number of whom are expected to move to the area for the duration.

2.3.5 CONSTRUCTION EQUIPMENT

A summary of vehicles to be used during construction activities, including the time period in which each will be used, the number required and the daily operating time of each is provided in Table 2-4.

2.3.6 CONSTRUCTION EXPENDITURES

The total estimated capital cost over a 4-year period for the IFGDP is $200 million (in 1979 dollars). An itemized breakdown of these costs is presented in Table 2-5.

TABLE 2-2

CONSTRUCTION ACTIVITY SCHEDULE

Construction Activity	Months After Go-Ahead	Schedule
Site Preparation		
A. Access Roads	1	Oct. 1, 1980 to Oct. 31, 1980
B. Construction Facilities	1	Oct. 1, 1980 to Oct. 31, 1980
C. Site Filling	1 to 9	Oct. 1, 1980 to June 30, 1981
D. Site Grading	10 to 15	July 1, 1981 to Dec. 31, 1981
Foundations	12 to 21	Sept. 1, 1981 to June 30, 1982
Warehouses and Shops	12 to 21	Sept. 1, 1981 to June 30, 1982
Underground Piping and Electrical	12 to 21	Sept. 1, 1981 to June 30, 1982
Barge Unloading Facilities	12 to 24	Sept. 1, 1981 to Aug. 31, 1982
Structural Steel Erection	15 to 24	Jan. 1, 1982 to Sept. 30, 1982
Equipment Setting	15 to 36	Jan. 1, 1982 to Sept. 30, 1983
Gasification Structure Erection	22 to 36	Aug. 1, 1982 to Sept. 30, 1983
Air Plant Erection	22 to 33	Aug. 1, 1982 to June 30, 1983
Above Ground Piping and Electrical	22 to 42	Aug. 1, 1982 to March 31, 1984
Instrumentation	31 to 45	April 1, 1983 to June 30, 1984
Insulation, Fireproofing, Painting	36 to 45	Sept. 1, 1983 to June 30, 1984
Preoperational Test	42 to 45	March 1, 1984 to June 30, 1984
IFG Distribution System	34 to 45	July 1, 1983 to June 30, 1984

TABLE 2-3

CONSTRUCTION LABOR FORCE

Number of Workers (Average)

	Period (Quarter)	Total	Pipefitters	Electricians	Iron Workers	Boilermakers	Site Buildup Laborers	Laborers
1980	4th	50					50	
1981	1st	50					50	
	2nd	50					50	
	3rd	200	220					
	4th	422	220	129				73
1982	1st	562	193	113	193			63
	2nd	562	193	113	193			63
	3rd	656	304	107	153	31		61
	4th	703	359	105	90	91		58
1983	1st	703	359	105	90	91		58
	2nd	703	359	105	90	91		58
	3rd	703	359	105	90	91		58
	4th	633	370	108	-	94		61
1984	1st	633	370	108	-	94		61
	2nd	411	224	-	-	114		73

TABLE 2-4

CONSTRUCTION VEHICLES

Type	Time Period	Number Required	Daily Operating Time (hr)
Pickup 1/2 Ton	1981 to 1984	13	6
M. Duty Tractor	1981 to 1984	2	8
H. Duty Tractor	1981 to 1984	1	8
Dredgers	1980 to 1981	3	22
50 Ton Crawler Crane	1980 to 1981	4	6
Bulldozers	1980 to 1981	6	8
Graders	1980 to 1981	2	8
Front-End Loader	1981 to 1983	2	6
80 Ton Crawler Crane	1982 to 1983	2	6
125 Ton Crawler Crane	1982 to 1983	2	6
150 Ton Crawler Crane	1982 to 1983	2	6
200 Ton Crawler Crane	1982 to 1983	2	6
25 Ton Truck Crane	1981 to 1983	3	6
45 Ton Hydraulic Crane	1981 to 1983	3	6
Cherry Picker	1982 to 1983	20	8
Welding Packs	1982 to 1983	6	8
600 CFM Air Compressors	1982 to 1983	4	8

TABLE 2-5

TOTAL ESTIMATED CONSTRUCTION COSTS

(1979 Dollars)

	Estimated Cost ($ million)
Direct Material	62.8
Subcontracts (Material and Labor)	82.8
Subcontracts for Field Labor	27.7
Construction Management	11.1
Engineering Cost	14.6
Miscellaneous (e.g. Insurance)	1.0
	$200 million

All major construction subcontracts (general construction, mechanical, electrical, etc.) will be bid on a competitive basis. Award of these subcontracts will be made to the lowest responsive and best qualified bidder.

2.4 PROCESS DESCRIPTION

The process sequence for the IFGDP, including all plant input and output streams, is described in detail in Sections 2.4.1, 2.4.2 and 2.4.3. A variety of gaseous, liquid and solid plant emissions are generated in the plant. The nature and fate of these emissions is described in Section 2.4.4. A detailed process description for the 15 major sections of the plant, including mass balances, is given in Section 2.4.5. A summary of plant material balances is given in Section 2.4.6. All material balance information presented in Sections 2.4.1 through 2.4.6 reflect normal plant operations during which three of the four gasifiers in the plant are operating at 100 percent capacity. It is also possible for all four gasifiers to operate at 75 percent capacity, termed "maximum operation." This mode of operation results in higher gaseous emission rates than the normal mode of operation. Therefore, the more conservative "maximum operation" emission rates are used in Section 2.4.4 to describe plant emissions.

Details of the process description reported in this section are those of the Phase I conceptual design as of August 1979. Process details may be changed and/or refined as a result of the final process design work of Phase II, which is expected to begin in 1980.

Coal gasification involves the incomplete combustion of coal with oxygen in the presence of steam. Several different chemical reactions occur that influence the nature of the product. These reactions are directed to optimize the desired product quality and yield based on operating temperature, pressure and residence time.

The raw product gas produced during gasification consists primarily of hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2) and methane (CH_4), in addition to smaller amounts of inorganic materials, such as ammonia (NH_3), hydrogen sulfide (H_2S) and hydrogen cyanide (HCN). Some organic materials may be produced, such as phenols, tars and oils during abnormal operating conditions. This raw gas receives further processing to upgrade product quality and to reduce levels of contamination. For low- and medium-Btu gas production, further processing consists primarily of gas cooling and scrubbing for the removal of entrained solids and water soluble contaminants and gas treating for the removal of hydrogen sulfide and carbon dioxide, which are acid gases.

To produce a high-Btu gas, further processing also includes carbon monoxide shifting (which converts carbon monoxide and water to hydrogen and carbon dioxide), carbon dioxide removal and methanation. Methanation increases the methane content of the product gas while reducing the carbon monoxide and hydrogen content according to the following reaction:

$$3H_2 + CO \rightarrow CH_4 + H_2O. \quad (2\text{-}1)$$

The overall gasification process consumes primarily coal, oxygen and water and produces an environmentally acceptable fuel gas as the main product. Sulfur is a by-product. A variety of environmentally significant gaseous, liquid and solid effluents are also generated which must receive attention and control.

2.4.1 SUMMARY OF THE PROCESS

The IFGDP will produce 46.3 billion Btu per day of medium-Btu fuel gas and R
4.1 billion Btu per day of high-Btu (950 Btu per standard cubic foot) pipeline gas. Approximately 154 million standard cubic feet per day of medium-Btu fuel gas at 300 ± 30 Btu per standard cubic foot will be available for distribution R
following credit generation. Total plant material requirements include 3158 R
tons per day of bituminous coal, 11,133 tons per day of air, 2.71 million R
gallons per day of water and 45 megawatts of electricity. Overall, the IFGDP's thermal efficiency is 68.0 percent, as calculated by dividing the Btu output from both the industrial fuel gas (IFG) and pipeline gas by the Btu input to the plant (coal plus purchased electricity).

The Institute of Gas Technology's U-GAS™ Process is used to generate the fuel gas in the plant. This system employs a fluidized-bed, oxygen-steam gasification process operating under conditions that promote the formation of ash agglomerates in the lower part of the bed. The fuel gas will be distributed via a pipeline system after cleanup and purification.

Figure 2-11 is a simplified block flow diagram of the IFGDP which shows the process sequence and plant input and output streams. The function and

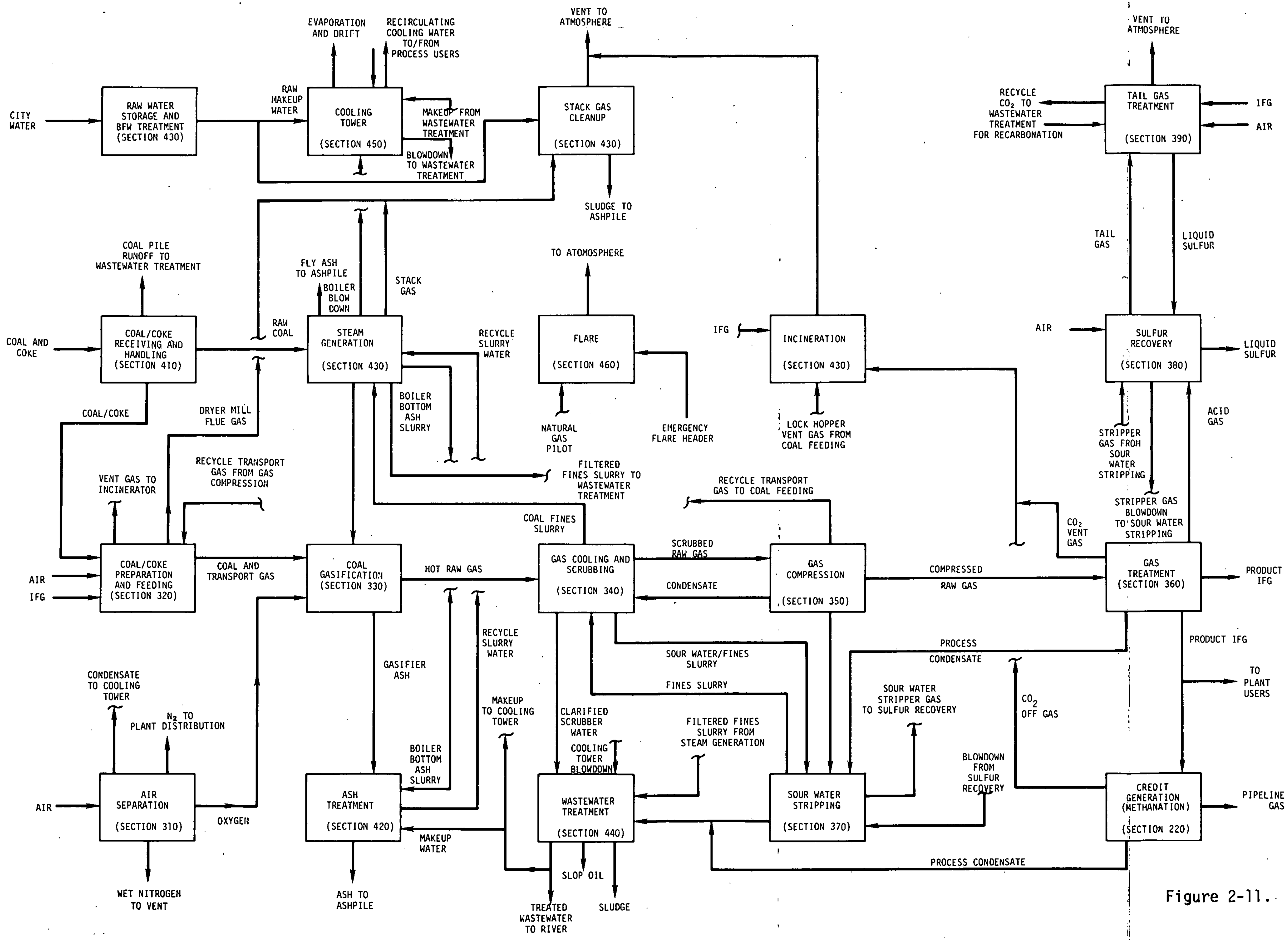

Figure 2-11. Overall Block Flow Diagram of the IFGDP

corresponding number of each plant section is summarized in Table 2-6. A detailed description of these plant sections is provided in Section 2.4.5.

Coal, oxygen and steam are reacted at high temperature in the gasifier, and coal devolatilization, combustion and gasification reactions take place. Raw gas from the gasifier is processed by cooling, followed by scrubbing to remove particulates and water soluble material. Finally, it is treated for acid gas removal prior to discharge to the IFG pipeline distribution system. A slipstream consisting of approximately 10 percent of this fuel gas is methanated to pipeline quality gas (i.e., 950 Btu per standard cubic foot) and is discharged as a "credit" to the Memphis natural gas distribution system at a pressure of 300 pounds per square inch gage. During periods when the plant is not operating because of maintenance or repair operations, this natural gas "credit" is withdrawn from the natural gas pipeline and is diluted with air or nitrogen to medium-Btu quality for distribution to IFG customers.

Wastewaters produced during processing are treated prior to reuse or discharge to the Mississippi River. Acid gases removed during Gas Treatment are either routed to the incinerator or treated for sulfur recovery. Ashes from the Gasification and Steam Generation units are dewatered and trucked to on-site solid waste disposal areas. Sludges from Wastewater Treatment and Flue Gas Desulfurization are dewatered and also sent to the on-site solid waste disposal areas.

2.4.2 FEEDSTOCKS

The primary plant feedstocks include coal/coke, water, air, a variety of supplementary chemicals and catalysts and electricity. Details regarding these commodities follow.

2.4.2.1 COAL/COKE

Sized coke, 1/4 inch by 0, is received in the plant via trucks prior to initial startup. The chemical analysis for the coke is given in Table 2-7.

TABLE 2-6

SUMMARY OF IFGDP PROCESS AND SUPPORTING SECTIONS

Section Name	Section Number	Section Function
Air Separation	310	Separates oxygen from air for use in gasification and separates nitrogen for plant nitrogen needs.
Coal/Coke Receiving and Handling	410	Receives coal/coke from the plant battery limits and transports coal/coke to respective storage piles or to Coal/Coke Preparation.
Coal/Coke Preparation and Feeding	320	Pulverizes and drys coal/coke and feeds the sized coal/coke to the gasifiers.
Coal Gasification	330	Gasifies coal to yield a raw product gas.
Ash Treatment	420	Dewaters gasifier and steam generation bottom ashes and transports this ash to a storage pile.
Gas Cooling and Scrubbing	340	Cools raw product gas and scrubs out fines and water soluble constituents to yield a cooled/scrubbed gas.
Gas Compression	350	Compresses cooled/scrubbed gas as required for Gas Treatment.
Gas Treatment	360	Removes acid gases from the compressed gas to produce the Industrial Fuel Gas (IFG) product.
Sour Water Stripping	370	Strips dissolved gases from condensates generated during Gas Cooling and Scrubbing, Gas Compression and Gas Treatment.

TABLE 2-6 (Continued)

Section Name	Section Number	Section Function
Sulfur Recovery/Tail Gas Treatment	380/390	Recovers sulfur as a liquid product from the hydrogen sulfide rich gas stream generated in Gas Treatment.
Credit Generation	220	Processes a slip stream of IFG from Gas Treatment by CO shifting and methanation to produce a pipeline quality gas.
Flare	460	Burns a pilot charge of IFG in readiness to receive gas discharges from various plant units in the event of an emergency shutdown.
Utilities	430	Three primary functions are: (1) receives, stores and distributes city water to plant users and prepares boiler feed water, (2) generates steam for gasification and other process users and scrubs boiler flue gas for SO_2 removal and (3) incinerates particulate and process gas streams prior to their discharge from the plant stack.
Wastewater Treatment	440	Treats process and nonprocess wastewaters prior to their reuse or discharge to the Mississippi River.
Cooling Tower	450	Provides process cooling water to fulfill all process wet cooling needs.
Facilities	470	Provides supporting facilities such as electric power distribution, buildings, maintenance, docks and fire protection.

TABLE 2-7

ANALYSIS OF COKE USED FOR STARTUP OF THE IFGDP

Ultimate	As Received Wt (%)	As Dried Wt (%)	MF* Wt (%)
Moisture	15.00	2.5	--
Ash	9.29	10.7	11.0
Carbon	73.52	84.3	86.5
Hydrogen	0.35	0.4	0.4
Nitrogen	0.53	0.6	0.6
Sulfur	0.70	0.8	0.8
Oxygen	0.61	0.7	0.7
	100.00	100.0	100.0
Proximate			
Moisture	15.0	2.5	--
Ash	9.3	10.7	11.0
Volatiles	2.6	3.0	3.1
Fixed Carbon	73.1	83.8	85.9
	100.0	100.0	100.0
Bulk Density lb/cf	48	50	--
HHV** Btu/lb	10,958	12,569	12,891
Hardgrove Grindability Index	45	--	--

* Moisture Free

** Higher Heating Value

Note: Coke has been obtainable in the proper size range of 1/4" by 0 for feed to the gasifier. This size range does not require coke crushing, and the availability is expected to be good.

Coke is fed to the gasifiers during startup operation. Once the initial startup period is complete, the proportion of coke to coal is decreased by 20 percent increments until the charge to the gasifiers is completely coal.

The plant design is based on washed Kentucky No. 9 bituminous coal used at a rate of 3158 tons per day. Coal will be received by barge from the Mississippi River. The characteristics of Kentucky No. 9 coal are given in Tables 2-8, 2-9 and 2-10.

2.4.2.2 WATER

Plant raw water is required at a rate of approximately 2.71 million gallons per day. This water will be obtained from the Memphis Light, Gas and Water System. Chemical analysis for water obtained from the Davis Pumping Station is given in Table 2-11.

2.4.2.3 AIR

The air input to the plant amounts to 11,133 tons per day. Most of this air (8055 tons per day) is supplied to the cryogenic unit for oxygen and nitrogen production. Pressurized oxygen produced in this unit is used in the gasifiers for the gasification of coal, and a small amount is used for ozonation in Wastewater Treatment. Nitrogen is used to provide several plant needs (i.e., pressurization of the coal lock hoppers and instrumentation use). The bulk of the nitrogen, however, is vented to the atmosphere.

The remaining air requirements are for the steam boiler (2105 tons per day) and for other process users.

2.4.2.4 CHEMICALS AND CATALYSTS

Chemical (including natural gas) and catalyst requirements of the IFGDP are summarized in Table 2-12.

TABLE 2-8

ANALYSIS OF DESIGN BASIS BITUMINOUS COAL FOR THE IFGDP
(Based on Washed Kentucky No. 9)

Ultimate	As Received 2 in. x 0 Wt (%)	As Dried 1/4 in. x 0 Wt (%)	MF* Wt (%)	MAF** Wt (%)
Moisture	11.0	2.50	--	--
Ash	12.0	13.15	13.48	--
Carbon	61.1	66.93	68.64	79.36
Hydrogen	4.3	4.71	4.83	5.58
Nitrogen	1.0	1.10	1.12	1.30
Chlorine	0.2	0.22	0.25	0.26
Sulfur	3.5†	3.83	3.93	4.54
Oxygen	6.9	7.56	7.75	8.96
	100.0	100.00	100.00	100.00
Proximate				
Moisture	11.0	2.50	--	--
Ash	12.0	13.15	13.48	--
Volatiles	35.4	38.78	39.78	45.97
Fixed Carbon	41.6	45.57	46.74	54.03
	100.0	100.00	100.00	100.00
HHV†† Btu/lb	11,157	12,222	12,536	14,490
Bulk Density lb/cf	42	44.4	--	--
FSI$^{\Delta}$	4 to 6	4-6	--	--
Hardgrove Grindability Index	58	60	--	--

* Moisture free

** Moisture and ash free

† Minimum sulfur content of coal on an "as received" basis is 2.8 percent, which is equivalent to 3.63 percent on an MAF basis.

†† Higher heating value

Δ Free swelling index

TABLE 2-9

SIZE CLASSIFICATION OF KENTUCKY
NO. 9 COAL USED IN THE IFGDP

Coal As Received From Mine; 2 in. x 0

Approximate Coal Size

Retained	Microns	Cum. wt (%)
+ 2 in.	50,800	2.56
+ 1 1/2	38,100	9.84
+ 1 1/4	32,000	12.79
+ 1	25,400	19.90
+ 3/4	19,000	28.56
+ 1/2	12,700	40.94
+ 1/4	6,350	59.18
+ 1/8	3,175	72.32
+ 10 Mesh	2,000	78.50
+ 100 Mesh	149	96.20
- 100 Mesh	--	100.00

Coal Feed To Gasifier

Approximate Coal Size*

Retained	Microns	Cum. wt (%)
+ 1/2 in.	6,350	1.8
+ 4 Mesh	4,760	12.4
+ 6	3,360	32.1
+ 12	1,680	58.6
+ 40	420	84.4
+ 70	210	90.8
+ 140	105	94.2
+ 200	74	95.1
+ 270	53	96.5
- 270	--	100.0

* Specification + 1/2 in. ≤ 2% - 100 Mesh ≤ 10%

TABLE 2-10

TYPICAL ANALYSIS OF ASH IN KENTUCKY NO. 9 COAL

Mineral Analysis of Ash	Percent Ignited Basis (%)
Silica, SiO_2	47.00
Alumina, AL_2O_3	22.21
Titania, TiO_2	1.03
Ferric Oxide, Fe_2O_3	19.75
Lime, CaO	3.00
Magnesia, MgO	1.02
Potassium Oxide, K_2O	2.55
Sodium Oxide, Na_2O	0.53
Sulfur Trioxide, SO_3	2.69
Phos. Pentoxide, P_2O_5	0.19
Strontium Oxide, SrO	0.00
Barium Oxide, BaO	0.01
Manganese Oxide, Mn_3O_4	0.00
Undetermined	0.02
	100.00

Alkalies as Na_2O, Dry Coal Basis	=	0.18
Silica Value	=	66.41
Base: Acid Ratio	=	0.38

Additional Ash Agglomerate Properties

Bulk Density -- lb/cf (dry)	76
-- lb/cf (with 10% moisture)	75
Fluid Bed Density @ 3.3 ft/sec	65
Complete Fluidization Velocity	3.3
Apparent Density lb/cf	140

Screen Analysis

USS*	Carbon (%)	Ash (%)	Wt (%)
6	60.2	39.8	4.4
12	41.8	58.2	18.0
20	5.6	94.4	70.2
40	12.4	87.6	7.2
Pan**	--	--	0.2
	--	--	100.0

* U.S. standard sieve

** Remaining in the pan

TABLE 2-11

CHARACTERISTICS OF WATER SUPPLIED BY THE MLGW SYSTEM
(Based on Water from the Davis Pumping Station)

Characteristic (mg/l, except pH)	
pH	7.5
Alkalinity, (as $CaCO_3$)	98.0
Total Hardness, (as $CaCO_3$)	86.0
Calcium Hardness, (as $CaCO_3$)	46.4
Magnesium Hardness, (as $CaCO_3$)	39.6
Iron (Fe)	0.02
Manganese (Mn)	0.00
Sodium and Potassium, (as Na)	10.6*
Fluoride (F)	1.00
Sulfate (SO_4)	4.0
Chloride (Cl)	5.0
Nitrate (NO_3)	0.1
Silica (SiO_2)	14.8
Dissolved Solids	118.0

* Calculated on the basis of maintaining electro-neutrality

TABLE 2-12

SUPPLEMENTARY MATERIAL REQUIREMENTS OF THE IFGDP

Chemicals Required	Plant Sections	Annual Requirements (lb)
Natural Gas	various	3,801,600*
Phosphate	430	6,006
Selexol Solvent	360	40,590
Sodium Carbonate	390	197,670
Potassium Carbonate	220	45,210
Sulfuric Acid	450	447,480
Caustic (50%)	440	11,880
Amine	430	99
Hydrazine	430	4,290
Corrosion Inhibitor	430	42,900
Dispersant	450	23,100
Chlorine	450	29,700
Activated Carbon	440	100,000
Hydrated Lime	440	9,036,060
Polymer	440	1,320
Phosphoric Acid (50%)	440	6,660
Soda Ash	440	712,800
Catalysts Required		
Rhone Progil Type CR Catalyst	380	41,250
N-25 American Cyanamid	390	6,336
Methanation Catalyst	220	10,560
United-G-3/C 12-3	220	7,920
United-C7-2	220	12,210

* Standard cubic feet

2.4.2.5 ELECTRICITY

Electrical power will be purchased from MLGW at 161 kilovolts and will be transformed to lower voltages for economical in-plant distribution. The electrical input to the plant during normal plant operation is 45 megawatts.

2.4.3 PRODUCTS AND BY-PRODUCTS SPECIFICATIONS

In addition to the industrial fuel gas main product, the plant also produces liquid sulfur and pipeline quality gas. Specifications for these outputs follow.

2.4.3.1 PRODUCT FUEL GAS

Product IFG gas is available for distribution at a rate of approximately 154 million standard cubic feet per day, with a heating value of 300 ± 30 Btu per standard cubic foot. The estimated composition of product gas is: R

Component	Mole (%)
H_2	41.5
CO	34.1
CO_2	17.9
CH_4	5.6
N_2	0.9
H_2O	0.026 (264 ppmv)*
COS	0.004 (42 ppmv)*
H_2S	0.001 (10 ppmv)*

The following specifications at the plant boundary were established for the product IFG during the Phase I Preliminary Engineering Design effort:

Pressure	150 psig
Temperature	80 to 120°F
Heating Value (HHV)	To be selected within allowable range of 270 to 330 Btu per scf

* Parts per million by volume

Sulfur Content H_2S	0.5 grain per 100 scf, maximum
Total S	5 grains per 100 scf, maximum
Water Dew Point at 150 psig	15°F, maximum

These specifications were communicated to the Department of Energy during Phase I. Phase II Engineering Design, scheduled to commence in 1980, will include more detailed trade-off studies on design alternatives which may change these specifications. For example, the present natural gas supply contract between MLGW and the Texas Gas Transmission Corporation specifies sulfur content (for H_2S) as 1 grain per 100 standard cubic foot and total sulfur content as 20 grains per 100 standard cubic foot. In any event, the plant will use Best Available Control Technology on emisssions into the environment.

2.4.3.2 SULFUR

Approximately 100 tons per day of liquid sulfur is produced in the sulfur recovery unit. The product is sold as liquid and transported from the plant site by tank truck. Production specifications for this sulfur are:

Temperature	290°F
Specific Gravity	1.78
Molecular Weight	32.064 (Elemental S)

2.4.3.3 PIPELINE QUALITY GAS

Pipeline quality gas is produced in Credit Generation at a rate of approximately 4.3_ million standard cubic feet per day. The estimated composition of this stream is: R

Component	Mole (percent)
CH_4	93.6
N_2	3.5
H_2	2.3
CO_2	0.6
H_2O	(300 ppmv)
CO	(28 ppmv)

The pipeline quality gas meets the following specifications at the plant boundary:

Pressure	300 psig
Temperature	120°F
Minimum Gross Heating Value (Dry Basis)	950 Btu per scf
Maximum CO Content	0.5 percent volume
Water Dew Point at 300 psig	15°F

The product gas is odorized from 0.5 to 1 pound odorant per million standard cubic feet and metered before being delivered.

2.4.4 SUMMARY OF ENVIRONMENTAL EMISSIONS

As described later in Sections 2.4.5.1 through 2.4.5.15, a variety of environmentally significant gaseous, liquid and solid emissions are generated by the IFGDP. Most of these emissions result while processing a number of intermediate process streams. Intermediate process streams are distinguished here as being environmentally significant streams generated within the plant which require further processing before being discharged as an emission. Since these intermediate streams influence the nature of plant emissions, the discussion of plant emissions will include a review of contributing intermediate process streams.

Plant emissions and important intermediate process streams are summarized in Table 2-13, which shows the source, nature and fate of each stream. These include 19 gaseous, 21 liquid and 7 solid streams that are either important intermediate process effluent streams or plant environmental emissions. As noted by asterisks in Table 2-13, plant environmental emissions comprise 10 gaseous, 6 liquid and 5 solid streams. Table 2-13 also indicates other minor emissions that are treated by Best Available Control Technology (BACT) before discharge to the environment.

The major plant emissions are generated in five plant sections which include: (1) Tail Gas Treatment (Section 390), (2) Steam Generation/Flue Gas Desulfurization/Vent Gas Incineration (Section 430), (3) Cooling Tower (Section 450), (4) Wastewater Treatment (Section 440), and (5) Ash Treatment (Section 420). The location of these sections in the plant plot plan is shown in Figure 2-12.

TABLE 2-13

SUMMARY OF THE SOURCE AND FATE OF GASEOUS, LIQUID AND SOLID EFFLUENTS FROM THE IFGDP

Section Number	Section Name	Gaseous Effluents/Emissions		Liquid Effluents/Emissions		Solid Effluent/Emissions	
		Stream Name	Stream Fate	Stream Name	Stream Fate	Stream Name	Stream Fate
310	Air Separation	air compressor waste gas	*	condensed moisture	Sec 450		
410	Coal/Coke Receiving and Handling			coal pile runoff	Sec 440		
320	Coal/Coke Preparation and Feeding	dryer mill flue gas	Sec 430				
		coke dryer vent gas	*				
		coal silo vent gas	*				
		feed hopper vent gas	Sec 430				
330	Coal Gasification	fines silo vent gas	Sec 430			agglomerate slurry	Sec. 420
340	Gas Cooling and Scrubbing			sour slurry water	Sec 370		
350	Gas Compression			sour water	Sec. 370		
360	Gas Treatment	CO_2 vent gas	Sec 430	sour condensate	Sec. 370		
				Selexol solvent blowdown	*		
370	Sour Water Stripping	sour water stripper gas	Sec 380	stripped wastewater	Sec 440		
380	Sulfur Recovery	tail gas	Sec 390				
		CO_2 vent gas	Sec 430				
390	Tail Gas Treatment	vent gas	**	Beavon-Stretford blowdown solution	*		
		sulfur separation vent gas	*				

* Nonsignificant plant emissions to the environment are indicated by an asterisk. The fate of intermediate process effluents is also indicated by the number corresponding to the plant section to which each stream is transported.

** A double asterisk indicates these environmental emissions which have been processed by best available control technologies before discharge to environment.

(Continued)

TABLE 2-13 (Continued)

Section Number	Section Name	Gaseous Effluents/Emissions: Stream Name	Gaseous Effluents/Emissions: Stream Fate	Liquid Effluents/Emissions: Stream Name	Liquid Effluents/Emissions: Stream Fate	Solid Effluents/Emissions: Stream Name	Solid Effluents/Emissions: Stream Fate
220	Credit Generation	CO_2 off gas	Sec 430	process condensate	Sec 440	consumed catalysts	*
		rich gas dryer vent gas	*	Benfield blowdown	*		
		air dryer vent gas	*				
420	Ash Treatment			ash pile runoff	Sec 440	ash and solid waste	**
430	Steam Generation/ Flue Gas Desulfurization	coal/coke fines vent	**	neutralization water	Sec 440	bottom ash slurry	Sec 420
				filtrate	Sec 440		
		fly ash silo vent	**	demineralizer backwash and carbon filter rinse	Sec 450	flyash	**
		boiler scrubber flue gas	**	boiler blowdown	Sec 450	flue gas scrubbing sludge	**
		plant stack gas	**	spent service water	Sec 440		
	Incineration	incinerator off gas	**				
440	Wastewater Treatment			effluent holding discharge	**	sludges	**
				slop oil	*		
450	Cooling Tower	evaporation	*	drift	*		
				blowdown	Sec 440		
460	Flare	off gas	*				
	Miscellaneous			storm water	Sec 440		
				sanitary wastewater	†		

* Nonsignificant plant emissions to the environment are indicated by an asterisk. The fate of intermediate process effluents is also indicated by the number corresponding to the plant section to which each stream is transported.

** A double asterisk indicates these environmental emissions which have been processed by best available control technologies before discharge to environment.

† To municipal sanitary sewer for treatment in wastewater treatment facility.

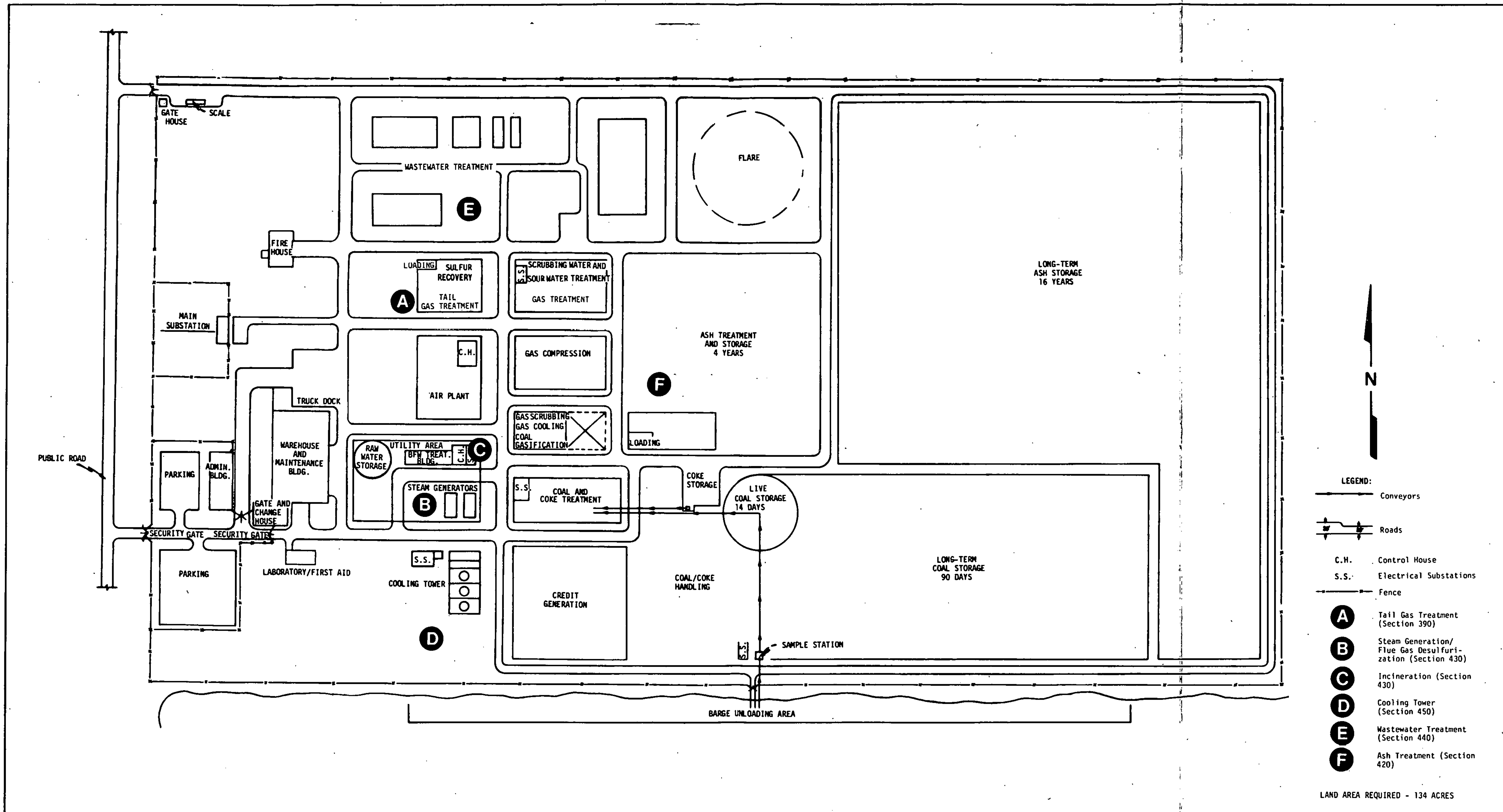

Figure 2-12. IFGDP Plot Showing Location of Systems from Which Major Plant Environmental Emissions are Generated

The gaseous, liquid and solid environmental emissions from the IFGDP include: (1) emissions from the plant sections listed above, (2) plant fugitive emissions and (3) emissions during startup, shutdown and emergency operation. Details regarding the source, magnitude, nature and fate of these emissions follow. Information provided below for major environmental emissions are based on the maximum plant operating conditions (i.e., four gasifiers operating at 75 percent capacity). Minor emissions indicated in Table 2-13, which are treated by BACT, are not discussed.

2.4.4.1 GASEOUS EMISSIONS

Environmentally significant emissions will be processed by BACT during normal operation of the IFGDP. Major gaseous emissions are:

- o Vent gas from Tail Gas Treatment (G-11)
- o Boiler scrubber flue gas from Flue Gas Desulfurization (G-15)
- o Off gas from Incineration (G-16)
- o Stack gas to atmosphere (G-19)
- o Evaporation from Cooling Tower (G-17)
- o Flue gas from the plant Flare (G-18)

The characteristics of these emissions are summarized in Table 2-14. The source of each of these streams is discussed below.

2.4.4.1.1 TAIL GAS TREATMENT (SECTION 390)

Effluents and emissions from the Tail Gas Treatment system are shown in Figure 2-13 and are summarized in Table 2-15. This system receives tail gas from Sulfur Recovery (Section 380) and removes nearly all sulfur compounds before the gas is vented to the atmosphere. The major emission from this system is the carbon dioxide-rich Stretford absorber-oxidizer vent gas (G-11), a slip stream of which goes first to Wastewater Treatment and is used to recarbonate lime-treated, clarified wastewater. Other emissions include: (1) evaporated water and air from the Stretford solution sulfur separation unit and (2) air

TABLE 2-14

GASEOUS EMISSIONS FROM THE IFGDP

	Gaseous Emission Characteristics (Stream Constituents Are Given in Units of lb/hr)					
	Tail Gas Treatment Vent Gas	Flue Gas Desulfurization Flue Gas	Incineration Off Gas	Stack Gas to Atmosphere **	Cooling Tower Evaporation	Flare Flue Gas
Stream Designation:	G-11	G-15	G-16	G-19	G-17	G-18
Stream Constituents						
N_2	19,400	307,760	85,820	393,580		76,210
CO_2	31,800	83,290	164,790	248,080		60
H_2O	1,500	49,980	16,785	66,765	459,500	1,045
O_2	---	20,990	3,330	24,320		40
H_2	12	---	---	---		---
SO_2	---	260	35	295		Less than 0.001
Particulates	---	32	3	35		Less than 0.01
NO_x	13	260	200	460		Less than 0.01
NH_3	1	---	---	---		---
Hydrocarbon (as CH_4)	---	5	1	6		Less than 0.01
CO	20	17	10	27		Less than 0.01
H_2S	10 ppm max	---	---	---		---
COS	2	---	---	---		---
CS_2	0.1	---	---	---		---
Ozone	---	Less than 0.1	---	Less than 0.1		---

Totals	52,748	462,594	270,974	733,588	459,500	77,355
Gas MW	35.0					27.8
Additional Characteristics						
Stack Exit Temp. °F	225			400		200
Stack Exit Velocity, ft/sec	120			44.3		17
Stack Diameter, inches	16.9			134		50
Stack Height, feet	100			150		250
*X Coordinate, feet	850			800	850-895	1,600
*Y Coordinate, feet	1,000			500	150-300	1,350

* The coordinate origin (X=0, Y=0) is located at the southwest corner of the plant site. The Y direction is directly north and the X direction is directly east

** Maximum level of operation (four gasifiers at 75 percent capacity)

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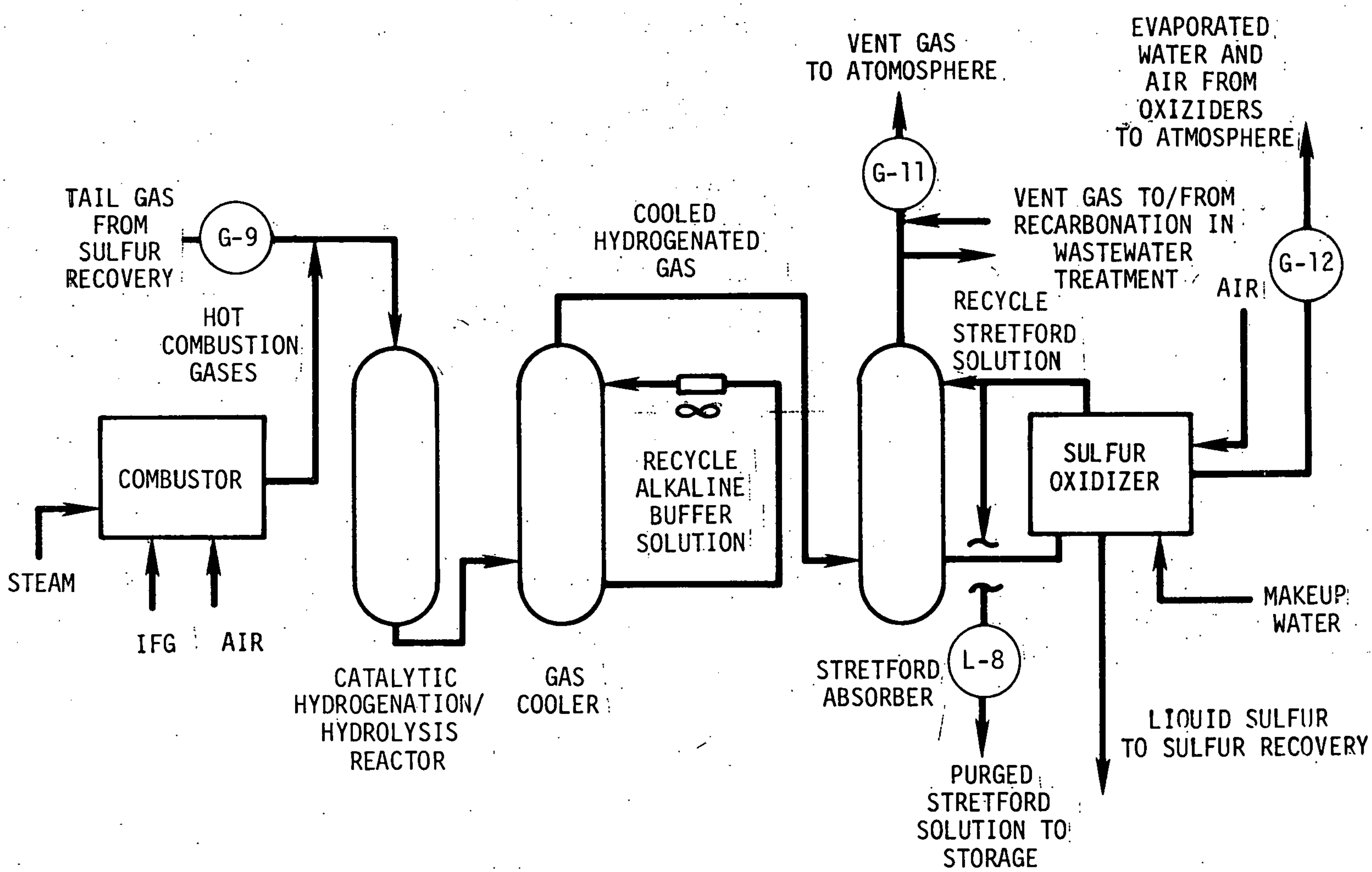

Figure 2-13. Effluents and Emissions from the IFGDP Beavon-Stretford Tail Gas Treatment System (Section 390)

TABLE 2-15

EFFLUENTS AND EMISSIONS FROM THE TAIL GAS TREATMENT SYSTEM (SECTION 390)

	Emissions (lb/hr)		
	Vent Gas to Atmosphere	Sulfur Separation Vent Gas	Evaporated Water
Stream Designation	G-11	G-12	G-12
Stream Constituents			
H_2	12		
CO	20		
N_2	19,400	4,499	
O_2	--	1,222	
CO_2	31,800	--	--
H_2S	10 ppm max	--	--
SO_2	--	--	--
COS	2	--	--
CS_2	0.1	--	--
CH_4	--	--	--
S	--	--	--
NO_x	13	--	--
NH_3	1	--	--
H_2O	1,500	247	9,872
TOTAL	52,748	5,968	9,872

and evaporated water resulting from an internal cooling system. These streams are shown as stream G-12 in Table 2-15. However, these streams are not anticipated to be environmentally significant, since their composition is essentially equivalent to air, with a high moisture content.

2.4.4.1.2 STEAM GENERATION/FLUE GAS DESULFURIZATION (SECTION 430)

Effluents and emissions from the Steam Generation/Flue Gas Desulfurization system are shown in Figure 2-14. Gaseous emissions include the coal/coke fines vent, fly ash silo vent and flue gas from Flue Gas Desulfurization. The coal/coke fines stream is transported from coal preparation to fines feeding by a stream of nitrogen, and the vent gas is not expected to represent a significant emission. The composition of the fly ash silo vent and desulfurized flue gas streams is shown in Table 2-14.

2.4.4.1.3 INCINERATION (SECTION 430)

Effluents and emissions of Incineration are shown in Figure 2-15. This figure shows that six process gas streams are incinerated prior to being discharged. These streams include:

- Tail gas from Sulfur Recovery (G-9)
- Acid gas from Sulfur Recovery (G-10)
- Fines silo vent gas from Coal Gasification (G-6)
- Feed hopper vent gas from Coal Preparation and Feeding (G-5)
- CO_2 vent gas from Gas Treatment (G-7)
- CO_2 off gas from Credit Generation (G-13)

Streams G-9, G-10 and G-6 are not normally routed to the incinerator, but are released to incineration in the case of emergency shutdown. The compositions of streams G-5, G-7 and G-13 are summarized in Table 2-16.

Sufficient IFG is burned in the incinerator to heat the gases in the incinerator to 1500°F to ensure destruction of all odorous compounds. This hot gas stream

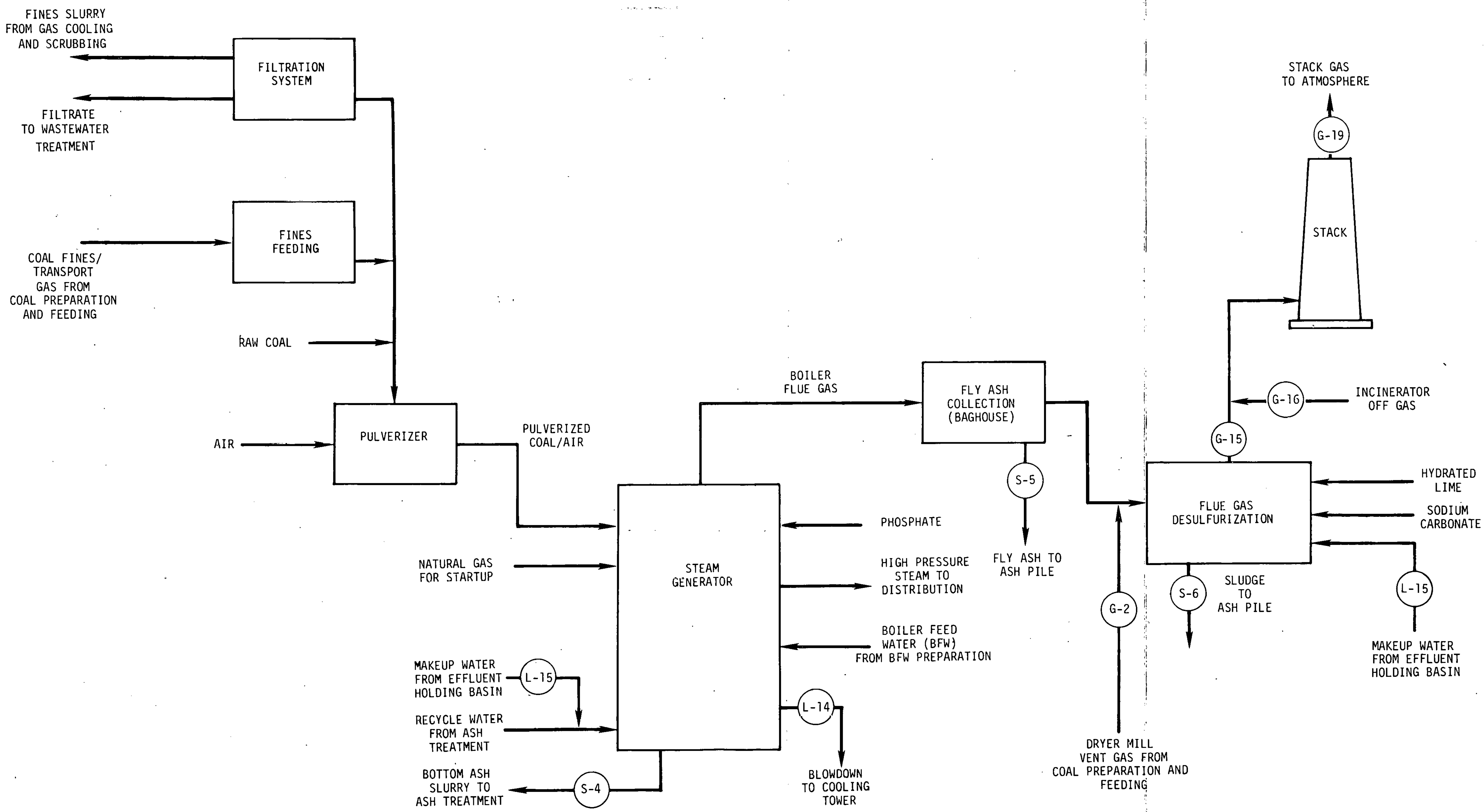

Figure 2-14. Effluents and Emissions from the IFGDP Steam Generation/Flue Gas Desulfurization System (Section 430)

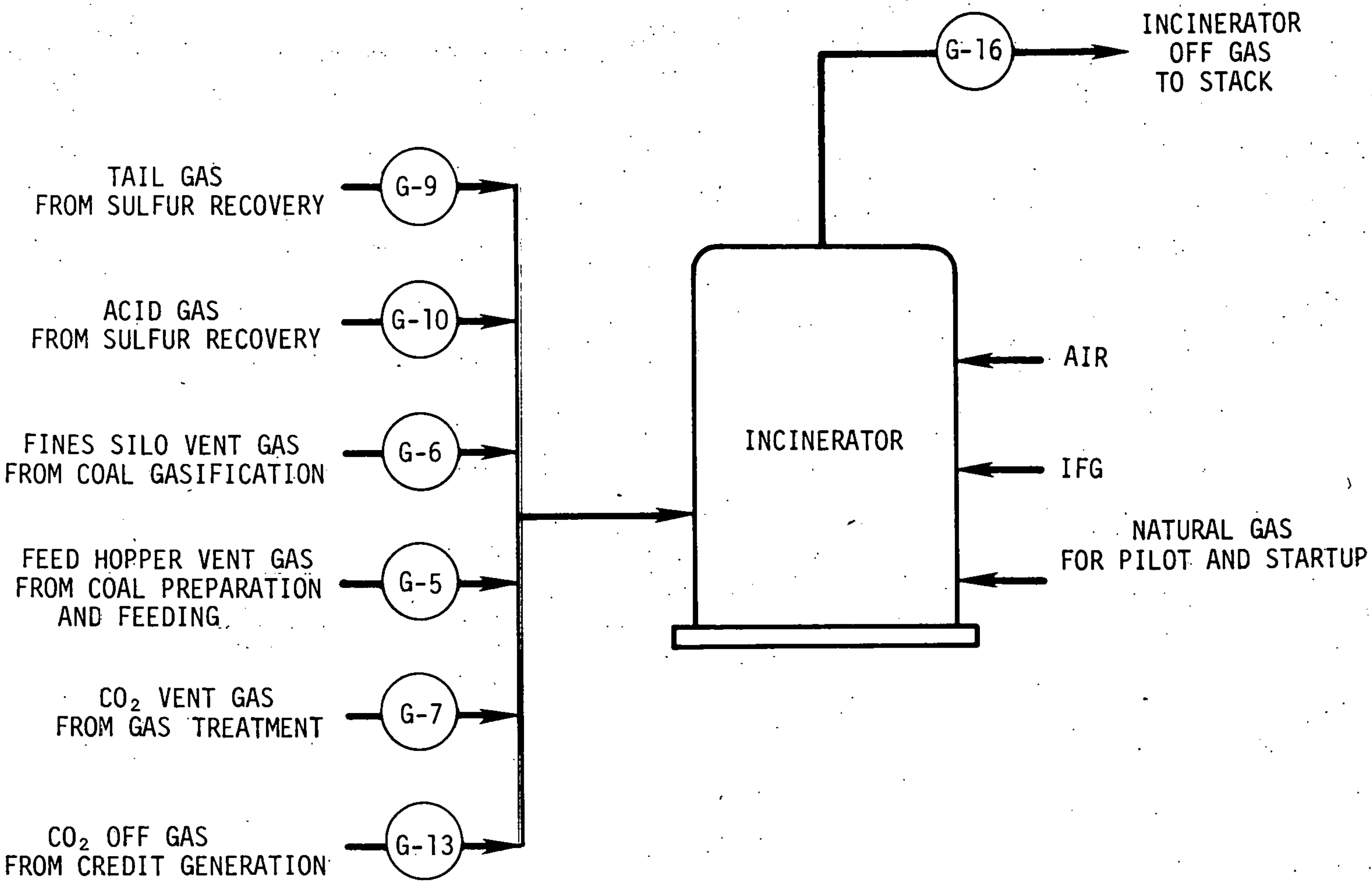

Figure 2-15. Effluents and Emissions from the IFGDP Incineration System (Section 430)

TABLE 2-16

EFFLUENTS AND EMISSIONS FROM INCINERATION (SECTION 430)

	Inputs, lb/hr						Emissions lb/hr
	Sulfur Recovery Tail Gas	Sulfur Recovery Vent Gas	Coal Gasif. Silo Vent Gas	Feed Hopper Vent	CO_2 Vent	CO_2 Off Gas	Incineration Off Gas
Stream Designation	G-9	G-10	G-6	G-5	G-7	G-13	G-16
Stream Constituents							
H_2				53	21	6	
CO				605	431	17	10
N_2				2,024	1,494	-	85,820
O_2				-	-	-	3,330
CO_2				506	12,262	26,679	164,790
H_2S				-	-	4	-
SO_2				-	-	-	35
COS				-	-	-	-
CS_2				-	-	-	-
CH_4				58	114	3	1
NH_3				-	-	-	-
NO_x				-	-	-	200
H_2O				-	24	4,026	16,785
Particulates							3
TOTAL (lbs/hr)	NNF*	NNF*	NNF*	3,246	14,346	30,735	270,974

*Normally no flow

is routed to the stack where it joins the scrubbed flue gas leaving the boiler flue gas scrubber. This provides the reheat required to obtain a plume rise. It is possible for the three gaseous emissions normally discharged to the incinerator to vary and to drop to zero at times. When this occurs, only sufficient IFG will be burned in the incinerator to heat the scrubbed boiler flue gas to 275°F.

2.4.4.1.4 COOLING TOWER (SECTION 450)

Effluents and emissions from the plant cooling tower are shown in Figure 2-16. The gaseous emission from this system is the cooling tower evaporation. This stream results from evaporation of recirculating cooling water as it falls through the cooling tower. Although only 2.6 percent of the circulating water is evaporated, the high volume of circulating water leads to an evaporation rate of 459,500 pounds per hour as shown in Table 2-14.

Cooling tower evaporation is distinguished from drift losses, which result from entrainment of water into the countercurrent air flow. Unlike drift loss, the evaporation stream leaves behind dissolved solids. Cooling water may contain water soluble gases (e.g., carbon dioxide, hydrogen sulfide and ammonia), which are dissolved as a result of possible leaks in cooling water process heat exchangers. These gases are evaporated along with the predominant water stream. A well maintained plant minimizes sources of leakage.

2.4.4.1.5 FLARE (SECTION 460)

The composition of emissions from the plant Flare is shown in Table 2-14. This emission reflects normal operation in which natural gas alone is utilized by the Flare. Emissions from the Flare during emergency operation would be much more significant since several process gas streams would be released to the Flare under emergency conditions.

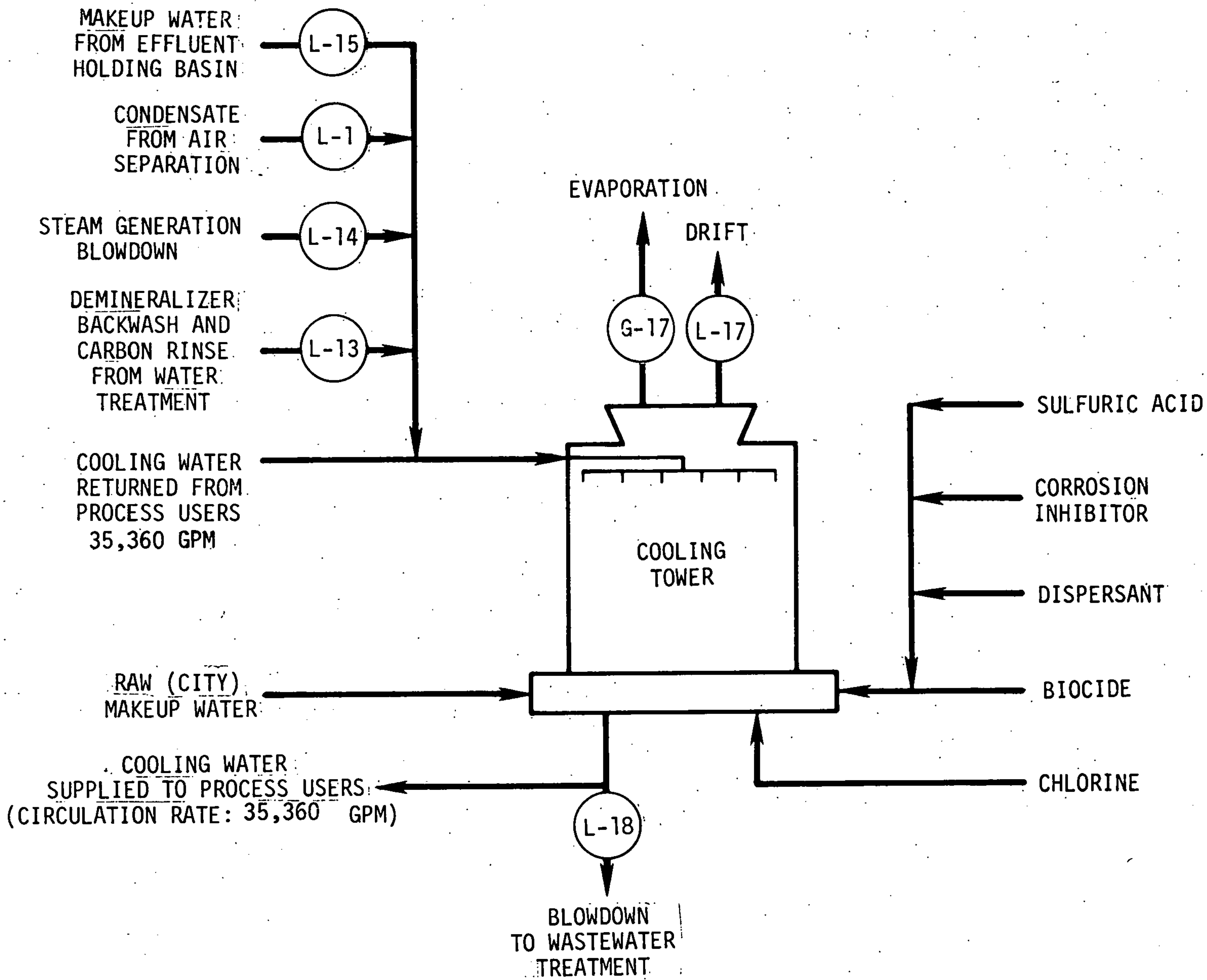

Figure 2-16. Effluents and Emissions from the IFGDP Cooling Tower System (Section 450)

2.4.4.1.6 PLANT FUGITIVE EMISSIONS

Fugitive particulate emissions are expected to occur at various points in the coal and ash handling and storage systems. To minimize these emissions, dust collection systems consisting of fabric filters, blowers and adequate hooding and ducting are provided. These systems are provided at the barge unloading area, the dried coal silo and the dried coke silo. All fabric filters are designed with automatic reverse jet bag cleaning using nitrogen as a cleaning medium to minimize fire and explosion hazards.

A wet dust suppression system is included in the coal live storage pile unloading system to condition the material so that stockpiling can be accomplished without dusting. The dust suppression system consists of a blending and proportioning system to properly mix the dust control compounds with water. It also includes a piping distribution system, pumps and injection nozzles.

Dust suppression in the coal dead storage pile is accomplished by spraying a chemical binder on the surface of the pile. Chemical binders, in general, are a blend of synthetic, long-chain organic polymers in a water base, developed to provide an effective, economical solution for protecting outdoor stockpiles. The application of these binders on the surface of the material creates a thin crust that is tough, durable and highly resistant to wind and rain.

2.4.4.1.7 EMISSIONS DURING ABNORMAL CONDITIONS

Emissions during abnormal operating conditions are summarized in Table 2-17. This table shows that the fate of emissions during abnormal operation is either Flare or Incineration.

The composition of the gasifier startup effluent will vary from that of exhausted hot air to that of off-specification product gas, while the composition of gasifier shutdown effluent will vary from that of product gas to

TABLE 2-17

SUMMARY OF GASEOUS EMISSIONS DURING ABNORMAL OPERATING CONDITIONS

Conditions	Source	Flow Rate	Temperature (°F)	Ultimate Fate
Gasifier Startup	Effluent from start up gasifier	50,000 scfm (Spent Hot Air) 45,000 scfm (Off Specification Product Gas)	200 to 300	Flare
Gasifier Shutdown	Effluent from shut-down gasifier	45,000 scfm (Product Gas) 50,000 scfm (Exhausted Steam) 50,000 scfm (Heated Nitrogen)	200 to 300	Flare
Diversion of Gas from Pipeline	Effluent from all on-line gasifiers	150,000 scfm	200 to 300	Flare
SRU* Startup/Shut-down and Diversion	Feed gas to Sulfur Recovery	6,200 scfm	110	Incinerator

*SRU refers to the sulfur recovery unit

exhausted steam to nitrogen purge gas. The diversion of gas from the pipeline will consist entirely of product gas. These streams are all sent to the plant flare. Abnormal operation in Sulfur Recovery leads to discharge of feed gas to the plant incineration system. This gas will consist primarily of carbon dioxide and hydrogen sulfide.

During emergency conditions, all process emissions from the safety valves except those from Air Separation will discharge into the flare system. Of the discharges from Air Separation, air will be vented locally while nitrogen and oxygen streams will flow to the air plant vent stack.

After being combusted in the flare, the gases are converted to products of combustion: (i.e., carbon dioxide, water and sulfur dioxide), and some NO_x may be formed. This is the accepted, proven manner for disposal of gaseous streams during abnormal operations.

2.4.4.2 LIQUID EFFLUENTS

As shown in Table 2-13, the major plant liquid effluents are generated in Wastewater Treatment (Section 440) and the Cooling Tower (Section 450). In addition, other potential liquid effluents may be generated in Gas Treatment (Section 360), Tail Gas Treatment (Section 390) and Credit Generation (Section 220).

From Table 2-13, plant liquid effluents are:

- o Treated wastewater to Mississippi River (L-15)
- o Cooling tower drift losses (L-17)
- o Recovered oil (L-16)
- o Selexol blowdown (L-6)
- o Stretford blowdown (L-8)
- o Benfield blowdown (L-10)

The composition of these streams is strongly linked to the process and the procedure in which each stream is generated. Unlike the gaseous emissions discussed in Section 2.4.4.1, the critical contaminants in each of the liquid emissions differ markedly from one stream to the next. Details regarding the composition of the six plant liquid emissions are provided in Sections 2.4.4.2.1, 2.4.4.2.2, 2.4.4.2.3 and 2.4.4.2.4.

2.4.4.2.1 WASTEWATER TREATMENT

Wastewaters are generated in the IFGDP from several sources. The type and degree of treatment and the ultimate disposal of these wastewaters depends on the source of the wastewater and on the type and concentration of pollutants in the water. Wastewaters and their sources are:

- o Process wastewater consisting of clarified blowdown from Gas Scrubbing (L-3), stripped condensate from Sour Water Stripping (L-7) and condensates from Credit Generation (collectively L-9)
- o Cooling tower blowdown (L-18)
- o Storm water falling on, and drained from the coal piles (L-2)
- o Storm water falling on, and drained from the ash pile (L-11)
- o Spent service water, such as from deck washings and flushings (L-19)
- o Storm water falling on, and drained from the area inside the limits of processing units (L-20)
- o Neutralization water from boiler feed water preparation (L-12)
- o Sanitary wastewater generated by plant personnel (L-21)

The quality and quantity of these streams is summarized in Table 2-18. Except for sanitary wastewater and ash pile leachate, all plant wastewater is treated

TABLE 2-18

SUMMARY OF LIQUID STREAM COMPOSITIONS IN THE IFGDP

	Influents and Intermediate Streams											Emissions	
	Storm Water	Spent Service Water	Treated Storm/ Service Water	Coal Pile Runoff Raw	Coal Pile Runoff Treated	Cooling Tower Blowdown Raw	Cooling Tower Blowdown Treated	Process Wastewater Raw	Process Wastewater Treated	Ash Pile Leachate	Neutral-ization water	Effluent Holding Basin Discharge	Sanitary Waste Water
Flow, GPM	125		125	15	15	280	280	550	550	20	40	90	10
Stream designation	L-20	L-19	--	L-2	--	L-18	--	--	--	L-11	L-12	L-15	L-21
Constituents* (mg/l, except pH)													
pH				2.5-3.0	8-9			6-9	6-9	10-11	6-8	6-9	6-9
TDS	150-350	150-350	150-350	500-5000	50-500	600-1000	600-1000	2000-3000	2000-3000	100-200	1000-10,000	1200-2400	300-600
TSS	50-800	50-800	5-50	50-800	20-50	100-200	<40	200-300	<10	10-200	10-20	20-30	200-400
Alkalinity										50-100			
Hardness										50-100			
COD	20-200	20-200	10-50	10-20	5-10	50-300	20-100	200-300	30-50	5-30		25-65	300-400
TOC	5-100	5-100	2-10			15-100	5-30	50-150	5-15	0-10		5-20	
BOD_5	10-800	10-150	5-40			20-100	10-50	100-200	10-20			10-30	200-300
Oil & Grease	10-200	10-200	5-20			5-15	4-12	10-20	5-10	<2		5-15	10-20
Phenol								20	<0.05			<0.1	
NH_3-N								25	1-5	0.1-0.5		0.5-3	
NO_3-N										0.3-0.5			
P										0-1			
CN-								5	<0.1	<0.01		<0.05	
SCN-								10	<0.5			<0.3	
H_2S								10	<0.1			<0.1	
CO_2								5	<1				
Ag								0.01	0.01			0.005	
As								0.05	0.05			0.03	
Be								0.01	0.01			0.005	
Cd								0.1	0.1			0.05	
Cr						5-15	<0.05	0.1	0.05			0.06	
Hg								0.05	0.05			0.03	
Ni								0.05	0.05			0.03	
Pb								1.0	0.2			0.5	
Sb								0.05	0.05			0.03	
Se								.2	.2			0.10	
Tl								0.05	0.05			0.03	
Zn						3-10	<0.05	0.5	0.5			0.3	
Others								<2	<2			<1	
Priority Organics								1-10	<1			<0.5	

* Abbreviations are TDS (total dissolved solids), TSS (total suspended solids), COD (chemical oxygen demand), BOD_5 (five-day biological oxygen demand), and TOC (total organic carbon). See List of abbreviations for definition of other terms.

at the plant site prior to discharge into the Mississippi River. The process flow diagram for Wastewater Treatment (Section 440) is shown in Figure 2-17. Wastewater Treatment is comprised of four treatment systems: (1) storm water and spent service water treatment, (2) coal pile runoff water treatment, (3) process wastewater treatment and (4) cooling tower blowdown treatment. Treatment occurring in the four treatment units as indicated in Figure 2-17 is summarized in Table 2-19.

Process condensates produced during Gas Cooling and Scrubbing, Gas Compression, Gas Treatment, and Credit Generation are ultimately treated collectively in the process Wastewater Treatment unit. Condensate from Gas Cooling and Scrubbing contains char fines from contacting the raw product gas. This water slurry is steam stripped for removal of gases, and char fines are removed by clarification. Clarified water proceeds to process Wastewater Treatment. The thickened fines slurry is sent to Steam Generation, where the slurry is filtered to recover char fines for boiler firing. The filtrate is sent to process Wastewater Treatment. Condensates from Gas Compression and Gas Treatment are steam stripped before being sent to process Wastewater Treatment. Condensates produced in Credit Generation (viz, acid gas removal, carbon monoxide shift, and methanation condensates) are routed directly to process Wastewater Treatment without steam stripping.

The composite of the aforementioned wastewater then receives sequential processing as follows: lime-flocculation/clarification, recarbonation, pressure filtration, ozonation/oxygenation, biological pressure filtration and granular activated carbon adsorption. As a result of excess dissolved oxygen provided by oxygenation, biological activity in the second pressure filter and activated carbon adsorption column is enhanced. This activity accounts for the substantial removal of residual organic pollutants from the wastewater. The activity on the activated carbon also serves to maintain a higher effective adsorptive capacity, which reduces the frequency of regeneration. Water treated in this manner is stored in the effluent holding basin.

The cooling tower blowdown is first treated in an electrolytic chromate destruct unit, where chromium and zinc are removed as insoluble hydroxide

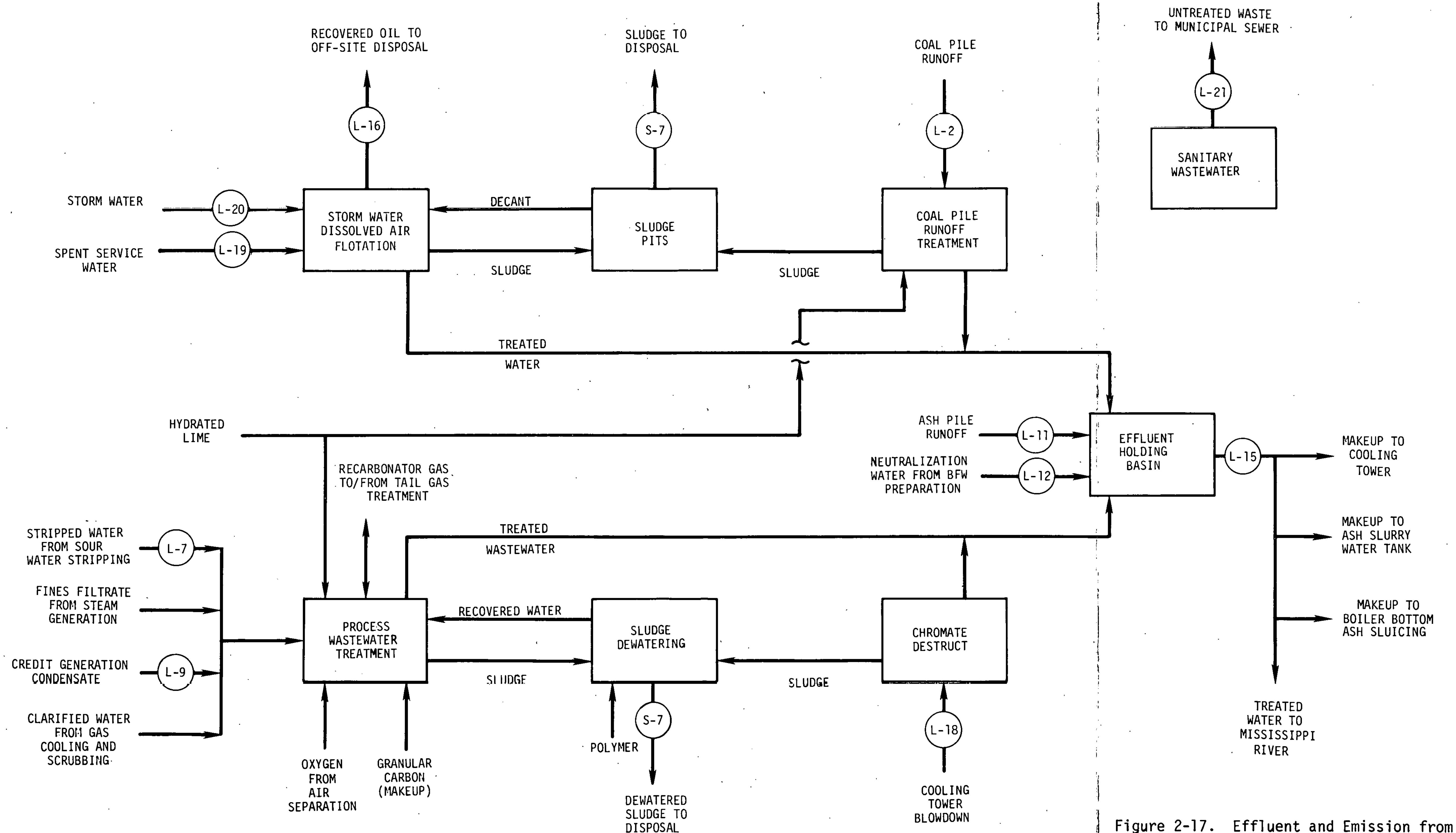

Figure 2-17. Effluent and Emission from the IFGDP Wastewater Treatment System (Section 440)

TABLE 2-19

SUMMARY OF UNIT PROCESSES USED FOR TREATMENT OF PROCESS AND NONPROCESS WATERS AND WASTEWATERS

Water Source	Treatment Prior to Discharge to Effluent Holding Basin
Process Wastewater	Steam Stripping Flocculation/Clarification Recarbonation Filtration Ozonation/Oxygenation Filtration Carbon Adsorption
Cooling Tower Blowdown	Electrolytic Chromate Destruction Clarification
Coal Pile Runoff	Neutralization Aeration Clarification
Inside Battery Limits Storm Water and Spent Service Water	Dissolved Air Flotation Oil Separation
Ash Pile Runoff	No Treatment
Sanitary Wastewater	Sent to Municipal Sewer

precipitates by clarification. If the cooling tower blowdown leaving the clarifier is free of oil and grease, it is discharged directly to the effluent holding basin. If the blowdown contains oils and grease, these materials are removed by routing this stream through the storm water dissolved air flotation unit prior to discharge to the effluent holding basin. Sludges produced during treatment of cooling tower blowdown and process wastewaters are dewatered and disposed of as discussed in Section 2.4.4.3. Recovered water is recycled to the process Wastewater Treatment unit.

Coal pile runoff is collected in a holding basin and is pumped at a controlled rate to a neutralization tank. Here, the pH of the water is raised from approximately 3 to a pH of 8 to 9. Neutralized water is aerated and clarified, and then sent to the effluent holding basin.

A short-term solid waste storage area sufficient for the first 4 years of ash production is provided. This area is lined with a commercially available plastic to permit collection of leachate in a sump from where the leachate is pumped to the effluent holding basin. Samples of this leachate are tested to confirm that it is acceptable for discharge without treatment. If the analyses show that treatment is required, an additional treatment facility is provided as required.

Storm water and spent service water are stored in a holding basin and are pumped at a controlled rate to a dissolved air flotation unit. Oil and other floatable material are separated as a froth and are withdrawn and stored as slop oil. Solids from the unit are released to the sludge pit. Treated water is sent to the effluent holding basin.

Neutralization water from boiler feed water preparation receives minimal treatment (pH adjustment) prior to release to the effluent holding pond. This stream is high in dissolved solids, but is otherwise clean and does not require further treatment.

Plant sanitary wastewater is sent to the municipal sanitary sewer for treatment in the municipal wastewater treatment facility.

2.4.4.2.2 WASTEWATER HOLDING BASINS

Three wastewater holding basins are provided to allow for storage of abnormally high flows of wastewater. A rainwater surge basin and a coal pile runoff surge basin are sized to hold the calculated runoff resulting from the maximum 10-year, 24-hour rainfall. Holding time depends on the rate these waters can be worked off through the treatment systems and is usually 3 to 4 days. The treated effluent holding basin is designed to hold 6 hours maximum treatment flow.

Holding ponds are built above the top of the site grade so that they will be above the 100-year flood. The ponds are made of compacted fill with inner slopes of 1 in 2 and are lined with waterproof lining.

2.4.4.2.3 COOLING TOWER DRIFT

The plant cooling tower system flow diagram is shown in Figure 2-16. Drift from the tower results from entrainment of recirculating cooling water into the upward air flow. In addition to the circulating cooling water composition shown in Table 2-18, this drift contains treatment chemicals used to maintain optimal operation in the tower.

The concentrations of chemical additives to the cooling water is provided in Table 2-20.

2.4.4.2.4 ADDITIONAL POTENTIAL LIQUID EMISSIONS

After a period of 9 months operation, a continuous blowdown of Stretford solvent from Tail Gas Treating (Section 390) commences (L-8). The analysis and average flow rate of this blowdown is shown as follows:

TABLE 2-20

CONCENTRATIONS OF ADDITIVES IN THE CIRCULATING COOLING WATER

Additive	Concentration (mg/l)
Corrosion Inhibitor (Drew CWT-102)	45
Dispersant (Drewsperse 738)	25
Biocide (Biosperse 240)	30
Chlorine	0 to 5

Component	lb/day
ADA*	6
Vanadium**	11
$NaHCO_3$	62
$Na_2S_2O_3$	530
Na_2SO_4	238
Water	2525
TOTAL	3372
Gallons per day	323

* Anthraquinone disulphonic acid

** Mostly as vanadate ion

This material is collected in a storage tank and periodically disposed of by a commercial disposal firm. The slow formation and increasing concentration of sodium sulfate and thiosulfate requires this blowdown. However, the licensor is currently developing a procedure to control the concentration of these substances. With this development, it may be possible to dispense with this blowdown.

Over a period of approximately 2 years, the concentration of potassium formate (HCOOK) in the Benfield Unit solvent (Section 220) will gradually increase to 10 percent. At this point, a blowdown (L-10) must be initiated to control the HCOOK concentration to not more than 10 percent. The data relative to this blowdown stream are as follows:

Component	lb/day
HCOOK	96
K_2CO_3	264
DEA*	24
V_2O_5	6
Water	600
TOTAL	990
Gallons per day	96

* Diethanolamine

This stream flows to the process Wastewater Treatment for removal of cyanates and diethanolamine.

The Selexol solvent used for acid gas removal in Gas Treatment (Section 360) is a glycol compound which is not blown down. If it accidentally becomes contaminated, it will be processed for organics recovery or burned.

2.4.4.3 SOLID EMISSIONS

As shown in Table 2-13, plant solid emissions are generated in Steam Generation/Flue Gas Desulfurization (Section 430), Wastewater Treatment (Section 440) and Ash Handling (Section 420). A summary of the flow rates and compositions of these solid streams is provided in Table 2-21. A brief description of the production of these emissions follows.

2.4.4.3.1 STEAM GENERATION/FLUE GAS DESULFURIZATION (SECTION 430)

The flow diagram for Stream Generation/Flue Gas Desulfurization is provided in Figure 2-14. Solid emissions from this area include:

- o Boiler bottom ash (S-4)
- o Boiler fly ash (S-5)
- o Flue gas desulfurization sludge (S-6)

The boiler bottom ash is sent as a slurry to Ash Treatment and treated as described under Section 2.4.4.3.3. Boiler flue gas passes through a baghouse dust collector prior to processing for flue gas desulfurization. Fly ash is removed at an efficiency of 99.9 percent in this collection system and is routed by a discharge hopper to a fly ash storage bin. When this hopper is full, fly ash is removed and trucked to the plant ash pile.

Flue gas from the dust collection system is treated by the FMC Dual Alkali Scrubbing System. In this system, the scrubbing solution contains Na_2SO_3,

TABLE 2-21

SUMMARY OF SOLID EMISSIONS FROM THE IFGDP

Stream Designation	Stream Composition (lb/hr): Sludge from Flue Gas Desulfurization S-6	Sludge from Wastewater Treatment S-7	Sludge from Chromate Destruct to Dewatering S-7	Total Sludge to Landfill --	Bottom Ash from Steam Generation S-4	Bottom Ash from Gasification S-1	Total Dewatered Bottom Ash to Disposal --	Fly Ash from Steam Generation S-5
Total flow	7,670	1,000	325	8,995	5,460	49,583	**55,143**	2,500
$Cr(OH)_3$	--	--	18	18	--	--	--	--
$Zn(OH)_2$	--	--	5	5	--	--	--	--
$Fe(OH)_3$	--	---	33	33	--	--	--	--
SS*	--	135	42	177	--	--	--	--
$CaSO_3$	4,190	--	--	4,190	--	--	--	--
$CaCO_3$	--	165	--	165	--	--	--	--
Na_2SO_3	210	--	--	210	--	--	--	--
Ash	30	--	--	30	3,905	35,452	39,357	--
H_2O	3,240	700	227	4,167	1,090	9,917	11,107	--
C	--	--	--	--	300	2,727	3,027	--
H	--	--	--	--	20	198	218	--
N	--	--	--	--	55	496	551	--
S	--	--	--	--	90	793	883	--
Fate:	Ash Pile	Sludge Dewatering	Sludge Dewatering	Ash Pile	Ash Handling	Ash Handling	Ash Pile	Ash Pile

* Suspended solids

$NaHSO_3$ and Na_2SO_4. The principal reaction accounting for 90 percent SO_2 removal from the gas phase is:

$$SO_2 + Na_2SO_3 + H_2O \rightarrow 2\ NaHSO_3. \qquad (2\text{-}2)$$

Na_2SO_3 is regenerated by reaction with hydrated lime:

$$2\ NaHSO_3 + Ca(OH)_2 \rightarrow CaSO_3 \cdot 1/2\ H_2O + Na_2SO_3 + 1\text{-}1/2\ H_2O. \qquad (2\text{-}3)$$

The resulting calcium sludge is thickened and filtered to produce a filter cake of 60 to 70 percent solids. This filter cake is stable and of low permeability and has suitable land bearing properties to allow construction of small structures. Tests performed at the Firestone plant in Pottstown, Pennsylvania, have shown that the sludge produced by this process can be safely landfilled. It is possible that this sludge may be sold to local farmers for use on fields to increase the sulfur value in the soil, as has been done in Pennsylvania. However, current plans are that this stable sludge will be mixed with fly ash and trucked to the ash pile.

2.4.4.3.2 WASTEWATER TREATMENT (SECTION 440)

As shown in Figure 2-17, solid emissions from Wastewater Treatment include:

- Solids from sludge pits resulting from coal pile runoff and storm water treatment sludges (S-7)

- Solids from dewatering of chromate destruct and process wastewater treatment sludges (S-7)

The sludge from process Wastewater Treatment is generated by lime flocculation of process wastewater to promote suspended solids removal. Oxygen is bubbled through the water to oxidize inorganics, and polyelectrolytes are added to enhance flocculant growth. Resulting water is clarified, and the sludge is dewatered and transported to the plant solid waste storage area.

Sludge from process Wastewater Treatment is combined with sludge from the chromate destruct unit during dewatering. Chromate destruct sludge results from electrolytic conversion of chromium and zinc present in cooling tower blowdown. These materials are precipitated as insoluble hydroxides: $Zn(OH)_2$ and $Cr(OH)_3$. Following clarification, the thickened sludge is sent to sludge dewatering. Dewatered sludge is sent to the plant solid waste storage pile. This storage pile is coincident with the ash storage pile, and sludges will be stored adjacent to the ash.

2.4.4.3.3 ASH TREATMENT (SECTION 420)

The process flow diagram of Ash Treatment system is shown in Figure 2-18. This system receives bottom ash slurries from Coal Gasification and Steam Generation.

Because of the temperature at which the gasifier ash is produced, it is expected to have a lightly glazed surface and to be resistant to leaching. Studies performed on samples of ash produced during test runs of the IGT U-GAS™ Pilot Plant in Chicago support this view. Leaching studies performed by Energy Impact Associates and Oak Ridge National Laboratory have shown that the test ash from the pilot plant is, indeed, resistant to leaching.

Approximately 425 tons per day of inert ash is produced during gasification. The ash removal system quenches ash from 1850°F to approximately 190°F, and removes it as a wet solid. This stream is combined with approximately 47 tons per day of inert ash from Steam Generation and is transported to ash dewatering. The ash does not present a dusting problem during handling because attrition losses are low, and it is kept wet.

The wet ash is conveyed to two alternately operating dewatering bins and is trucked to the ash storage area following dewatering.

2.4.4.3.4 ASH/SOLIDS STORAGE PILE

Two ash storage areas are used during the life of the IFGDP. One of these is the short-term storage area that has sufficient area to store the equivalent

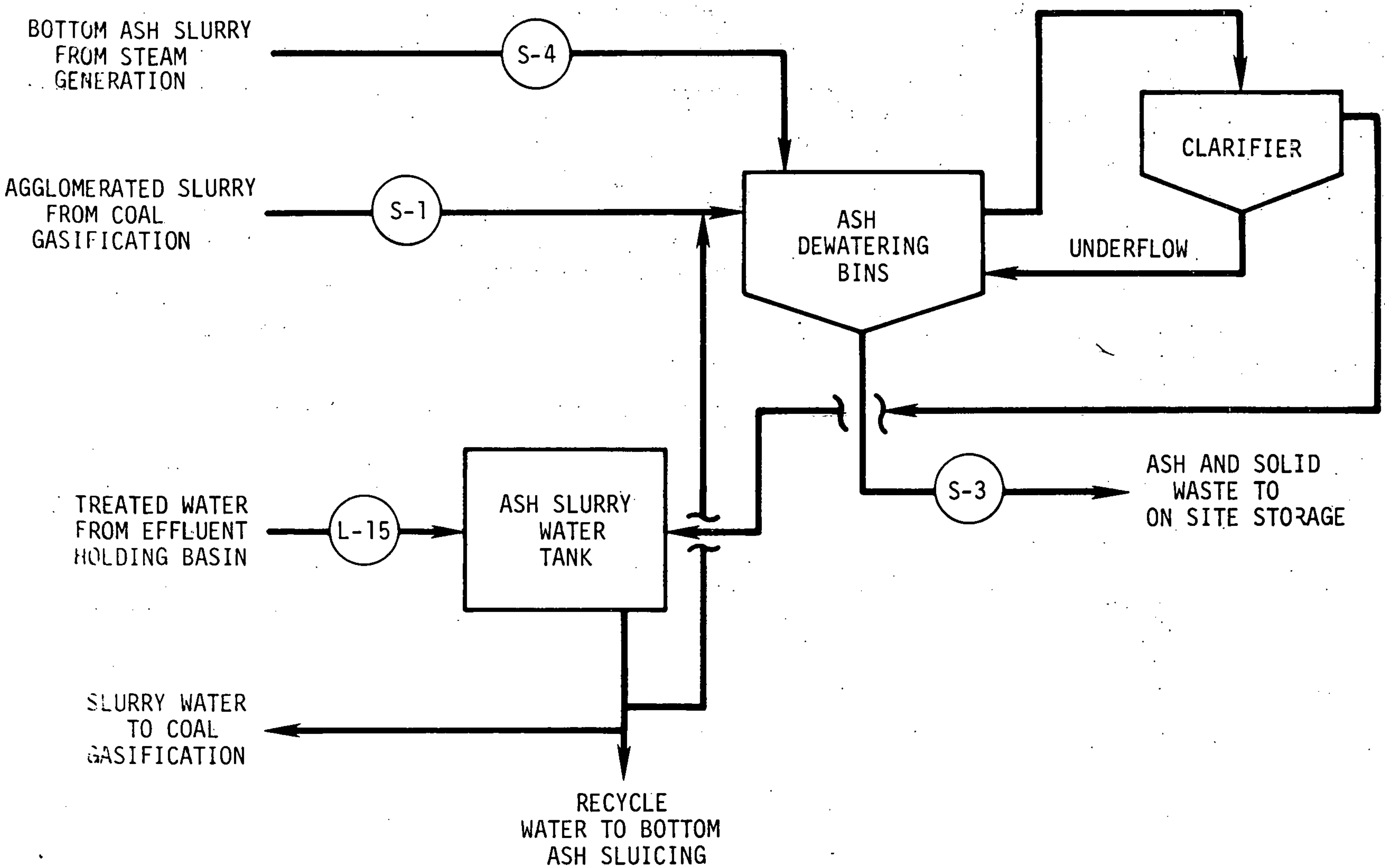

Figure 2-18. Effluents and Emissions from the IFGDP Ash Treatment System (Section 420)

of 4 years production of ash. Using the southwest corner of the plot plan as an origin, this area is located within the zone defined by 750 to 1150 feet north and 1300 to 1800 feet east. A long-term ash pile will store the equivalent of 16 years of ash production and will cover a plot surface of 1,100,000 square feet. This pile is located in the northeast corner of the plant site. The short-term ash storage area will be lined with a commercially available plastic. If analyses of ash pile leachate over the first 4 years of operation indicate that this lining is necessary, the long-term ash storage pile will be similarly lined.

2.4.4.3.5 PLANT PARTICULATE EMISSIONS

Two vent gas streams will be a source of particulate emissions. These streams are:

- o Dryer mill vent gas (G-2)
- o Boiler flue gas (G-15)

Gas composition for these streams is discussed in Section 2.4.4.1. All of the vent gases flow through fabric filters prior to discharge. The particulate removal efficiency of these filters is 99.9 percent. The baghouse filter manufacturer estimates about 1 to 4 pounds per hour (average concentration 0.02 grain dry standard cubic feet) of particulates will be discharged to the atmosphere from each vent.

Other particulate emissions are expected to occur as fugitive emissions from various points in the coal and ash handling and storage systems. These emissions are expected to amount to 4 pounds per hour of particulates.

EPA limits particulate emissions from coal drying systems to less than 0.031 grains dry standard cubic feet (DSCF). Federal regulations limit emissions to less than 0.018 grains dry standard cubic feet and 10 percent opacity for pneumatic transport and less than 20 percent opacity for coal handling and storage. Through use of closed systems throughout the plant, emissions in these areas are also expected to be significantly less than allowable.

2.4.5 DETAILED PROCESS DESCRIPTION

Detailed process descriptions are given in this section of the report for the 15 major sections of the IFGDP. Mass balances are also included for following sections: Air Separation, Coal/Coke Preparation and Feeding, Gasification, Ash Treatment, Gas Cooling and Scrubbing, Gas Compression, Gas Treatment, Sour Water Stripping, Sulfur Recovery, Tail Gas Treatment, Credit Generation, Wastewater Treatment and Cooling Tower. These balances are based on the normal operating condition of the plant (three gasifiers operating at 100 percent capacity).

2.4.5.1 AIR SEPARATION (SECTION 310)

The Air Separation system employs a cryogenic distillation unit that provides gaseous oxygen to the gasifiers and gaseous nitrogen to the instrument and plant nitrogen systems. The overall system mass balance is shown in Table 2-22. This system has as an input a large air stream from the atmosphere and produces four outputs: (1) wet waste gas to the atmosphere, (2) oxygen to coal gasification and Wastewater Treatment, (3) nitrogen to the Gas Treatment carbon dioxide stripper and other plant users and (4) condensed moisture to the Cooling Tower and plant sewer.

Incoming air is filtered and compressed in two stages to a pressure of approximately 85 pounds per square inch gage, and knockout drums are used to separate condensate water formed as a result of interstage and aftercooling. The interstage condensate is a low flow stream containing impurities not removed by filtering and is discharged to the plant sewer system. The aftercooler condensate is of sufficient quality for use as makeup to the plant Cooling Tower.

Compressed air is fed to the air separation package, which consists of a heat exchanger and two cryogenic distillation columns. The first column produces an overhead product of specification nitrogen (10 parts per million by volume oxygen) and the bottom product from the second column is specification oxygen (98 percent oxygen by volume).

TABLE 2-22

MASS BALANCE FOR THE IFGDP AIR SEPARATION SYSTEM

(SECTION 310)

	Input (lb/hr)	Output (lb/hr)
Air from atmosphere	671,249	
Wet waste gas to atmosphere		506,756
Oxygen to Coal Gasification		146,938
Oxygen to Wastewater Treatment		450
Nitrogen to plant users		6,700
Nitrogen to CO_2 stripper in Gas Treatment		1,485
Condensed moisture to Cooling Tower		7,850
Condensed moisture to sewer		1,070
Totals	671,249	671,249

Product oxygen (98 percent by volume pure) leaves the separation package at 94°F and 2.7 pounds per square inch gage and is compressed in three stages to 105 pounds per square inch gage for delivery to Coal Gasification (Section 330). A side stream of oxygen from the second compressor (30 pounds per square inch gage) is sent to Wastewater Treatment (Section 440) for use in ozonation.

Product nitrogen (bone dry, 10 parts per million oxygen) leaves the separation package at atmospheric pressure and 94°F and is sent to both Gas Treatment (Section 330), where it is employed as a stripping medium for carbon dioxide stripping, and to the plant nitrogen package. The primary use of nitrogen from the plant nitrogen package is as a lock gas for pressurization of the feed lock hopper in Coal Preparation and Feeding. Liquid nitrogen is produced continously in the Air Separation package and is stored for subsequent vaporization by either of two vaporization packages. This nitrogen is used for startup gas to Coal Gasification (see Section 2.4.5.4).

Excess oxygen produced during normal plant operation is stored as a liquid and is vaporized and used when necessary as an emergency backup source of oxygen feed gas.

Emissions from this system include one gaseous and two liquid streams. The gaseous stream is discharged directly to the atmosphere from the Air Separation package as wet waste gas (molar composition of 97.4 percent nitrogen, 1.3 percent oxygen and 1.3 percent water). This gas consists primarily of nitrogen, but also contains other air constituents such as carbon dioxide and argon. The liquid effluent results from condensation in interstage cooling and is routed to the sewer. High quality water from the aftercooler is routed to the Cooling Tower where it is used as makeup.

2.4.5.2 COAL/COKE RECEIVING AND HANDLING (SECTION 410)

Coal and coke are received intermittantly at the plant battery limits. Coal is used for gasification and steam generation, while coke is used for start-up purposes.

2.4.5.2.1 COKE RECEIVING AND HANDLING

Sized coke (1/4 inch by 0) is delivered by truck and is transported by front-end loaders to a coke reclaim area. During periods of gasifier restartup, coke is conveyed to the coke preparation and receiving system.

2.4.5.2.2 COAL RECEIVING AND HANDLING

Washed coal (2 inches by 0) is delivered to the plant by 1500-ton barges and is transported via a barge unloading and conveying system to the plant live coal storage pile. Coal is continuously reclaimed from the live storage pile and is transferred to Coal Preparation and Feeding and to Steam Generation. The rate of coal feed to these two areas is 3110 tons per day and 48 tons per day, respectively. The live coal pile can hold a supply of coal sufficient for 14 days of operation at 110 percent of the plant normal operation material balance.

Coal from the live coal storage pile can be transferred with front-end loaders or other mobile equipment to the plant dead coal storage pile. This is a long-term pile which can hold a 90 day supply of coal at 110 percent of the plant material balance.

A wet dust suppression system is used in the live coal storage pile stockpiling and unloading system. A blending and proportioning system properly mixes the dust control compounds with water. It also includes a piping distribution system, pumps and spray nozzles.

Dust suppression in the dead coal storage pile is accomplished by spraying a chemical binder on the surface of the pile. Chemical binders, in general, are a blend of synthetic, organic long-chain polymers in a water base, developed to provide an effective, economical solution for protecting outdoor stockpiles. The application of these binders on the surface of the material creates a thin crust that is tough, durable and highly resistant to wind and rain.

Rainwater runoff from the short- and long-term coal piles is collected in the coal pile runoff surge basin and is discharged to Wastewater Treatment. Details regarding the nature and fate of this runoff are discussed in Section 2.4.5.13.

2.4.5.3 COAL/COKE PREPARATION AND FEEDING (SECTION 320)

This section discusses facilities for preparing and feeding coke during plant startup and for feeding coal during normal plant operation.

2.4.5.3.1 COKE PREPARATION AND FEEDING

Coke is conveyed from Coke Receiving and Handling and dried by contact with an air and natural gas combustion gas. Coke fines entrained with the exhausted drying gas are removed by a bag filter and are fed to the coke silo. Dried coke from the dryer is screened and stored in the coke silo. The coke silo is maintained under a nitrogen atmosphere to minimize the possibility of spontaneous combustion.

During gasifier startup or gasifier restartup, coke is withdrawn from the coke silo and is conveyed to the coal feed lock hopper system.

2.4.5.3.2 COAL PREPARATION AND FEEDING

Table 2-23 shows the mass balance for the Coal/Coke Preparation and Feeding system during normal plant operation (i.e., coal without coke being fed to the gasifiers). Inputs to this system include: (1) raw coal from Coal Receiving and Handling, (2) air from the atmosphere for coal and coke combustion drying gases, (3) nitrogen for feed lock hopper pressurization and coal and coke silo atmosphere blanketing, (4) transport gas from Gas Compression for delivering coal to Coal Gasification and (5) desulfurized IFG from Gas Treatment for pressurization of the injection hoppers. System outputs include: (1) sized dried coal and transport gas to Coal Gasification, (2) hopper vent gas to Incineration, (3) dryer mill flue gas to Flue Gas Desulfurization and (4) fines to Steam Generation.

TABLE 2-23

MASS BALANCE FOR THE IFGDP COAL/COKE PREPARATION AND FEEDING SYSTEM (SECTION 320)

	Input (lb/hr)	Output (lb/hr)
Raw coal from Coal Receiving and Handling	259,192	
Air from atmosphere	51,919	
N_2 from Air Separation	2,007	
Transport gas from Gas Compression	22,884	
Desulfurized IFG from Gas Treatment	1,239	
Sized dried coal to Coal Gasification		227,489
Transport gas to Coal Gasification		22,884
Vent gas to Incineration		3,246
Flue gas to Flue Gas Desulfurization		77,488
Fines to Steam Generation		6,134
Totals	337,241	337,241

Raw coal is conveyed from Coal Receiving and Handling and is fed to a dryer mill where the coal is simultaneously crushed as required and dried by contacting an air and fines combustion gas. Dried coal is separated from the moist drying gas, and the coal is stored in the coal silo. Fines from the moist drying gas are removed by passing the gas through a bag filter, and filtered gas is recycled to the dryer mill. To maintain a balance on the water evaporated from the coal, a portion of the recycled moist gas is routed to the flue gas scrubbing system in Flue Gas Desulfurization.

The coal silo is sized for a surge capacity of 12 hours and, like the coke silo, is maintained under a nitrogen atmosphere to minimize the possibility of spontaneous combustion. Coal from this silo is conveyed to the coal feeding system, which consists of a series of three consecutive hoppers: (1) a receiving hopper, (2) lock hoppers and (3) two injection hoppers. Each of the four gasifiers has its own feeding system. During operation, the lock hoppers are pressurized with nitrogen, and the injection hoppers are pressurized with IFG.

2.4.5.3.3 COAL/COKE FINES RECOVERY

Coal fines recovered in the dryer mill bag filter and coke fines recovered from the coke dryer exhaust filter are used inside the plant as fuel. These fines are used to supplement fuel needs in either the dryer mill or in the steam generation boiler of the plant Steam Generation system. Excess fines are transported to the coal silo for storage.

2.4.5.3.4 SYSTEM FUGITIVE EMISSIONS

In order to minimize fugitive emissions, the following dust collection and dust suppression systems are provided in this section of the plant. Dust collection systems consist of 99.9 percent removal efficiency bag houses, fans and dust pick-up ducting included in the barge unloading area, coal/coke handling conveyors and coke dryer. Filter bag houses are also included in the coal crushing and drying system as well as in the vent systems for the dried coal and coke silos and for the gasifier feed lock hopper system. All bag houses are designed for automatic reverse jet bag cleaning using nitrogen as a cleaning medium to minimize fire hazards.

2.4.5.4 COAL GASIFICATION (SECTION 330)

During plant startup, fuel inputs to the gasifier are fuel gas and coke. Once sufficient temperature has been reached in the gasifier, coal feed begins and is increased (with a decrease in coke feed) until normal steady-state operation is achieved. Details regarding the startup and normal modes of operation are provided below.

2.4.5.4.1 GASIFIER STARTUP

The main objective during gasifier startup is to heat up the gasifier to sufficiently high temperatures so that when coal is added it will react with steam and oxygen. Startup heaters are used in which fuel gas is burned in a mixture of oxygen and nitrogen to generate a flue gas. Once the temperature has reached approximately 800°F, or about 200°F below the autoignition temperature of the coke, coke feed is initiated and continues until a bed height of 20 feet is achieved. Bed temperature is slowly increased by adjusting the flow of nitrogen, a diluent to the flue gas mixture. Once autoignition occurs, the startup heater is shut off and oxygen feed is initiated until a bed temperature of about 1850°F is achieved. Steam feed is slowly initiated to replace the nitrogen feed, and coal feed begins by increments of 20 percent of the normal operation coal feed rate until the gasifier can be put into the automatic control mode.

2.4.5.4.2 NORMAL GASIFIER OPERATION

The IFGDP design is based on Kentucky No. 9 bituminous coal with the characteristics specified in Table 2-8. During normal operation, three of the four plant gasifiers operate at 100 percent capacity, while the fourth gasifier is on standby. Figure 2-19 is a schematic view of the main features of a plant

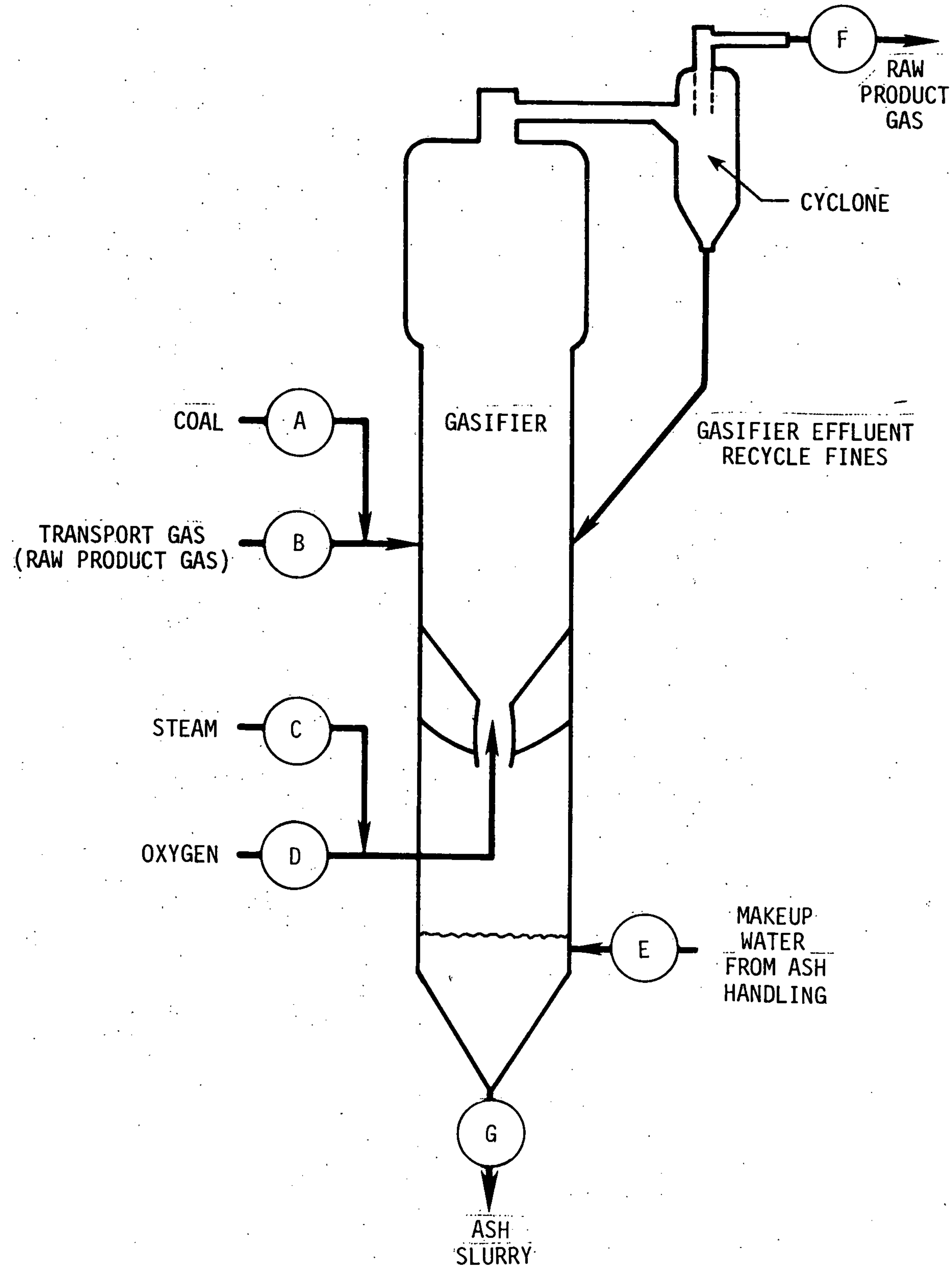

Figure 2-19. Feeds and Effluent Streams from the IFGDP Gasification Section

gasifier. Input streams include: (1) coal from Coal Preparation and Feeding, (2) oxygen from Air Separation, (3) steam from Steam Generation and (4) makeup ash slurry water from Ash Treatment. Outputs are raw product gas to Gas Cooling and Scrubbing and the agglomerate ash slurry to Ash Treatment.

The normal operation material balance for streams A through G in Figure 2-19 for all three gasifiers is summarized in Table 2-24. This material balance was calculated based on an agglomerate ash composition of 85 percent, a fines loss of 3 percent of coal feed, heat loss of 75 Btu per pound of dry coal and a product gas recycle of 0.1 pound of gas per pound of coal.

Sized, dried coal is fed to the gasifier from Coal/Coke Treating and Feeding with recycle raw gas from Gas Compression. Oxygen from air separation and steam (500°F, 115 pounds per square inch gage) generated inside the plant mixed and enter the gasifier below the coal feed location.

In this gasifier, there is a carbon-rich, dense-phase fluidized bed of coal, reacting simultaneously with steam and oxygen to produce carbon monoxide, carbon dioxide and hydrogen. Two reaction zones are maintained within the gasifier, each with different chemistry, temperature and function. The larger reaction zone is a nonslagging, dense-phase, steam-oxygen fluidized bed at about 1875°F, where most of the coal is reacted to gaseous products. The superficial gas velocity is above 4 feet per second at bed outlet conditions. The smaller zone, the ash agglomerating zone, at the bottom of the gasifier, is maintained at a higher temperature with a superficial gas velocity an order of magnitude higher than the velocity in the larger zone. In the turbulent agglomerating zone, ash particles preferentially adhere to other ash particles and grow to form agglomerates. When these reach a certain size, they fall out through the bottom ventrui throat, countercurrent to feed gas flow.

Product gas rises in the gasifier and exits at the gasifier top. Fines entrained in the raw gas are mostly recovered by cyclones and returned to the gasifier.

TABLE 2-24

MATERIAL BALANCE AROUND GASIFIER DURING NORMAL IFGDP OPERATION

	Inputs (lb/hr)					Outputs (lb/hr)		
						Raw Gas to Gas Cooling and Scrubbing		
	Coal from Coal Preparation and Feeding Stream A*	Raw Transport Gas from Gas Compression Stream B*	Steam from Steam Distribution Stream C*	Oxygen from Air Separation Stream D*	Makeup Water from Ash Treatment Stream E*	Fines Stream F*	Gas Stream F*	Agglomerate Ash Slurry to Ash Treatment Stream G*
Carbon	152,249					5,187		4,734
Hydrogen	10,713					22		--
Oxygen	17,189			144,358		--		--
Nitrogen	2,484			2,580		44		111
Sulfur	8,715					88		235
Ash	30,452					1,483		28,959
Subtotal**	221,802	22,477	0	146,938	0	6,824	440,046	34,049
Water	5,687	407	268,644		5,489		190,525	
H_2		858					16,770	
CO		9,793					191,469	
N_2		261		2,580			5,076	
O_2		--		144,358			--	
CO_2		10,153					198,948	
H_2S		457					9,018	
SO_2		--					--	
COS		36					667	
CS_2		--					--	
CH_4		919					17,984	
S		--					--	
NH_3		--					114	
Total†	227,489	22,884	268,644	146,938	5,489	6,824	630,571	34,049

* See Figure 2-19 for input/output locations.

** Denotes total flow rate of stream on a moisture free basis. Water content is not reflected in the hydrogen and oxygen entries.

† Denotes total flow rate of stream including moisture.

The ash agglomerate from the high-temperature zone in the gasifier drops into the water-filled bottom section where it is quenched. The quenched agglomerates fall through the bottom section to Ash Treatment where they are separated from water and trucked away to ash storage.

2.4.5.5 ASH TREATMENT (SECTION 420)

Bottom ashes produced in Coal Gasification and in Steam Generation are routed to the Ash Treatment system for dewatering and disposal. As shown in Table 2-25, system inputs include gasifier and boiler bottom ash slurries and makeup slurry water consisting of treated wastewater from the effluent holding basin in the Wastewater Treatment section. Outputs include dewatered ash to disposal and recovered water which is recycled to Coal Gasification and to Steam Generation for ash slurrying.

Agglomerated ash is quenched in the bottom of the gasifiers and drops by gravity into the ash hooper in the Ash Treatment section. Quenched ash is withdrawn as a slurry and, with the use of the pressure in the gasifier, is hydraulically conveyed to the dewatering bins. Gasifier ash is combined with bottom ash from Steam Generation; composite ash is settled; and dewatered settled ash is discharged into trucks and is transported to the ash pile. Two dewatering bins are provided and used alternately (i.e., one will be filling while the other will be settling and/or unloading). During filling, water from the dewatering bins overflows into the clarifier, where ash fines are separated and pumped back to the dewatering bins. The overflow water from the clarifier is collected in a surge tank and recirculated to the ash hopper and to the steam boiler for quenching and ash conveying.

Losses of recycle water due to steam generated during quenching of the agglomerates and atmospheric evaporation occur at the ash dewatering bins. The clarifier and the recycle water surge tank are made up with treated effluent from Wastewater Treatment.

Ash is stored in one of two ash storage piles at the plant site. A short-term ash pile is sufficiently large to store the equivalent of 4 years of ash

TABLE 2-25

MASS BALANCE FOR THE IFGDP ASH TREATMENT SYSTEM (SECTION 420)

	Input (lb/hr)	Output (lb/hr)
Ash agglomerates from Coal Gasification	34,049	
Bottom ash slurry from Steam Generation	221,864	
Makeup water from Wastewater Treatment	14,160	
Makeup water to Coal Gasification		5,489
Recycle slurry water to Steam Generation		221,229
Solid Waste to Ash Pile		43,355
Totals	270,073	270,073

production based on normal plant operation. The second pile is sufficient to enable storage of an additional 16 years of ash production.

The hazards associated with the ash itself are expected to be minimal. The metals contained in the ash are expected to be in the nearly insoluble oxide form. Leaching studies show that the ash is resistant to leaching. The rainfall drained from the ash pile is initially collected for analysis to demonstrate that it does not contain pollutants in unacceptable concentrations.

2.4.5.6 GAS COOLING AND SCRUBBING (SECTION 340)

In this system, hot raw product gas from Coal Gasification is cooled from 1860°F to 236°F and is water scrubbed to remove entrained fines. Inputs to this system are the raw product gas from Coal Gasification and scrubbing water from Gas Compression. Outputs are the cooled and scrubbed raw gas to Gas Compression and slurry water to Sour Water Stripping. The mass balance for this system is shown in Table 2-26.

In Gas Cooling, raw product gas from Coal Gasification is cooled by heat transfer with boiler feed water in waste heat recovery steam generators. As a result of this waste heat recovery, 335,790 pounds per hour of superheated steam (900 pounds per square inch gage, 840°F) and 890 pounds per hour of saturated steam (85 pounds per square inch gage) are generated. Further stream cooling is achieved by heat exchange in which boiler feed water is preheated, and final cooling of the raw gas from 450°F to 240°F occurs in a direct contact water spray tower. Overhead gas from the spray tower is scrubbed by two venturi scrubbers, and scrubbed gas proceeds to the Gas Compression section.

The water used for venturi scrubbing is process condensate generated in the Gas Compression section. Water used in the venturi scrubber is subsequently returned for use in the direct contact water spray tower. The water bottoms from the spray tower consequently contain the bulk of entrained solids removed from the raw product gas as a result of contacting water in the spray tower

TABLE 2-26

MASS BALANCE FOR THE IFGDP GAS COOLING AND SCRUBBING SYSTEM (SECTION 340)

	Input (lb/hr)	Output (lb/hr)
Raw product gas from Coal Gasification	630,571	
Fines in raw gas from Coal Gasification	6,824	
Process condensate from Gas Compression	92,250	
Stripped slurry water from Sour Water Stripping	116,029	
Fines in stripped slurry from Sour Water Stripping	6,824	
Scrubbed raw gas to Gas Compression		616,621
Sour slurry water to Sour Water Stripping		106,200
Fines in sour water slurry to Sour Water Stripping		6,824
Clarified water to Wastewater Treatment		95,557
Concentrated slurry water to Steam Generation		20,472
Fines in concentrated slurry to Steam Generation		6,824
Totals	852,498	852,498

and in the two venturi scrubbers. Fines slurry water is stripped in Sour Water Stripping and is returned for clarification. Clarified water is routed to Wastewater Treatment, and the concentrated fines slurry is pumped to Steam Generation as a 15 percent slurry.

2.4.5.7 GAS COMPRESSION (SECTION 350)

This system compresses the cooled scrubbed gas from Gas Cooling and Scrubbing as necessary for delivery to the IFG distribution system. The mass balance for this system is shown in Table 2-27. Input to this system is cooled scrubbed gas from Gas Cooling and Scrubbing, and outputs are: (1) compressed raw gas to Gas Treatment, Section 360; (2) process condensate to Gas Cooling and Scrubbing, Section 340; (3) sour condensate to Sour Water Stripping, Section 370 and (4) transport gas to Coal Preparation and Feeding, Section 320.

Scrubbed raw gas from Gas Cooling and Scrubbing is cooled from 236°F to 110°F, and is compressed from approximately 50 pounds per square inch gage to 192 pounds per square inch gage. Compressed gas is then sent to Gas Treatment for acid gas removal. Part of the condensate formed as a result of cooling prior to compressing is knocked out and recycled to Gas Cooling and Scrubbing. The remaining condensate is combined with that resulting from cooling the compressed gas, and the total condensate is pumped to Sour Water Stripping, Section 370.

2.4.5.8 GAS TREATMENT (SECTION 360)

This system employs Allied Chemical's Selexol process to selectively remove sulfur compounds (primarily hydrogen sulfide and some carbonyl sulfide) and to reduce gas moisture before discharge to the IFG distribution system. A small fraction of the carbon dioxide is also removed in order to raise and maintain control of the product gas heating value. Gas treating is achieved in two absorption steps: (1) most of the sulfur compounds, water moisture and some carbon dioxide are removed in the first absorber and (2) additional carbon dioxide is removed in the second absorber as necessary to provide a product IFG of specification heating value.

TABLE 2-27

MASS BALANCE FOR THE IFGDP GAS COMPRESSION SYSTEM (SECTION 350)

	Input (lb/hr)	Output (lb/hr)
Cooled scrubbed gas from Gas Cooling and Scrubbing	616,621	
Compressed raw gas to Gas Treatment		419,350
Process Condensate to Gas Cooling and Scrubbing		92,250
Sour Condensate to Sour Water Stripping		82,137
Transport gas to Coal Preparation and Feeding		22,884
Total	616,621	616,621

The mass balance for this system is shown in Table 2-28. Inputs are (1) compressed gas from Gas Compression, (2) nitrogen from Air Separation and (3) an odorant. System outputs are (1) product IFG to distribution, Coal Preparation and Feeding, other miscellaneous internal uses and Credit Generation, (2) acid gas to Sulfur Recovery, (3) carbon dioxide vent gas to Incineration and (4) condensate to Sour Water Stripping.

Compressed raw gas from Gas Compression is cooled, and the condensed water is removed in a knockout drum. Part of this water is delivered to the hydrogen sulfide stripper for maintaining water balance, and the remainder is sent to Sour Water Stripping.

The cooled raw gas then enters the Selexol hydrogen sulfide absorber when cold lean Selexol solvent physically absorbs essentially all of the hydrogen sulfide as well as most of the carbonyl sulfide and some carbon dioxide. The resulting product gas meets the required sulfur specifications given in Section 2.4.3.1. Absorber overhead gas, after exchanging heat with the incoming raw gas and recycle gas, passes to the Selexol carbon dioxide absorber for the removal of sufficient carbon dioxide to maintain a heating value of 300 Btu per standard cubic foot in the product IFG.

The cold rich solvent from the bottom of the Selexol hydrogen sulfide absorber passes through three stages of preheating and flashing in order to provide an acid gas with sufficient hydrogen sulfide concentration for treatment by Sulfur Recovery. Preflashed solvent is further stripped in an hydrogen sulfide stripper. The overhead steam from the hydrogen sulfide stripper is condensed and returned to the stripper while the acid gas is routed to Sulfur Recovery. Solvent from the bottom of the hydrogen sulfide stripper is cooled by heat exchange with cold rich solvent and is further chilled by refrigeration. Chilled lean solvent is returned to the top tray of the hydrogen sulfide absorber.

Rich solvent from the bottom of the carbon dioxide absorber is regenerated in the carbon dioxide stripper using dry nitrogen delivered from Air Separation to the bottom of the carbon dioxide stripper.

TABLE 2-28

MASS BALANCE FOR THE IFGDP GAS TREATMENT SYSTEM (SECTION 360)

	Input (lb/hr)	Output (lb/hr)
Compressed gas from Gas Compression	419,350	
N_2 stripping gas from Air Separation	1,485	
Odorant (tetrahydrothiophene)	7	
Product IFG to:		
IFG distribution		329,140
Coal Preparation and Feeding		1,239
Miscellaneous internal users		2,985
Credit Generation		35,543
CO_2 vent gas to Incineration		14,346
Acid gas to Sulfur Recovery		36,125
Condensate to Sour Water Stripping		1,464
Total	420,842	420,842

2.4.5.9 SOUR WATER STRIPPING (SECTION 370)

This system treats plant sour waters from Gas Compression and Gas Treatment and sour slurry water from Gas Cooling and Scrubbing to remove hydrogen sulfide, carbon dioxide and ammonia. The mass balance for this system is shown in Table 2-29. System outputs include: (1) stripped water to Wastewater Treatment, (2) sour water stripper gas to Sulfur Recovery and (3) stripped slurry water to Gas Cooling and Scrubbing.

Two distinct forms of sour water are generated, one being a 6 percent slurry and the other a solids-free process condensate. A baffled tower is used for the slurry case. A trayed tower of conventional design is used for the solids-free sour-process condensate.

Slurry water from Gas Cooling and Scrubbing is stripped of hydrogen sulfide and ammonia using live steam. Stripped slurry water is cooled and passes to the clarifier in Gas Cooling and Scrubbing. Overhead stripping steam from the slurry water stripper is used in the sour water stripper, thereby reducing the overall steam required for the second stripping system.

Sour condensate from Gas Treatment and Gas Compression is stripped of hydrogen sulfide and ammonia within a sour water stripper by means of overhead steam from the slurry water stripper and internally generated steam.

The sour water stripper overhead vapors are cooled and partially condensed to a temperature of 220°F, and the vapor portion of the flow is separated from the condensate and flows to Sulfur Recovery. The separated condensate is returned to the sour water stripper as reflux.

Stripped water from the bottom of the sour water stripper is cooled from a temperature of 268°F to 95°F and is pumped to Wastewater Treatment.

TABLE 2-29

MASS BALANCE FOR THE IFGDP SOUR WATER STRIPPING SYSTEM (SECTION 370)

	Input (lb/hr)	Output (lb/hr)
Sour slurry water from Gas Cooling and Scrubbing	106,200	
Fines in sour slurry from Gas Cooling and Scrubbing	6,824	
Stripping steam	23,781	
Sour water from Gas Compression	82,137	
Sour water from Gas Treatment	1,464	
Stripped slurry water to Gas Cooling and Scrubbing		116,029
Fines in stripped slurry to Gas Cooling and Scrubbing		6,824
Stripped water to Wastewater Treatment		96,742
Sour water stripper gas to Sulfur Recovery		811
Total	220,406	220,406

2.4.5.10 SULFUR RECOVERY (SECTION 380)/TAIL GAS TREATMENT (SECTION 390)

These combined systems recover sulfur from Selexol hydrogen sulfide stripper and sour water stripper effluents. The Sulfur Recovery System consists of a Claus unit employing a thermal reaction step with sulfur dioxide generation followed by three stages of catalytic reaction in order to effect an overall sulfur recovery in excess of 96 percent based on the incoming gas feeds. The tail gas from the Claus unit is treated to remove essentially all of the remaining sulfur compounds before being discharged to the atmosphere. The mass balances for the Sulfur Recovery system and the Tail Gas Treatment system are shown in Table 2-30 and Table 2-31, respectively.

2.4.5.10.1 SULFUR RECOVERY

Acid gas from Gas Treatment and a stoichiometric volume of air are preheated to approximately 450°F by heat exchange using high pressure steam. The preheated acid gas is split so that 60 percent of the total incoming stream is passed to the muffle furnace and 40 percent is bypassed to the first reactor. The portion of acid gas passed to the muffle furnace is further split so that part of the gas is fed to the muffle furnace burner and the remainder is fed to the second zone of the furnace. The acid gas fed to the burner is mixed with the sour water stripper gas from the sour water stripper upstream of the burner.

The acid gas is partially combusted in the first zone of the muffle furnace where sulfur dioxide is generated. The bypassed acid gas is added to the second zone of the furnace. The Claus reaction proceeds in the muffle furnace with the formation of sulfur vapors. By bypassing 33 percent of the furnace acid gas feed to the second zone, the first zone combustion of acid gas and sour gas takes place at a temperature of 2400°F and thus assists in the destruction of the ammonia contained in the sour water stripper gas.

The hot acid gas exits the muffle furnace and is cooled to a temperature of 350°F. Sulfur is condensed and flows by gravity through a sulfur seal to a collection pit.

TABLE 2-30

MASS BALANCE FOR THE IFGDP SULFUR RECOVERY SYSTEM (SECTION 380)

	Input (lb/hr)	Output (lb/hr)
Acid gas from Gas Treatment	36,125	
Sour water stripper gas from Sour Water Stripping	811	
Process air from atmosphere	18,581	47,438
Claus unit tail gas to Tail Gas Treatment		47,440
Liquid sulfur product		8,364
Liquid sulfur from Tail Gas Treatment	285	
Total	55,802	55,802

TABLE 2-31

MASS BALANCE FOR THE IFGDP TAIL GAS TREATMENT SYSTEM (SECTION 390)

	Input (lb/hr)	Output (lb/hr)
Claus unit tail gas from Sulfur Recovery	47,438	
Process air from atmosphere	10,600	
IFG from Gas Treatment	1,390	
Steam to Combustion chamber	1,390	
Makeup water	2,500	
Steam to sulfur melter	650	
Air to sulfur separation cooling unit from atmosphere	158,685	
Stretford absorber vent gas to atmosphere and Wastewater Treatment		47,843
Air from oxidizers to atmosphere		5,968
Liquid Sulfur to Sulfur Recovery unit		285
Air from sulfur separation cooling unit to atmosphere		168,557
Total	222,653	222,653

The cooled gas is reheated to above its sulfur dew point and is combined with the portion of acid gas feed which bypassed the muffle furnace. The combined acid gas stream is then fed to the first reactor where the Claus reaction proceeds. The first reactor effluent is cooled, and the condensed sulfur flows by gravity to the rundown pit.

Sulfur is recovered in two additional stages in which cooled acid gas is reheated, passed through the Claus reactor and cooled to condense sulfur.

Sulfur is stored as a liquid in a 15-day production capacity storage tank. This sulfur has a quality of 99.9 percent by weight pure and will be sold as a by-product.

The tail gas exiting the final sulfur condenser flows to Tail Gas Treatment at a temperature of 280°F and a pressure of 3.0 pounds per square inch gage for final cleanup.

2.4.5.10.2 TAIL GAS TREATMENT

The Tail Gas Treatment system consists of a hydrogenation/hydrolysis unit followed by a Stretford absorber unit and Stretford solution oxidizer/sulfur separation system.

In the hydrogenation/hydrolysis unit, the tail gas from Sulfur Recovery is preheated to the desired hydrogenation and hydrolysis reaction temperatures by mixing with combustion gases formed by burning product IFG in the presence of air and steam. These combustion gases provide additional reducing gas (hydrogen and carbon monoxide) to ensure nearly complete hydrogenation of sulfur dioxide and free sulfur to hydrogen sulfide. The combined stream is fed to the hydrogenation reactor where sulfur compounds are converted to hydrogen sulfide.

The hot hydrogenation reactor effluent is cooled in a waste heat exchanger followed by cooling in a direct contact condenser tower. The cooled tail gas enters the Stretford absorber for countercurrent contact with lean Stretford solution, and hydrogen sulfide is oxidized to elemental sulfur. The treated tail gas is discharged to the atmosphere from the top of the absorber and contains less than 10 parts per million by volume of hydrogen sulfide and 200 parts per million by volume total sulfur.

In the Stretford solution oxidizer/sulfur recovery unit, the sulfur laden Stretford solution is regenerated to its original state by air blowing.

The regenerated Stretford solution is cooled and returned to the Stretford absorber. Froth resulting from air blowing contains elemental sulfur, which is floated off the Stretford solution oxidizer and is heated to melt the sulfur. The hot solution and molten sulfur enters the sulfur decanter where the sulfur is separated from the solution. The decanted sulfur is returned to the sulfur rundown pit in Sulfur Recovery and the solution is cooled and recycled to the Stretford absorber.

In the Stretford solution, some of the hydrogen sulfide undergoes side reactions and is converted to sodium thiosulfate and sodium sulfate. Eventually, the buildup of these solids requires purging of some of the solution. This purge is accumulated in a storage tank and is trucked away for off-site disposal.

2.4.5.11 CREDIT GENERATION (SECTION 220)

This system upgrades IFG from an industrial fuel gas quality of 300 ± 30 Btu per standard cubic foot to a pipeline quality gas of 950 Btu per standard cubic foot. This pipeline quality gas is discharged to the MLGW natural gas system as a "credit" which can be withdrawn and adjusted to IFG quality when the plant is not producing sufficient IFG to meet its demand. The mass balance for this system is shown in Table 2-32. Inputs include: (1) product IFG from Gas Treatment, and (2) steam from Steam Generation to the carbon monoxide shift reactors; while outputs include: (1) carbon dioxide off gas to Incineration, (2) acid gas removal and methanation process condensates to

TABLE 2-32

MASS BALANCE FOR THE IFGDP CREDIT GENERATION SYSTEM (SECTION 220)

	Input (lb/hr)	Output (lb/hr)
Product IFG from Gas Treatment	35,543	
Steam to CO shift	18,187	
CO_2 off gas to Incineration		30,735
Acid gas removal condensate to Wastewater Treatment		8,821
Methanation condensate to Wastewater Treatment		6,426
Drying unit vent gas to atmosphere		24
Pipeline gas to MLGW pipeline distribution		7,724
Total	53,730	53,730

Wastewater Treatment, (3) drying unit vent gas to the atmosphere and (4) pipeline quality gas to the MLGW pipeline distribution system.

The Credit Generation system consists of the following process units:

- o Gas compression
- o Carbon monoxide shift conversion
- o Acid gas removal
- o Methanation
- o Methanated gas drying and odorization
- o Credit withdrawing system

Details regarding processing in each of these units follow.

2.4.5.11.1 GAS COMPRESSION

Gas from the Gas Treatment unit enters the Credit Generation system and is compressed to 325 pounds per square inch gage. The compressor is monitored and controlled by the IFG dispatcher.

2.4.5.11.2 CARBON MONOXIDE SHIFT CONVERSION

A portion of the compressed gas is heated by heat exchange with shift reactor effluent. Steam required for the shift reaction and for satisfying the reaction equilibrium is added to the gas. The heated gas and steam mixture enters the shift reactor where carbon monoxide in the feed gas reacts with steam over a bed of high temperature shift catalyst to form hydrogen and carbon dioxide. This reaction is exothermic, resulting in an increase in reactant temperature. The reaction effluent is cooled by heat exchange with the feed gas. The amount of compressed gas which bypasses the shift reactor is controlled so that after mixing with the shifted gas, the resultant mixture will have a hydrogen to carbon monoxide molar ratio of approximately 3 to 1.

2.4.5.11.3 ACID GAS REMOVAL

The acid gas removal step employs the proprietary Benfield hot potassium carbonate process to remove carbon dioxide and a residual quantity of hydrogen sulfide in the shifted gas. Gas from shift conversion is cooled, and heat given up by the gas stream is used for scrubbing solution regeneration. Condensate separated from the gas stream is cooled and forwarded to Wastewater Treatment.

The cooled gas at 260°F is scrubbed by the Benfield solution in a carbon dioxide absorber. The carbon dioxide lean solution is introduced to the top of the tower and flows downward, countercurrent to the gas flow, and arrives at the bottom of the tower rich in carbon dioxide content. Rich solution is regenerated in the carbonate solution regenerator by steam stripping. Regenerated solution is first flashed in multiple stages to generate part of the stripping steam and then pumped back to the carbon dioxide absorber. Steam in the carbon dioxide vent gas from the solution regenerator is condensed and returned to the solution regenerator. The cooled carbon dioxide stream from this step, containing a trace of sulfur, is forwarded to Incineration for disposal.

2.4.5.11.4 METHANATION

Scrubbed gas is preheated to 700°F and flows through two beds of zinc oxide catalyst that serve as guard chambers for the removal of final traces of sulfur compounds prior to entering the methanation reactors. The methanation step employes Conoco Methanation Company's proprietary technology. It converts the purified hydrogen and carbon monoxide containing gas stream into high-Btu pipeline quality gas. The methanation process is a catalytic fixed-bed, adiabatic, gas recycle process. A highly active nickel catalyst is used to effect the methanation reactions. Reaction temperatures are controlled by recycling a portion of cooled product gas.

There are three primary methanation reactors. These reactors are connected in a series-parallel arrangement. Fresh feed to the methanation step is split so that portions flow to each reactor. A methane rich gas is circulated through the three primary reactors in series by means of a mechanical circulator. The circulating rich gas removes the exothermic reaction heat from the fixed bed reactors. Reactor temperature rises are limited by judicious control of the circulating rich gas flow rate.

The circulating rich gas is itself cooled in an exchanger by generating steam after each reactor for heat recovery. The bulk of the methanation reaction takes place in these three reactors.

A cleanup methanation reactor is used to accomplish the remainder of the required methanation reaction. This reactor operates at a lower temperature than the primary methanation reactors in order to effect the additional reaction.

Methanated gas from the cleanup methanator is cooled and forwarded to the gas drying step.

2.4.5.11.5 METHANATED GAS DRYING AND ODORIZATION

Pipeline gas is dried in a glycol type drying system. Dried pipeline gas at about 300 pounds per square inch gage is odorized and flows to the MLGW Weaver Station through an existing 16 inch pipeline. The IFGDP receives a credit for this gas.

2.4.5.11.6 CREDIT WITHDRAWING SYSTEM

When the IFGDP is totally or partially out of service for some reason or when the IFG production rate cannot satisfy demand, natural gas from MLGW's natural gas supply pipeline is withdrawn to satisfy the Btu demand of IFG customers. Natural gas at 1031 Btu per standard cubic foot is adjusted by the addition of dried air or nitrogen to the IFG heating value of 300 Btu per standard cubic foot and introduced into the IFG distribution pipeline upstream of the IFG odorization station as an IFG substitute. Air from the discharges of one of the two air compressors in the Air Separation section is further compressed, cooled and dried to provide dry air necessary to dilute the natural gas to product IFG quality.

2.4.5.12 FLARE (SECTION 460) AND INCINERATION (SECTION 430)

The Flare and Incineration system provide for the burning of combustible vapors and gases during periods of emergency and normal plant operation. The function of the Flare system is to provide for safe burning of combustible vapors released from process equipment during startup, shutdown and operational upsets. In the incinerator, various gas streams containing atmosphere-polluting contaminants (e.g., sulfur compounds, carbon monoxide, combustible hydrocarbons and ammonia precluding direct emission to the atmosphere) are combusted. Because controlled combustion is required during operating upsets or during intermittent discharges, some additional streams (listed in Section 2.4.5.12.1) are directed to the incinerator.

2.4.5.12.1 FLARE

The plant Flare receives the emergency discharge from vents and safety valves in the various process units connected to a single flare header. The Flare pilot flame uses natural gas as the fuel.

The elevated Flare includes the following features:

- Facilities for smokeless burning of hydrocarbons by the injection of steam into the Flare tip

- An air seal, located underneath the Flare tip to prevent air back-diffusion into the system

- A flame front generator for igniting pilots. Since no plant air system is included in this plant, a separate air blower is included for pilot ignition

- Facilities for automatic nitrogen injection to compensate for the system "contraction" after a flame blowout

A knockout drum is provided in the Flare header to separate all liquid droplets from the gas.

Dry nitrogen from Air Separation is continuously injected into the far end of the Flare header for purge, thereby maintaining a positive pressure in the system at all times.

The height and location of the Flare is designed so that the heat radiation will not be hazardous to personnel or equipment in its immediate vicinity. The flare is designed for a total heat flux at the base of the stack of 1500 Btu per hour per square foot, including solar radiation.

2.4.5.12.2 INCINERATION

The Incineration system provides a means for the destruction of trace hydrocarbons, the combustion of hydrogen and carbon monoxide and the conversion of sulfur compounds into sulfur dioxide in various process vent gases. The incinerator is designed so that the off gas is contacted with an excess of air, at a minimum residence time of 0.8 second, producing a 1500°F minimum flue gas temperature before air preheat. A high degree of turbulence is provided to ensure thorough mixing of the combustibles with oxygen.

The heat available from the combustion process is not sufficient to make the incineration process self-supporting. Product IFG is normally burned as required to make the process self-sustaining. During startup and emergency operations, natural gas supplies the necessary heat to sustain combustion.

Primary air needed for combustion of the fuel gas is preheated using the incinerator flue gas as the heating medium. Secondary air needed for combustion of the off gases is also preheated in a similar fashion. Quench air enters the incinerator at ambient conditions as required to prevent the incinerator flue gas temperature from exceeding 1800°F. Combustion air is supplied by a motor driven blower, included in the incineration package, for all requirements including primary, secondary and quench air.

The flue gases, after heat exchange with the combustion air, are mixed with the flue gases from Flue Gas Desulfurization and then dispersed to the ambient atmosphere by means of the stack. To maintain good dispersion of the stack effluents, a minimum effluent temperature of 260°F is necessary. The incinerator flue gas supplies this heat under all operating conditions.

Streams normally routed to Incineration during plant operation include:

- Off gas from the Credit Generation Benfield unit. The process basically removes carbon dioxide and the bulk of the sulfur compounds present in the product gas feed stream. The off gas is rich in carbon dioxide and water vapor, with residual amounts of hydrogen sulfide present.

- Vent gas from the feed lock hoppers in Coal Preparation and Feeding feeds the incinerator on regular cycles. The hoppers are pressurized with a combination of product gas and nitrogen. A portion of this gas is sent to the incinerator during loading of the coal feed.

- Carbon/dioxide-rich vent gas from Gas Treatment, produced from the two stage Selexol process. This gas, containing carbon monoxide and traces of reduced sulfur compounds, is continuously fed to the incinerator.

Streams discharged to incineration during emergency operation include:

- An emergency load from Sulfur Recovery is combusted in the incinerator during upset conditions when the Sulfur Recovery system cannot accept feed. This vent gas stream is rich in hydrogen sulfide, carbonyl sulfide and ammonia.

- Gas from emergency condition Tail Gas Treatment will be vented if the Beavon package is shut down. This vent gas stream is rich in carbon dioxide, nitrogen and water.

- If fines recycle to the gasifier is not operating, a vent stream containing carbon monoxide as the major pollutant will be sent to the incinerator from Coal Gasification.

2.4.5.13 WASTEWATER TREATMENT (SECTION 440)

Wastewaters are generated in the IFGDP from several sources. The type and degree of treatment and the ultimate disposal of these wastewaters depend on the source of the wastewater and on the type and concentration of pollutants in the water. The wastewaters and their sources are:

- Storm water falling on and drained from the area inside the limits of processing units
- Spent services water (e.g., from deck washings and flushing)
- Cooling tower blowdown
- Storm water falling on and drained from the coal pile
- Storm water falling on and drained from the ash pile
- Process wastewater consisting of clarified blowdown from Gas Scrubbing, filtrate from the flurry filter in Steam Generation, stripped condensate from Sour Water Stripping and condensate from Credit Generation
- Sanitary wastewater generated by plant personnel
- Neutralized demineralizer chemicals

The mass balance for the Wastewater Treatment system is shown in Table 2-33. Details regarding the treatment of these wastewaters follow.

TABLE 2-33

MASS BALANCE FOR THE IFGDP WASTEWATER TREATMENT SYSTEM (SECTION 440)*

	Input (lb/hr)	Output (lb/hr)
Inside battery limits storm water	**	
Spent service water	50,000	
Stripped water from Sour Water Stripping	96,742	
Fines filtrate from Steam Generation	18,766	
Condensate from Credit Generation	15,247	
Clarified water from Gas Cooling and Scrubbing	95,557	
Coal pile runoff	**	
Ash pile runoff	**	
Neutralization water from Utilities	25,695	
Cooling tower blowdown	106,000	
Treated wastewater from effluent holding basin		340,195
Water in sludge to disposal		445
Makeup to Ash Treatment		14,160
Makeup to Cooling Tower		37,500
Makeup to Utilities		15,707
Total	408,007	408,007

* Excluding chemicals

** Normally no flow

2.4.5.13.1 STORM WATER AND SPENT SERVICE WATER

The plant area storm water and the spent service water drain to a oily water sewer and flow to a storm water diverter. During dry periods, the water flows through the diverter and is pumped to the treatment area. During periods of heavy rain, the wastewater flows exceed the capacity of the treatment system, and the excess is automatically pumped to the storm water holding basin where it is stored and worked off through the treatment system after the rain ceases. Normally, both spent service water and storm water from the holding basin is pumped directly to the dissolved air flotation (DAF) unit for treatment.

The DAF unit removes oil and solids in the wastewater to acceptable limits. Floatable material, removed as a froth from the DAF unit, flows by gravity to a sump and then is transferred to a tank that can be heated (via steam coils in the tank) to 180°F to enhance oil and low density solids separation. Water separated in the tank is returned by gravity to the storm water holding basin. Solids that settle to the bottom of the tank are removed periodically to the sludge settling basins.

The separated oil and any entrained solids are drained by gravity to a sump and then removed for subsequent off-site disposal.

Treated wastewater leaving the DAF unit flows to the effluent holding basin and is normally recycled to the cooling tower and to Ash Treatment as makeup. Excess treated water is discharged to the Mississippi River.

2.4.5.13.2 COAL PILE RUNOFF AND COOLING TOWER BLOWDOWN

The cooling tower blowdown is first sent to the chromate destruct unit, where chromium and zinc are precipitated as insoluble hydroxides. If the cooling tower blowdown leaving the chromate destruct unit is free of oil and grease, it will be discharged directly to the effluent holding basin. If the blowdown contains oils and grease, it is treated in the storm water DAF unit before being discharged to the effluent holding pond.

Coal pile runoff is collected in the coal pile runoff holding basin and is then pumped at a controlled rate to the neutralization tank. Lime is fed to this tank continuously to adjust the pH to approximately 8.5. The neutralized wastewater flows by gravity to an aerating basin where a fixed aerator aerates and mixes the incoming stream, thereby oxidizing inorganic materials present in the wastewater and causing them to form insoluble hydroxides. The aerated stream flows by gravity to a clarifier where insoluble precipitate settles from the water and is pumped to sludge pits.

Decant from the sludge pits is returned by gravity to the coal pile runoff holding basin. Sludge is removed periodically from one of the sludge pit sections, while the other is maintained in operation. Sludge removed from the pit is trucked away. It can be used as landfill off-site or stored on-site. The clarified wastewater from the clarifier flows to the effluent holding basin and is recycled to the Cooling Tower or Ash Treatment areas or discharged to the outfall.

2.4.5.13.3 ASH PILE LEACHATE

Leachate tests performed on samples of bottom ash taken from the IGT U-GAS™ pilot plant give strong indication that the ash pile leachate will be suitable for direct discharge. Therefore, a separate treatment system is not provided in the design for this stream at this time.

Initial noncommercial operation of the plant during Phase III of the program will consist of short-duration runs of a single gasifier. These runs will produce small quantities of ash that will be used for additional leaching tests and other evaluations by potential customers. Excess ash from this phase will be stored on the site in the short-term storage area. The short-term area is sufficiently large to provide storage for the first 4 years of ash production during commercial operation and is lined to permit collection of leachate in a sump from where the leachate is pumped to the effluent holding basin.

Collection and testing of leachate from the short-term area during Phase III will be used to determine whether or not treatment of actual storage-area leachate is necessary. Treatment to acceptable levels will be provided during Phase III if analyses from either type of leaching show that treatment is required. The existing wastewater treatment system is most likely adequate for any treatment needed. Should this system be inadequate, however, additional treatment equipment will be installed. While this equipment is being added, and prior to commercial operation, ash pile leachate will be stored in one or more of the holding basins that are unused during Phase III noncommercial operation. Sufficient time is available for this because of the small amount of ash that will be generated during this phase. This approach ensures that, should there be any toxic concentrations in the ash pile leachate, toxic concentrations will not be discharged.

2.4.5.13.4 PROCESS WASTEWATERS

The combined process wastewater stream enters a mix tank where lime is added as needed to adjust the pH and to form a floc which promotes the removal of suspended solids. Oxygen is bubbled through the water to oxidize inorganics and to promote formation of insoluble precipitates. Polyelectrolyte is added to the water in a clarifier, and precipitated solids are internally recycled to promote additional flocculant growth. Settled sludge in the clarifier is drained to a sump and pumped to a sludge dewatering system consisting of a belt filter press. Water removed from the sludge is returned to the mix tank, and dewatered sludge is transported to the plant solid waste storage area on-site.

The clarifier effluent is pumped into a recarbonation drum. Recarbonation is accomplished by diffusion of carbon/dioxide-rich vent gas from Tail Gas Treatment, which returns the pH of the clarifier effluent to a normal level. Phosphoric acid is added to the water to provide nutrient for subsequent treatment steps.

Process wastewater is then filtered as a final pretreatment step prior to ozonation and biological carbon absorption. The filtrate enters the ozone generation and contacting system where ozone is added from an ozone generator. The ozone reacts with organics in the water to make them more readily biodegradable. The ozone generator is fed by oxygen from Air Separation. The effluent from the ozone contactor is pressure filtered. A colony of biologically active organisms form on the bed of the filter and, with the high oxygen content of the ozonated water, the organisms remove a substantial amount of the organic pollutants from the water. The pressure filter effluent is mixed with the spent ozone off-gas from the ozone contactor. This gas is nearly pure oxygen. This raises the oxygen content of the wastewater, which had been depleted of oxygen by the biological activity in the filter.

The oxygenated water goes to either of two carbon absorbers. In the absorbers, an apparent symbiotic relation exists. A colony of biologically active organisms form on the carbon. The presence of the organisms maintains the absorptive capacity of the carbon without the necessity for frequent regeneration.

Treated process effluent is then stored in an effluent holding tank. This water can then be used for various functions including: (1) backwashing pressure filters and carbon absorbers, (2) motive water for carbon eductors and (3) other miscellaneous washing and dilution operations. The overflow from the effluent holding tank flows to the effluent holding basin; and from there, it can be recycled to the Cooling Tower or Ash Treatment areas or discharged to the outfall.

When necessary, the carbon is regenerated and reused. When the minimum effluent quality is reached, or when a predetermined carbon capacity is achieved, spent carbon is removed from the absorbers and is regenerated thermally.

The thermal regeneration of carbon is as follows:

- Spent carbon is conveyed in a water slurry to the regeneration system for preliminary dewatering.
- Dewatered spent carbon is fed to a reactivation furnace.
- The hot regenerated carbon is quenched in water.
- The cooled cleansed regenerated carbon is pumped to the regenerated carbon storage tank.

- Flue gas from the regenerating furnace is scrubbed before it is exhausted to the atmosphere.

2.4.5.13.5 SANITARY WASTEWATER

The sanitary wastewater is sent to the municipal sanitary sewer for treatment in the municipal wastewater treatment facility.

2.4.5.13.6 NEUTRALIZED DEMINERALIZER CHEMICALS

After neutralization and pH adjustment, demineralizer regenerational chemicals and wash water are pumped directly to the effluent holding basin for discharge to the outfall.

2.4.5.14 COOLING TOWER (SECTION 450)

One cooling tower is used to service all process sections of the plant. This tower is a mechanical draft, cross flow system containing five 12,000 gallon per minute capacity cells. Cooling water, circulated at a rate of 35,360 gallons per minute, is supplied at a temperature of 88°F to process users and is returned at a temperature of 114°F. The mass balance for this section is shown in Table 2-34.

To maintain optimal operating performance in the tower, chemicals that inhibit corrosion, scaling and fouling and microbial activity are added to the recirculating water. As listed in Table 2-35, these include a chromium/zinc corrosion inhibitor, a polymeric dispersant, a brominated nitrilopropionamide microbiocide, chlorine and sulfuric acid.

The primary source of makeup water to the cooling tower is city water. Supplementary makeup water is obtained from the treated effluent holding pond, from moisture condensed in air separation and from boiler feed water preparation backwash and blowdown. It should be noted that it may be possible, after analyses of treated wastewater are conducted during plant operations, to send a normal continuous flow of treated wastewater as makeup to the cooling

TABLE 2-34

MASS BALANCE FOR THE IFGDP COOLING TOWER SYSTEM (SECTION 450)*

	Input (lb/hr)	Output (lb/hr)
Makeup Water	574,500	
89.0% City water		
6.5% Treated wastewater		
1.4% Air Separation condensate		
3.1% Backwash/rinse water from Wastewater Treatment		
Circulating return water	17,680,000	
Circulating Water Supply		17,680,000
7.3% Credit Generation		
0.6% Utilities		
0.2% Coal/Coke Receiving and Handling		
19.2% Air Separation		
27.2% Gas Cooling and Scrubbing		
16.9% Gas Compression		
21.7% Gas Treatment		
6.0% Sour Water Stripping		
0.4% Ash Handling		
0.5% Miscellaneous Users		
Evaporation		459,500
Drift		9,000
Blowdown (to Wastewater Treatment)		106,000
Total	18,254,500	18,254,500

* Excluding chemicals

TABLE 2-35

CHEMICAL ADDITIVES TO RECIRCULATING COOLING WATER (SECTION 450)

Additive	Composition	Dose
Corrosion inhibitor (Drew CWT-102)	35% chromic acid 12% zinc oxide	5 to 10 mg/l hexavalent chromium 3 to 10 mg/l zinc 130 lb/day to maintain 45 ppm residual
Dispersant (Drewsperse 738)	contains a mixture of polysiloxane-polyoxyalkene copolymer and oxyalkylene polymer, where the alkyl group is either ethyl- or propyl-	70 lb/day 25 ppm maintained in circulating water
Biocide (Biosperse 240)	5% active (2,2-Dibromo-3-nitrilo-proplonamide) 95% inactive	1 to 6 oz per 1000 gallons makeup water to maintain a 30 ppm residual
Chlorine	Cl_2	90 lb/day Added for 1 hour until a circulating concentration of 5 mg/l is reached
Sulfuric Acid	66° Baume H_2SO_4	1260 lb/day

tower from the Wastewater Treatment section. In this way, makeup from the Davis Pumping Station would be substantially reduced.

Effluents from this system include evaporation and drift losses to the atmosphere and blowdown, which is treated in Wastewater Treatment. The evaporation rate is 2.6 percent of the cooling water circulation rate, while drift loss is approximately 0.05 percent of the circulating rate. The blowdown has the same chemical composition, but undergoes treatment prior to discharge to the plant off-site.

2.4.5.15 STEAM GENERATION/FLUE GAS DESULFURIZATION (SECTION 430)

The IFGDP employs waste heat recovery and coal-fired boilers to generate high pressure (900 pounds per square inch gage) steam for process distribution. Of the 466,738 pounds per hour of high pressure stream generated during normal plant operation, 71.9 percent is generated by waste heat recovery, and the remaining 28.1 percent is generated in the boiler. Flue gas resulting from combustion in the coal-fired boilers requires desulfurization prior to discharge to the atmosphere.

2.4.5.15.1 WASTE HEAT RECOVERY/STEAM GENERATION

High pressure superheated steam (nominally 900 pounds per square inch gage, 840°F) is generated through waste heat recovery in Gas Cooling and Scrubbing (Section 340) and the utility area steam generators. Sufficient steam generating capacity is available to assure that an adequate supply of steam is available for an orderly shutdown under power outage conditions. The plant can maintain normal operations during boiler turnaround with one power boiler down for maintenance.

The steam header system consists of two main steam levels: high pressure (900 pounds per square inch gage, 840°F) and low pressure (85 pounds per square inch gage, 420°F). Two other steam levels are available in limited areas of the plant for dedicated services: 125 pounds per square inch gage, 505°F and 50 pounds per square inch gage, 298°F.

Most of the high pressure steam is used in process units after expanding through back pressure turbines to the ultimate required steam conditions. Superheated 125 pounds per square inch gage steam for the largest consumers, the gasifiers, is produced by turbine exhaust. In the event of an emergency requiring the air compressor topping turbine to be shut down or bypassed, high pressure steam can be let down directly to the gasifiers through a pressure control valve.

Much of the low pressure 85 pounds per square inch gage steam demand is derived from other on-site back pressure turbines. The remaining 83 percent steam production results from flashed boiler blowdowns and a small quantity of letdown from the 900 pounds per square inch gage header for control purposes. The major consumers of this steam are the hydrogen sulfide stripper reboiler in Gas Treatment and the strippers in Sour Water Stripping. The balance of the 85 pounds per square inch gage steam is utilized in buildings, heating, the Flare, the carbonate regenerator reboiler in Credit Generation and other miscellaneous minor consumers.

A small amount of 50 pounds per square inch gage, saturated steam is generated through waste heat recovery in Sulfur Recovery and the Beavon package unit in Tail Gas Treatment. Part of this steam is used within these two units; the excess is sent directly to the deaerator for boiler feed water deaeration. The remainder of the deaerating stripping steam requirement is obtained from the 85 pounds per square inch gage steam header.

2.4.5.15.2 COAL-FIRED BOILERS/STEAM GENERATION

Each package boiler is designed to produce 225,000 pounds per hour of 915 pounds per square inch gage, 865°F steam for use in the 900 pounds per square inch gage superheated steam header. Both steam generators will normally operate at reduced capacity, producing about 105,000 pounds per hour of high pressure steam. Conventional pulverized coal-fired boilers designed to utilize both coal fines and char fines as part of the fuel requirement are used.

Coal fines from Coal/Coke Preparation and Feeding and gasifier fines from Coal Gasification are pneumatically conveyed to a receiving bin and combined with filtered char fines containing a maximum of 25 percent moisture. These fines are mixed and homogenized with raw coal from Coal/Coke Handling in a pulverizer. The resultant material is fed to the pulverized coal burners.

Top and bottom ash is produced in the steam generator from coal combustion. Roughly 20 percent of the total ash is removed by a bottom ash sluicing system to Ash Treatment. The remaining top ash passes through a dust collector, is throughly wetted within a mixing chamber and is trucked away to the ash pile.

The resultant flue gas produced, after exchanging heat in an air preheater, is blown into the stack gas cleanup package for removal of sulfur dioxide.

2.4.5.15.3 FLUE GAS DESULFURIZATION

Because high sulfur coal is used for fuel in Steam Generation, high levels of sulfur dioxide are produced by combustion which must be treated in order to limit emissions to environmentally acceptable levels. In order to prevent pollution of the atmosphere, 90 percent of the sulfur dioxide is removed in the FMC Double Alkali Flue Gas Desulfurization unit.

Basically, the FMC Double Alkali system consists of sodium sulfite scrubbing of sulfur dioxide and regeneration of the scrubbing solution with hydrated lime. After removal of particulate matter in a baghouse, steam generator flue gas is fed to the stack gas cleanup package. Here it is combined with the dryer mill flue gas prior to entering the absorber. Upon entering the absorber, the flue gas is contacted with scrubbing solution containing sodium sulfite (Na_2SO_3), sodium bisulfite ($NaHSO_3$) and sodium sulfate (Na_2SO_4).

The principal reaction in the absorber is between sulfur dioxide in the flue gas and sodium sulfite in the absorbing solution:

$$SO_2 + Na_2SO_3 + H_2O \rightarrow 2\ NaHSO_3. \qquad (2\text{-}4)$$

Some oxidation of the sodium sulfite occurs in the absorber as follows:

$$Na_2SO_3 + 1/2\ O_2 \rightarrow Na_2SO_4. \qquad (2\text{-}5)$$

The absorber is maintained at a pH of 6 to 7 as a highly buffered sulfite system. This avoids calcium carbonate scaling at a higher pH and increased sulfur dioxide vapor pressure reducing scrubbing effectiveness at a lower pH.

The recirculation scrubbing solution is constantly bled according to sulfur dioxide inlet flow, thereby maintaining a constant pH. From this bleed stream, sodium sulfite is regenerated by reaction with hydrated lime as follows:

$$2NaHSO_3 + Ca(OH)_2 \rightarrow CaSO_3 \cdot 1/2\ H_2O + Na_2SO_3 + 1\text{-}1/2\ H_2O. \qquad (2\text{-}6)$$

The preceding reaction takes place in a low-residence time, stirred tank at a controlled pH of 8.5, the titrametric endpoint. The calcium sludge is thickened and filtered to produce a filter cake of 60 to 70 percent solids, which is washed to minimize sodium losses. Sodium sulfite solution is produced in the thickener and, as filtrate, is returned via a holding tank at pH = 8.5 to the absorber. In this manner, required sodium makeup is in the range of 2 to 5 percent of sulfur dioxide collected.

Makeup is in the form of a saturated soda ash solution (sodium carbonate); and, according to the following reaction, maintains the scrubbing solution:

$$Na_2CO_3 + 2NaHSO_3 \rightarrow 2\ Na_2SO_3 + H_2O + CO_2. \qquad (2\text{-}7)$$

The resultant filter cake, produced at vacuum filters, is disposed of by mixing it with fly ash and trucking it to the on-site ash pile.

2.4.5.16 SUPPORT FACILITIES

Numerous nonprocess support facilities are required for the operation of the IFGDP. A description of these facilities is given in this section.

2.4.5.16.1 WATER SUPPLY AND STORAGE

Raw water makeup consists of pretreated city water provided by the City of Memphis water system. Analysis of water entering the plant battery limits based on water from the Davis Pumping Station is given in Table 2-11.

The recirculation scrubbing solution is constantly bled according to sulfur dioxide inlet flow, thereby maintaining a constant pH. From this bleed stream, sodium sulfite is regenerated by reaction with hydrated lime as follows:

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Raw water makeup consists of pretreated city water provided by the City of Memphis water system. Analysis of water entering the plant battery limits based on water from the Davis Pumping Station is given in Table 2-11.

The city water/firewater storage tank contains water of sufficient quality to use as makeup for the Cooling Tower, as well as for emergency potable and service water and influent to the demineralizer package for boiler feedwater treatment. The upper section of the storage tank contains 942,000 gallons, based on an 8-hour holdup for process and utility use. The lower section of this tank contains 1,032,000 gallons and provides a 4-hour reserve holdup of firewater, based on two 2000 gallon per minute firewater pumps operating simultaneously. Together, the total tank capacity of both sections represents 1,974,000 gallons.

Water from the upper section of the storage tank flows by gravity directly to the Cooling Tower basin. Potable and service water are normally supplied by the city at a pressure of 80 pounds per square inch gage at the plant battery limits. If this supply is temporarily cut off, the city water pumps, taking suction from the upper section of the storage tank, can supply such water at about 65 pounds per square inch gage by manually opening a valve. These pumps normally supply water to the demineralizer package for use as boiler feedwater makeup.

2.4.5.16.2 FIREWATER SYSTEM

The primary plant fire safety system is the firewater system. The firewater system has an underground grid distribution system consisting of loops with sectional valves around the process units and coal piles. Fire hydrants are located on the grid at distances of nominally 150 feet for on-sites and 300 feet for off-sites.

The firewater system has three firewater pumps, each rated at 2000 gallons per minute with a discharge pressure of 150 pounds per square inch gage. These three firewater pumps are driven by one motor and two diesel engines. The water supply is obtained from the city water/firewater tank, which serves a dual purpose of providing firewater storage and treated city water storage. This tank has a total capacity of 1,974,000 gallons. The lower 1,032,000 gallons of water is reserved for firewater use, which allows the city water pumps access to the upper 924,000 gallons only. The 1,032,000 gallons represent a 4-hour supply at 4000 gallons per minute with two pumps operating.

The firewater pumps are on automatic pressure start with time delay. The motor-driven pump starts first; then, a diesel engine-driven pump; and finally, a second diesel engine-driven pump. For fail-safe operation, the diesel engine-driven pumps are completely independent of any outside power source. If required, all three pumps can be run simultaneously.

The pressure in the fire main is maintained by a slipstream off the discharge of the city water pumps, which have a discharge pressure of 75 pounds per square inch gage. The firewater grid serves all process units.

Steam coils are provided in the lower section of the city water/firewater tank to guard against freezing during the winter.

2.4.5.16.3 BOILER FEEDWATER TREATMENT

City water at 65°F average, from the city water storage tank, undergoes treatment in a demineralizer package to upgrade the water quality for use the high pressure superheater boiler. This system has an activated carbon filter to remove chlorine found in the city raw water to protect the downstream resin beds of the demineralizer. Cation exchangers (weak acid unit) reduce hardness and alkalinity, and a degasifier removes carbon dioxide and reduces the load on the following resin bed. Anion exchangers (strong base unit) remove silica and other anions. Demineralized undeaerated water is stored in the demineralized storage tank, providing an 8-hour holdup. From this tank, the demineralized water is pumped through a raw gas/demineralized water exchanger and condensate demineralized water exchanger, respectively, to raise the temperature from 65°F to 165°F before a deaeration.

Low pressure condensate collected from the condensate flash drum, reboiler, building heating, steam tracing and the Beavon unit is cooled from 312°F to

165°F by exchanging heat with cold demineralized water and is then stored in the condensate storage tank. Condensate recovery has been maximized in order to minimize raw water intake costs. Four hours of condensate holdup is maintained to protect against possible leakage of a process stream into the condensate. Adequate holdup permits condensate dumping until the problem is corrected.

The deaerator normally operates at 5 pounds per square inch gage. Steam is used as the stripping medium, and a nominal 1000 pounds per hour is vented to ensure adequate deaeration. Demineralized water is supplied as makeup water and maintains the storage compartment level in the deaerator. Deaeration provides water of quality suitable for high pressure steam generation at 915 pounds per square inch gage, 865°F.

Final oxygen control is maintained by chemical addition of hydrazine, an oxygen scavenger, directly to the deaerator. Amine is added in the form of morpholine to the boiler feedwater pump suction line to control corrosion of piping.

A neutralization tank is provided to collect rinse and regenerant streams from the demineralizer package. These wash streams are then neutralized with 66° Baume sulfuric acid or 50 percent caustic, as required. Wastes are then drained to the sampling basin.

2.4.5.16.4 POWER DISTRIBUTION, LIGHTING AND COMMUNICATION

Electrical power is purchased at 161 kilovolts and transformed to various lower voltages for economical in-plant distribution. The incoming power at 161 kilovolts is stepped down to 23 kilovolts at the main substation, located on-site and owned by the IFGDP. The incoming power is metered at 161 kilovolts. Unit substations are located centrally to concentration of loads. Electrical users receive power at 4.16 kilovolts, 480 volts or 120 volts, depending upon the horsepower of the motors that are outlined in the basic engineering data. The large drive motors use 23 to 4.16 kilovolts captive transformers and reduced voltage starting if needed.

SUBSTATIONS

Main Substation -- 23 Kilovolts

Incoming power is received at 161 kilovolts via loop feeders. The main substation has two fully rated transformers (for the plant) to transform 161 kilovolts to 23 kilovolts. Transformers are rated as 161 kilovolts to 23 kilovolts 25/33.3/41.6 megavolt amperes at 65°C temperature rise. An automatic transfer scheme provides switchover for the plant load to one of the transformers in case of trouble in the other transformer. The 23 kilovolt system is solidly grounded.

The 23 kilovolt, metal-clad, 1200-ampere circuit breakers have short circuit interrupting capacity at 30,000 amperes.

Substations -- 4.16 Kilovolts

The 4.16 kilovolt substations are located central to 4.16 kilovolt loads. Feeds to 4.16 kilovolt substations are from the 23 kilovolt main substation. The transformer is sized for the load with a primary disconnect switch at 600 amperes. An alternate feed to the 4.16 kilovolt substation protects against cable failure.

The 4.16 kilovolt circuit breakers are rated 1200 amperes and will short circuit at 250 megavolt amperes.

Substations -- 480 Volts

In general, 480 volt substations are fed from 23 kilovolt substations via a loop feeder. A dual disconnect switch with a fuse is provided in the primary protection. The 480 volt substations have a 4.16 kilovolt primary feed.

Transformers are 1000 kilovolt amperes. The 23 kilovolt primary dual switch is 200 amperes.

Power Distribution

The following design criteria have been defined:

- Motors 150 horsepower and below, with the exception of fractional horsepower motors, on the 480 volt system and in general, are fed from 480 volt motor control centers having combination circuit breaker starters.

- Motors 200 horsepower to 1250 horsepower use 4.16 kilovolt motor control centers.

- Motors 1500 horsepower to 6000 horsepower use circuit-breaker-type starters in 4.16 kilovolt switchgears.

- Motors larger than 6000 horsepower at 4.16 kilovolts are fed directly from 23 kilovolt switchgear through a captive transformer. The captive transformer provides load tap changers in order to decrease starting megavolt amperes, where required.

- The 23 kilovolt in-plant distribution is underground. All other in-plant distribution is overhead.

- An emergency generator is provided.

- An uninterruptible power supply system is provided.

- Emergency lighting inside the plant is provided.

- No fence lighting is included.

- Street lighting is provided. High pressure sodium lighting is used.

- Aviation obstruction lights are provided.
- The large air compressors are driven by synchronous electric motors.
- All other electric motors are induction motors.
- A fire alarm system inside the plant is provided and connected to a fire station outside the plant. A steam whistle is provided to sound the fire alarm and for coded emergency calls.
- Alternate cables to critical single services provide reliability against cable failure.
- Transformers have nontoxic oil.
- A walkie-talkie radio communication system is provided.
- A beeper-type call system is provided.
- Sound-powered phones are included for communication to high structures.
- An intercom for critical process areas is installed (hard-wired-type).
- A paging system is included.
- Television monitoring is included at the Flare.
- Substation buildings are prefabricated metal.

2.4.5.16.5 PLANT AIR AND INSTRUMENT NITROGEN

Plant air is supplied from air compression facilities within the Air Separation plant. Distribution piping over the interconnecting piperack supplies users through numerous utility stations located strategically throughout the plant. Where necessary, users are tied directly to the system. In the event that the Air Separation plant is on turnaround, plant air is supplied by a portable compressor(s) tied into the distribution system.

Nitrogen is supplied from waste nitrogen available in the Air Separation plant. Two reciprocating compressors compress available waste nitrogen to the desired pressure required for distribution to the gasifier lock hoppers and instrument nitrogen system. One compressor handles normal demands, and the second provides backup and peak demands.

Nitrogen is also available through vaporization of liquid nitrogen from storage. This independent source provides backup in the event that the compressors are out of service. It also can provide for startup.

Nitrogen is used to "sweep purge" the Flare header. This nitrogen is supplied from the compressed nitrogen source. The purging/blanketing nitrogen for the coal transport system is supplied from the emergency vaporized nitrogen system.

An independent nitrogen system supplied by nitrogen bottles is provided to purge the Flare knockout drum in the event of hot blows. The pumping prevents cool-down following a hot blowdown since air will be drawn into the Flare header and drum system.

2.4.5.16.6 INTERCONNECTING PIPING

An elevated interconnecting pipe rack routes process and utility piping. Pipe racks are interconnected in the process blocks, utility block, Waste Treatment facilities, Cooling Tower and Flare area. The rack width and one or two decks of the pipe racks have provisions for a 30 percent future expansion. The main section parallels the major interplant access road. Several sections of air fan heat exchangers are located above this rack between the Coal Gasification and Gas Compression plant sections.

Periodically, piping expansion loops are provided as required by piping stress analyses. These are located adjacent to the main rack.

2.4.5.16.7 SEWERS

Several sewer system networks are provided. A sanitary sewer collects all waste from sanitary facilities in buildings and directs the flow to an intertie with the municipal sewer system network.

Process area rain runoff is directed through a sewer system to the storm water holdup pond in the Wastewater Treatment area. Rain runoff from the coal pile area is directed through a sewer system to the coal pile runoff holdup pond in the Wastewater Treatment area.

2.4.5.16.8 BUILDINGS

Buildings for the IFGDP complex are provided in accordance with the tabulated building list presented in Table 2-36. This list indicates the nominal building dimensions and designates the basic construction materials. Buildings meet standard industry design. The envisioned scope of supply includes necessary foundations, structural framing, sheathing, roofing, insulation, plumbing, heating and ventilating and/or air conditioning along with electrical power and lighting circuitry. All design and construction is in accordance with applicable local and state codes.

Allowance is provided for office furnishings for the administration building and other office areas for personnel. Tools and shop equipment to sufficiently outfit the various craft shops for normal maintenance of plant equipment are provided. Laboratory equipment for sampling and analyzing process streams, change house lockers and facilities for personnel convenience are also provided.

TABLE 2-36

IFGDP LIST OF BUILDINGS

Service	Area ($feet^2$)	Construction Material
Administration	7,200	Structural Steel
Warehouse/Maintenance/Change House	20,000	Masonry
Laboratory/First Aid	3,200	Prefab Metal
Firehouse	1,800	Prefab Metal
Main Control House	3,000	Masonry, Blast Resistant
Gasifier Control House	1,500	Masonry, Blast Resistant
Utility Control House	3,000	Masonry
Boiler Feedwater Treatment	4,800	Prefab Metal
Gate Houses (two)	400 each	Masonry
Electrical Substations (nine)	(size varies)	Prefab Metal

2.4.5.16.9 ROADS AND FENCES

ROADS

The IFGDP contains paved roads to provide operating and maintenance access to all processing units and utility support facilities. In general, battery limit areas of units are surrounded by peripheral roads to satisfy fire fighting and safety requirements. The paved width of all roads is 25 feet with exception of the main approach and entrance roads which are 30 feet wide. Paving is asphaltic cement consisting of 2-inch finished road surface binder, 4-inch subbinder, and 6-inch subbase. The asphaltic cement is applied over a surface and compacted to 95 percent of maximum density.

FENCES

A primary fence, included on the fence line shown on the plot plan (Figure 2-12), encompasses the entire IFGDP site. This is a cyclone-type fence, 6 feet high, with a three-strand barbed wire anticlimber topping. A gate is provided at the gate house with remote control circuitry. The gate at the secondary plant entrance serves as the primary truck entrance.

Secondary fencing is provided to enclose outdoor storage associated with the warehouse, electrical transformer yards, gas meter station and vehicle parking areas.

2.4.5.16.10 DOCK FACILITIES

Docking facilities are sized to handle clusters of 9 or 16 coal barges at one time. The facilities include a string of dock/mooring cells fabricated from interlocking steel sheet piling, each cell filled with river-run sand and gravel and capped by a 12-inch-thick reinforced concrete slab.

Facilities to unload individual coal barges are located at the midway point in the mooring cell line and are accessible from shore via trestle roadway.

2.4.6 PLANT MATERIAL BALANCES

Figure 2-20 shows a schematic representation of the IFGDP input and output streams. Details of plant inputs (as feedstocks) and outputs (as products) are provided in Section 2.4.2 and Section 2.4.3, respectively. Details of plant emissions are provided in Section 2.4.4. This section provides information concerning important overall plant material balances which include:

- Mass balance
- Energy balance
- Water balance
- Sulfur balance

2.4.6.1 OVERALL PLANT MASS BALANCE

The overall plant mass balance for normal plant operation (three gasifiers running at 100 percent capacity) is shown in Table 2-37. Major plant inputs include coal (3158 tons per day), water (11,278 tons per day) and air (11,133 tons per day). Of the total coal feed, 98.5 percent goes to Coal Preparation and Feeding for gasification, and the remaining 1.5 percent is used in Steam Generation. Most of the input air (72.5 percent) goes to Air Separation to produce the oxygen required in Coal Gasification. Additional process air is used in Coal Preparation and Feeding for coal drying (5.6 percent), in Steam Generation (18.9 percent), in Sulfur Recovery (1.9 percent) and in Tail Gas Treatment (1.1 percent). Raw water is used primarily as makeup to the Cooling Tower (64.8 percent) and as makeup to boiler feed water preparation (34.4 percent).

These inputs result in a variety of outputs. Major product outputs are product IFG (3950 tons per day), pipeline quality gas (93 tons per day) and liquid R
sulfur (100 tons per day). Other major outputs are plant emissions including treated wastewater (4282 tons per day), waste stack and vent gases (11,036 tons per day) and solid wastes (566 tons per day).

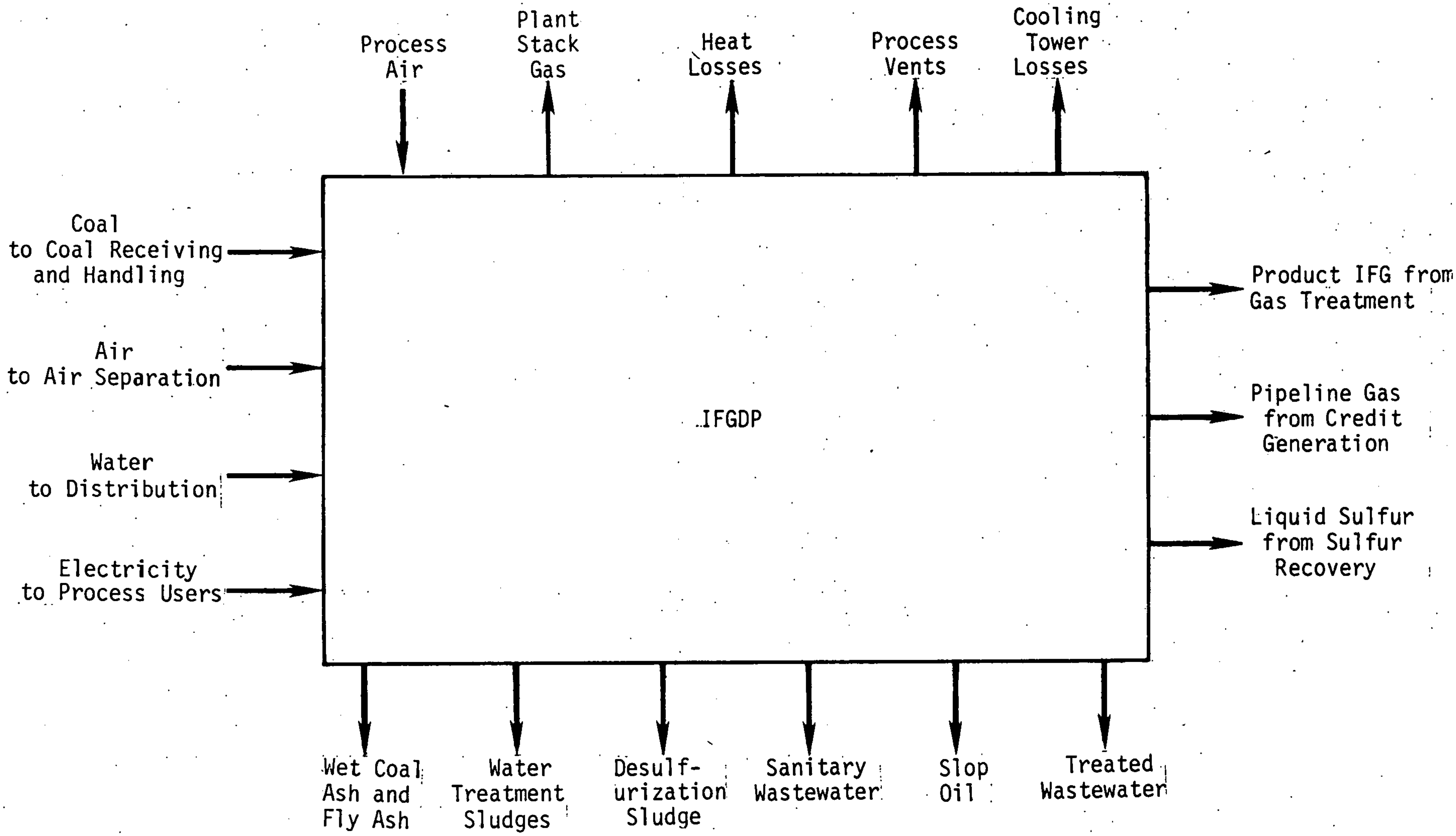

Figure 2-20. Overall Plant Material Balance for the IFGDP

TABLE 2-37

OVERALL MASS BALANCE FOR THE IFGDP

	Input (lb/hr)	Output (lb/hr)
Coal to Coal Receiving and Handling	263,200	
Air to Air Separation	671,200	
Plant raw water from MLGW system	939,800	
Process and reactor air from atmosphere	81,100	
Air to Steam Generation from atmosphere	175,300	
Chemicals and catalysts	1,400	
Product IFG from Gas Treatment to distribution		329,200
Pipeline quality gas from Credit Generation to distribution		7,700
Liquid Sulfur from Sulfur Recovery to sale		8,400
Wastewater from effluent holding pond to Mississippi River		340,200
Wet ash from Ash Treatment to ash pile		43,400
Waste gas from Air Separation to atmosphere		506,800
Plant stack gas to atmosphere		331,600
Evaporation and drift from Cooling Tower to atmosphere		468,500
Evaporation from Beavon Tail Gas Treatment to atmosphere		9,900
Tail gas from Beavon Tail Gas Treatment to atmosphere		47,800
Fly ash from Steam Generation to ash pile		2,500
Wastewater to municipal sewer		18,500

(Continued)

TABLE 2-37 (Continued)

	Input (lb/hr)	Output (lb/hr)
Vents from various process systems to atmosphere		13,300
Sludges and spent catalysts to disposal		4,200
Total	2,132,000	2,132,000

2.4.6.2 OVERALL PLANT ENERGY BALANCE

The overall plant energy balance for normal plant operations is shown in Table 2-38. Major energy inputs to the process include the higher heating value (HHV) of the coal and purchased electricity. In terms of total plant heat input, 62.0 percent is recovered as product IFG, 5.5 percent is recovered as pipeline gas and 1.1 percent is recovered as by-product sulfur. Major plant waste energy streams are the Cooling Tower losses (15.6 percent of input energy), air fan losses (7.0 percent of input energy), coal ash (2.3 percent of input energy) and plant stack, vent and waste gases (3.6 percent of input energy). Overall thermal efficiency, expressed as the percentage of input coal and electrical energy recovered as product IFG and pipeline gas, is 68.0 percent. The efficiency calculated by including the sulfur product is 69.1 percent.

2.4.6.3 OVERALL PLANT WATER BALANCE

The overall plant water balance for normal plant operations is shown in Table 2-39. Water inputs to the process include raw makeup water (93.9 percent of the material balance), water as coal moisture (2.9 percent of the material balance) and water in air to the process (1.8 percent of the material balance). Water produced as a result of combustion for coal drying in Coal Preparation and Feeding and in Steam Generation and as a result of chemical reaction in Credit Generation, Sulfur Recovery and Tail Gas Treatment collectively accounts for the remaining 1.4 percent of input water in the material balance.

Water outputs from the process leave primarily as cooling tower losses (46.8 percent), as treated wastewater to the Mississippi River (34.0 percent) and as water in waste vents and stack gas (7.3 percent). A large amount of water (9.0 percent) is consumed by the gasification reactions. The remaining water outputs are sanitary wastewater and blowdowns to municipal treatment (1.8 percent), occluded water in sludges and solid wastes to disposal (1.1 percent) and moisture in the product gas.

TABLE 2-38

OVERALL ENERGY BALANCE FOR THE IFGDP

	Input (MMBtu/hr)*	Output (MMBtu/hr)
Coal to Coal Receiving and Handling	2,936.5	
Air to Air Separation	16.4	
Purchased electricity from MLGW	153.9 (45.1 MW)	
Process and reactor air from atmosphere	1.9	
Air to Steam Generation from atmosphere	4.3	
Product IFG from Gas Treatment to distribution		1,929.1
Pipeline quality gas from Credit Generation to distribution		171.4
Liquid Sulfur from Sulfur Recovery to Sale		33.8
Wet ash from Ash Treatment to ash pile		70.2
Waste gas from Air Separation to atmosphere		6.0
Plant stack gas to atmosphere		70.7
Evaporation and drift from Cooling Tower to atmosphere		487.0
Evaporation from Beavon Tail Gas Treatment to atmosphere		11.0
Tail gas from Beavon Tail Gas Treatment to atmosphere		2.4
Air fan losses		218.8
Vents from various process systems to atmosphere		2.4
Miscellaneous heat losses		110.2
Total	3,113.0	3,113.0

* MMBtu/hr = millions of Btu per hour

TABLE 2-39

OVERALL WATER BALANCE FOR THE IFGDP

	Input (lb/hr)	Output (lb/hr)
Water in air to Air Separation	13,094	
Water in process air to users	4,985	
Water in Coal to Coal Receiving and Handling	28,944	
Raw makeup water from MLGW station	939,416	
Water produced by chemical reactions	6,482	
Water produced from coal combustion	7,384	
Water consumed by Coal Gasification		89,702
Treated wastewater to Mississippi River		340,195
Water to municipal waste treatment		18,489
Water in sludges and solid waste to disposal		10,517
Cooling tower evaporation and drift losses		468,500
Water in vents and stack gases		72,818
Water in product IFG and pipeline gas		84
Total	1,000,305	1,000,305

2.4.6.4 OVERALL PLANT SULFUR BALANCE

The overall plant sulfur balance for normal plant operations is shown in Table 2-40. Sulfur enters the process as bound sulfur in the coal, and 90.9 percent of input sulfur is recovered as a liquid sulfur product. The sulfur content of sludges and solid wastes (ash) to disposal accounts for 8.2 percent of input sulfur, and 0.2 percent leaves the process in product IFG. The remaining sulfur output (0.7 percent) leaves the process in the main plant stack gas and in the vent gas from Tail Gas Treatment.

2.4.7 PROCESS CONTROL AND FLEXIBILITY

In this section, key process parameters in the planned operation of the IFGDP are described, and the importance of their control on plant operation and flexibility is discussed.

2.4.7.1 PROCESS CONTROL

Process control points include those involving flow, temperature, pressure or composition. The detection, monitoring and maintenance at predetermined levels of these independent or dependent process variables is vital to the successful operation of the IFGDP.

The rate of the coal gasification reaction in the gasifier is complex and depends on many factors such as particle size in the fluid bed, particle reactivity with steam and oxygen, fluid-bed temperature profile, fluid-bed density and gas residence time. The coal must be fed at a rate sufficient to keep the fluidized bed depth relatively constant. Therefore, monitoring of the bed depth is important.

The feed injection location is also an important parameter. The feed injection point for the IFGDP is located about 15 feet below the top of the fluidized bed to allow more complete gasification of the coal.

TABLE 2-40

OVERALL SULFUR BALANCE FOR THE IFGDP

	Input (lb/hr)	Output (lb/hr)
Sulfur in coal to Coal Preparation and Feeding	9,064	
Sulfur in coal to Steam Generation	139	
Liquid sulfur from Sulfur Recovery		8,366
Sulfur in plant stack gas		63
Sulfur in vent gas from Tail Gas Treatment		1
Sulfur in product IFG from Gas Treatment		22
Sulfur in sludge from Flue Gas Desulfurization		516
Sulfur in ash from Ash Treatment		235
Total	9,203	9,203

The flow rates for steam and oxygen, and their ratio, determine fluid-bed temperature and gas superficial velocity. Gas velocities control gas residence time and fluid-bed density. Monitoring and accurate control of the oxygen and steam flow rates are vital parameters in the successful gasification of coal.

As the ash agglomerates form in the gasifier, they are removed by falling through the venturi opening. The quantity of the steam-oxygen mixture passing through the venturi throat of the gasifier determines the resistance that the ash particles encounter when falling from the reactor. This, in turn, determines the size to which the ash particles must agglomerate before they can pass downward through the venturi throat. Thus, the flow rates of steam and oxygen passing through the venturi throat must also be monitored and accurately controlled.

The IFGDP and its associated customer interface configuration is designed to operate to a variable customer demand. The fuel value of the product gas is monitored and controlled by selective carbon dioxide removal to maintain the gas in the required range of the fuel values.

Various vent gases to the atmosphere are monitored continously to detect any malfunction in the environmental control equipment. For example, tail gas from the Tail Gas Treatment (Section 390) is continuously analyzed for hydrogen sulfide and other environmentally significant gases, and any excessive concentrations are immediately brought to the attention of the plant operators.

After suitable treatment, wastewater from several sources such as Cooling Tower blowdown, clarified scrubber water, filtered fines slurry, coal pile runoff, etc., are discharged to the river for ultimate disposal. Monitoring of the various streams is necessary to ensure that environmental regulations are not violated by equipment malfunction or operator error.

2.4.7.2 PLANT FLEXIBILITY

The IFGDP is designed to operate with washed Kentucky No. 9 bituminous coal. Both subbituminous coal and lignite are more reactive than bituminous coal and require lower operating temperatures and lower residence times in the gasifier for complete carbon utilization. If there are future requirements to use these types of coal, the gasifier design incorporates provisions to vary the residence times. Major turndown of the plant is not required during commercial operation, since IFG demand reduction can be offset by supplying more IFG to the credit unit, up to a maximum of 30 percent of plant capacity. During initial operation it is expected that the plant will operate for some time with a single gasification train. The downstream gas processing units are designed to permit a very high turndown ratio (to about one-third of rated), which means that the process will still function on the output of only one gasifier. Overall, the entire plant is designed to operate at one-third of plant capacity and still produce IFG.

2.4.8 OPERATING PERSONNEL

A work force of approximately 270 persons is required during plant operations. Approximately 50 workers are professionals, such as managers, superintendents and engineers. The remainder includes plant operators, laboratory and engineering technicians, administrative support personnel and permanent maintenance personnel. Some maintenance services and support service personnel are contracted and add approximately 140 additional jobs. In addition to plant personnel, approximately 200 to 300 workers are required by the coal company contracted to supply the coal.

2.4.9 OPERATIONAL EXPENDITURES

The annual projected operating cost is tabulated in Table 2-41.

TABLE 2-41

ANNUAL OPERATING COSTS*

(Plant Capacity: 50 Billion Btu per day)

Item	Calculation Basis for 100% Service Factor	Annual Cost
Coal	$3158 \frac{t}{d} \times 330 \frac{d}{yr} \times \frac{\$26.00}{t}$	$27,095,640
Catalysts & Chemicals		833,990
Water	$2,710 \frac{M\,gal}{d} \times 330 \frac{d}{yr} \times \frac{\$.25}{Mgal}$	223,575
Purchased Electricity	$45,036 \frac{Kwhr}{hr} \times 24 \frac{hr}{d} \times 330 \frac{d}{yr} \times \frac{\$.02}{Kwhr}$	7,133,702
Operating Supplies	30% Process Labor**	549,000
Maintenance Supplies		1,738,000
Maintenance S/C Labor		2,768,000
Labor, Supervision, G&A		6,493,000
Local "In Lieu of Taxes"	$3.74/$100 assessed (@55% PDIC† - 10%)	2,581,000
Insurance	$0.25/$100 investment	174,000
TOTAL GROSS OPERATING COSTS		$49,589,907
Sulfur Credit	$100 \frac{LT}{d} \times 330 \frac{d}{yr} \quad \frac{\$48}{LT}$	1,584,000
NET ANNUAL OPERATING COSTS		$48,005,907

* 1978 dollars

** Per U.S. ERDA, "Factored Estimates for Western Coal Commercial Concepts," 1/30/76

† PDIC = Plant Depreciable Investment Cost

2.5 FAULT AND FAILURE ANALYSIS

The process areas and systems that may be sources of initial or independent system failure or that may create potentially hazardous conditions are discussed briefly in this section in general terms. No judgments about the reliability or probability of failure of these systems or sections are made.

2.5.1 PROCESS DESIGN

Process design failure analysis covers many facets. Use of recognized codes such as American Society of Mechanical Engineers (ASME) Pressure Vessel Code, Instrument Society of America (ISA) Instrumentation Standards and American National Standards Institute (ANSI) Piping Codes minimizes the risk of fire and explosion damage.

All design aspects of the IFGDP will conform with the latest edition of the applicable sections of the following codes:

- American Society of Mechanical Engineers (ASME)
- American Society of Testing Materials (ASTM)
- American Iron and Steel Institute (AISI)
- American Institute of Steel Construction (AISC)
- American Concrete Institute (ACI)
- American National Standards Institute (ANSI)
- American Institute of Electrical Engineers (AIEE)
- National Electrical Code (NEC)
- National Electrical Manufacturers Association (NEMA)
- Tubular Exchange Manufacturers Association (TEMA)
- Other governing codes of standard practice

Sections of these codes are designated below, and any state or local code or regulation that supplements them shall also be applicable to detailed design.

Design Area	Applicable Codes or Regulations*
Pressure Vessels	ASME Section VIII, Div. 1
Boilers	ASME I
Buildings and Structural	AISC, ACI, AMCA, ASHRAE
Electrical	ANSI, FCC, NEC, NEMA, UL, AIEE
Sanitary	EPA and state regulations
Aircraft Warning	FAA
Safety	OSHA, NFPA
Air Pollution	BACT
Water Pollution	BACT
Solid Waste	BACT
Noise	OSHA
Piping and IFG Pipeline	ANSI B 31.1 (Power Code Piping)

The process design incorporates one or more of the following features:

- o Isolation Valves
- o Pressure Relief Valves
- o Depressurization/Safety Relief Systems

Isolation valves isolate major vessels and are capable of automatic operation from the control room. These valves have a self-closing mechanism that fails safe if damaged by fire or explosion.

Depressurization or safety relief systems for reactors and vessels utilize the same type of valving as the isolation valving system. The depressurizing system is operable in a fire situation. This means that the depressurizing valves are remotely operated by electric or pneumatic power. The operating control is placed distant from the vessel for accessibility if a fire occurs.

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* See List of Abbreviations for definition of all acronyms.

2.5.2 STRUCTURAL DESIGN

Structural design for fire resistance requires fireproofing designed for 2 to 3 hours of resistance. Fire resistance specifications are adhered to by using the following codes: ASTM E-119, NFPA 251, UL 263 or ANSI A 2.1. Critical equipment will be designed to withstand expected overpressure.

2.5.3 POSSIBLE SYSTEM FAILURES (PIPING AND FEEDING)

Three possible failures and hazards in coal/coke handling and feeding are discussed below:

Gasifier Rupture -- Four gasification trains are provided, and each gasification train can be operated to produce up to one-third of the plant production requirements. Normally, three trains are operating at 100 percent capacity, and the spare train is on standby.

A sudden rupture of a gasifier shell would constitute a catastrophic failure in the plant and would discharge the majority of the contents to the atmosphere within a matter of minutes. This would amount to approximately 75 tons of fine solids (coal, char, ash) and 60,000 standard cubic feet of raw gas of the following approximate composition:

	Volume (%)
H_2	26.2
CO	21.5
N_2	0.5
CO_2	14.2
H_2S	0.85
COS	0.03
CH_4	3.5
H_2O	33.2
NH_3	0.02
	100.00

With feed continuing for 2 minutes, the maximum expected atmospheric emissions before all feeds are stopped would be an additional 1 ton of solids and 135,000 standard cubic feet of raw gas.

Most of the gas/solids discharge would take place at the gasifier operating temperature of 1875°F. The gas would ignite, and local equipment damage due to gas flames and hot solids would occur. Hazard to personnel in the immediate area would exist. However, there would be no hazard or damage outside of the plant area.

Raw Gas Compressor Line Failure -- A sudden rupture of the raw gas compressor discharge line would discharge approximately 260,000 standard cubic feet of raw gas at 370°F if the feed gas to the compressor continued for up to 2 minutes before flow was shut off. The raw gas from the compressor has the following approximate composition:

	Volume (%)
H_2	38.9
CO	32.1
N_2	0.8
CO_2	21.1
H_2S	1.25
COS	0.05
CH_4	5.2
NH_3	Trace
H_2O	0.6
	100.00

Ignition might occur, and personnel in the immediate area would be exposed to the hazard. If ignition did not occur, the toxic effects of hydrogen sulfide and carbon monoxide would constitute a hazardous condition to personnel in the immediate area. There is no reason to expect any hazard or damage outside of the plant area.

Interconnecting Piping Failure -- Rupture or blockage of interconnecting piping would require isolation of that section. Depending on which section had to be isolated, it may or may not cause a plant shutdown. Highly volatile products would be discharged until that section could be isolated. Some of these products are toxic in higher concentrations, and they are combustible in the presence of oxygen and sparks or flames. The major hazard to workers would be from explosions, fires and hydrogen sulfide and carbon monoxide gas leaks, which are toxic in sufficiently high concentrations. There is no reason to expect any hazard or damage outside of the plant area.

Coal/Coke Handling and Feeding Hazards -- Coal or coke dust is a potentially explosive mixture. The coal/coke transport system is an enclosed system that is safeguarded from leaks and sparks that could induce combustion. Dried coal and coke silos and conveyors handling dry coal or coke are maintained under a nitrogen atmosphere to minimize the possibility of spontaneous combustion.

2.6 HEALTH AND SAFETY

As in any major industrial facility, workers in the IFGDP can be exposed to a variety of potential health and safety hazards. Many of these hazards (e.g., noise, heat stress and general construction) are not necessarily a result of the coal gasification processes, but are associated with other aspects of the plant. Requirements established by the Occupational Safety and Health Administration (OSHA) and similar organizations will be implemented to provide protection for personnel during plant construction, maintenance and operation. Special guidelines for coal gasification plants, developed by the National Institute for Occupational Safety and Health (NIOSH), based on experience with related industries, will be evaluated.

A number of potentially hazardous and toxic materials can be generated inside the process units of the IFGDP from the processing of coal. These materials include: (1) various metallic and nonmetallic trace elements, (2) polycyclic aromatic hydrocarbons (PAH), (3) organometallic compounds and (4) gaseous compounds containing nitrogen, sulfur and other coal-bound elements.

Although the majority of the trace elements in coal are expected to remain in the bottom ash withdrawn from the gasifier, several elements (arsenic, beryllium, mercury, selenium, cadmium, fluorine and lead) are driven from the coal during devolatilization and exit the gasifier in the raw product gas stream.

Although the high temperature operation of the gasifier tends to destroy the PAH compounds, some of them can condense in the downstream cleanup trains, while others can possibly pass through the system.

Organometallic compounds, and especially metal carbonyls, may be formed as a result of coal gasification processing. These compounds exhibit an enhanced formation in the presence of carbon monoxide (CO), but are relatively unstable in air and will dissociate to CO and the metal or to other intermediates. Sulfur-containing gases (i.e., sulfur dioxide, hydrogen sulfide, carbonyl sulfide and carbon disulfide) and nitrogen-containing gases (i.e., ammonia and hydrogen cyanide) are generated during coal gasification. In addition, other gases, such as non-methane hydrocarbons (e.g., benzene and toluene) may also be generated.

In order to minimize the threat of exposure to these materials, MLGW will undertake steps to protect employee health and safety. Consideration of hazardous materials and means to maintain worker health and safety will be undertaken during the detailed design in Phase II, scheduled to begin in 1980.

2.7 TOXICOLOGY

Numerous government, industry and university programs dealing with toxicology studies involving coal gasification products and by-products have been performed or are currently underway. The goal of these studies is to improve current understanding of the health effects resulting from exposure to potentially toxic and hazardous material associated with coal conversion processes. These programs are designed to minimize the likelihood and the effects of harmful exposure to these materials. Two areas of interest are (1) effects on plant personnel resulting from exposure during plant operation and maintenance and (2) effects on the general public resulting from plant operation and from the use of plant products and by-products.

Toxicology information will be reviewed as part of the IFGDP program to assess its relevance to this plant.

2.8 DECOMMISSIONING

The eventual diposition of the IFGDP at the end of its useful economic life cannot be addressed with certainty at the present time. The continued operation of any or all parts of the plant at the end of its estimated 20-year life will depend upon the future needs of MLGW and the community, the relationship of IFG to other available energy sources, environmental impacts, economics and technical viability of the plant at that time.

Because the known coal reserves in the United States far exceed those needed during the estimated life of the plant, the project facilities could conceivably be maintained, repaired or replaced to extend the overall useful life beyond 20 years. Plans cannot be made until such time as those items mentioned above can be thoroughly defined and properly evaluated.

Assuming that the plant is eventually decommissioned, it is likely that the plant site will be taken over by other industrial users because of its location in an industrial area with access to barge transportation. All equipment not wanted by the industrial user will be salvaged. All solvents and catalysts will be returned to the manufacturer or sold. Ash will remain on-site if a commercial outlet for it has not been found.

LIST OF ABBREVIATIONS

LIST OF ABBREVIATIONS

~	approximately
@	at
β	buffer capacity
°F	degrees Fahrenheit
≤	less than or equal to
'	minutes
$\mu g/m^3$	micrograms per cubic meter
μmhos/cm	micromhos per centimeter
x	multiplied by
%	percent
A	abundance where A = 1-10
A	abundant
A	autumn
a_o	epicentral acceleration
AAG	ash-agglomeration gasifier
ACE	U.S. Army Corps of Engineers
ACI	American Concrete Institute
ADA	Anthraquinone disulphonic acid
Ag	silver
AG	agricultural
AIEE	American Institute of Electrical Engineers
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
Al_2O_3	alumina
ALK	alkalinity
AMCA	Air Moving and Conditioning Association
ammonia-N	ammonia-nitrogen
ANSI	American National Standards Institute
As	arsenic
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
Avg	average
B	abundance where B = 11-25
BACT	Best Available Control Technology
BaO	barium oxide
Be	beryllium
BFW	boiler feed water
BHC	1,2,3,4,5,6-hexachlorocyclohexane
BOD	biological oxygen demand
BOD_5	five-day biological oxygen demand
Btu	British thermal unit
$Btu/hr\text{-}ft^2$	Btu per hour per foot squared
Btu/lb	Btu per pound
Btu/scf	Btu per standard cubic foot
C	abundance where C = 26-50
C	carbon
C	centigrade
C	common
Ca	calcium
$CaCO_3$	calcium carbonate
CaO	lime
$Ca(OH)_2$	calcium hydroxide
$CaSO_3$	calcium sulfite
Cd	cadmium
cfm	cubic feet per minute
CFR	Code of Federal Regulations
CH_4	methane
cm/sec	centimeters per second
cm^2	square centimeters
CN	cyanide
CO	carbon monoxide
Co.	county
CO_2	carbon dioxide
COD	chemical oxygen demand
COE	U.S. Army Corps of Engineers
COS	carbonyl sulfide
Cr	chromium
Cr	creek
$Cr(OH)_3$	chromium hydroxide
CS_2	carbon disulfide
C.S.T.	Central standard time
Cum wt	cumulative weight
D	abundance where D = 51-100
DAF	dissolved air flotation
dB	decibel
dBA	A-weighted decibel
DBH	diameter at breast height
DEA	diethanolamine
DO	dissolved oxygen
DOC	dissolved organic carbon
DOE	Department of Energy
DRC	Delta Refining Company
DSCF	dry standard cubic feet
DW Standards	Drinking Water Standards
E	abundance where E = more than 100
E	east
E	endangered
E	energy
e.g.	for example
EIA	Energy Impact Associates
Elemental S	Elemental sulfur
elev.	elevation
EPA	U.S. Environmental Protection Agency
EPA Criteria	U.S. Environmental Protection Agency "Quality Criteria for Water
ER	Environmental report
Est.	estimated
F	fall
Fe	iron
FAA	Federal Aviation Agency
FCC	Federal Communications Commission
$Fe(OH)_3$	iron hydroxide
Fe_2O_3	ferric oxide

(Continued)

FSI . . . . free swelling index
ft . . . . foot
ft/sec . . . . feet per second
FWEC . . . . Foster Wheeler Energy Corp.
g . . . . acceleration of gravity
GC/MS . . . . Gas Chromatograph/Mass Spectrometer
gpd . . . . gallons per day
gpm . . . . gallons per minute
GW . . . . groundwater
H . . . . hydrogen
H' . . . . Shannon-Wheaver diversity index
H_2 . . . . hydrogen
H_2O . . . . water
H_2S . . . . hydrogen sulfide
ha . . . . hectare
HCN . . . . hydrogen cyanide
HCOOK . . . . potassium formate
Hg . . . . mercury
HHV . . . . higher heating value
Hi-Vol . . . . high volume
HMO . . . . Health Maintenance Organization
HP . . . . horse power
hr . . . . hour
IFG . . . . industrial fuel gas
IFGDP . . . . industrial fuel gas demonstration plant
IGT . . . . Institute of Gas Technology
in. . . . . inch
ISA . . . . Instrument Society of America
JTU . . . . Jackson tubidity units
K_2CO_3 . . . . potassium carbonate
K_2O . . . . potassium oxide
kips . . . . 1000 pounds
km . . . . kilometer
kv . . . . kilovolts
kva . . . . kilovolt amperes
lb/cf . . . . pounds per cubic feet
LM . . . . Lake McKellar
LNG . . . . liquid natural gas
LR . . . . lost record
m . . . . meter
M . . . . Richter magnitude
m^2ha . . . . square meters expressed in hectares
m^3 . . . . cubic meters
M-3 . . . . heavy industrial district
MAF . . . . moisture and ash free
MATCOG . . . . Mississippi-Arkansas-Tennessee Council of Governments
max . . . . maximum
MBAS . . . . methylene blue active substances
mcf . . . . thousand cubic feet
MF . . . . moisture free
MFD . . . . Memphis Fire Department
Mg . . . . magnesium
mgd . . . . million gallons per day
mg/kg . . . . milligrams per kilogram
mg/l . . . . milligrams per liter
MgO . . . . magnesia
mi . . . . miles
min . . . . minimum
MLGW . . . . Memphis Light, Gas and Water
mm . . . . millimeter
MMBtu . . . . million Btu
Mn . . . . manganese
Mn_3O_4 . . . . manganese oxide
mph . . . . miles per hour
MR . . . . Mississippi River
MSCHD . . . . Memphis and Shelby County Health Department
m/sec . . . . meters per second
MSHA . . . . Mine Safety and Health Administration
msl . . . . mean sea level
mva . . . . megavolt amperes
MW . . . . megawatts
N . . . . nitrogen
N . . . . north
N_2 . . . . nitrogen
N/A . . . . not applicable
N/A . . . . not available
$NaHCO_3$ . . . . sodium bicarbonate
$NaHSO_3$ . . . . sodium bisulfite
Na_2CO_3 . . . . sodium carbonate
Na_2O . . . . sodium oxide
Na_2SO_3 . . . . sodium sulfite
Na_2SO_4 . . . . sodium sulfate
NC . . . . Nonconnah Creek
ND . . . . none detected
NEC . . . . National Electrical Code
NEMA . . . . National Electrical Manufacturers Association
NFPA . . . . National Fire Protection Association
NH_3 . . . . ammonia
NH_3-N . . . . ammonia nitrogen
Ni . . . . nickel
NIOSH . . . . National Institute for Occupational Safety and Health
N.N.F. . . . . normally no flow
No. . . . . number
NO_2 . . . . nitrogen dioxide
NO_3-N . . . . nitrate nitrogen
NO_x . . . . nitrogen oxides
NPDES . . . . National Pollutant Discharge Elimination System
O_2 . . . . oxygen
O_3 . . . . ozone
OSHA . . . . Occupational Safety and Health Administration
p . . . . permanent
P . . . . phosphorus
P_2O_5 . . . . phosphorus pentoxide
PAH . . . . polycyclic aromatic hydrocarbons
Pan . . . . remaining in the pan

(Continued)

LIST OF ABBREVIATIONS (Continued)

Pb . . . . lead
PCB . . . . polychlorinated biphenyls
PCS . . . . potassium chloroplatinate standards
pH . . . . hydrogen ion concentration
Pop. . . . . population
ppm . . . . parts per million
ppmv . . . . parts per million by volume
Project COED . . . . Project Char-Oil-Energy-Development
psf . . . . pounds per square foot
psia . . . . pounds per square inch absolute
psig . . . . pounds per square inch gage
P.T.U. . . . . platinum-cobalt units
Q_{3-20} . . . . once-in-twenty-year 3-day consecutive high or low flow
r . . . . correlation coefficient
R . . . . resident
re . . . . regarding
RFP . . . . request for proposal
RM . . . . river mile
ROW . . . . right-of-way
S . . . . south
S . . . . special
S . . . . special concern
S . . . . sulfur
S . . . . summer
Sb . . . . antimony
scf . . . . standard cubic foot
scfm . . . . standard cubic feet per minute
SCN^- . . . . thiocyanate
SCOT . . . . Shell Claus Off-gas Treatment
Se . . . . selenium
SiO_2 . . . . silica
SMSA . . . . Standard Metropolitan Statistical Area
SNG . . . . synthetic natural gas
SO_2 . . . . sulfur dioxide
SO_3 . . . . sulfur trioxide
SO_4 . . . . sulfate
sp . . . . *species*
Sp . . . . spring
spp . . . . species (pl.)
SrO . . . . strontium oxide
SRU . . . . sulfer recovery unit
SS . . . . suspended solids
Std. dev. . . . . . . standard deviation
STP . . . . sewage treatment plant
Su . . . . summer
T . . . . threatened
T . . . . transient
T/D . . . . tons per day
TDE . . . . 1,1,-dichloro-2,2-bis (p-chlorophenyl) ethane
TDS . . . . total dissolved solids
TEMA . . . . Tubular Exchange Manufacturers Association
Tennessee Criteria . Tennessee Water Quality Criteria
Ti . . . . titanium
TiO_2 . . . . titania
TKN . . . . total kjeldahl nitrogen
Tl . . . . thallium
TOC . . . . total organic carbon
TSP . . . . total suspended particulates
TSS . . . . total suspended solids
TVA . . . . Tennessee Valley Authority
U . . . . uncommon
U-GAS[TM] Process . . medium Btu industrial fuel gas
UL . . . . *Underwriters Laboratories*
U.S. . . . . United States
U.S. ACE . . . . U.S. Army Corps of Engineers
USFWS . . . . U.S. Fish and Wildlife Service
USGS . . . . U.S. Geological Survey
USS . . . . U.S. standard sieve
V . . . . vanadium
V . . . . very uncommon
v . . . . visitor
V_2O_5 . . . . vanadium pentoxide
var. . . . . variety
viz . . . . that is
W . . . . west
Wt . . . . weight
yr . . . . year
Zn . . . . zinc
$Zn(OH)_2$ . . . . zinc hydroxide