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ENVIRONMENTAL ASSESSMENT

PHILADELPHIA GAS WORKS

MEDIUM-BTU COAL GASIFICATION PROJECT

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Under

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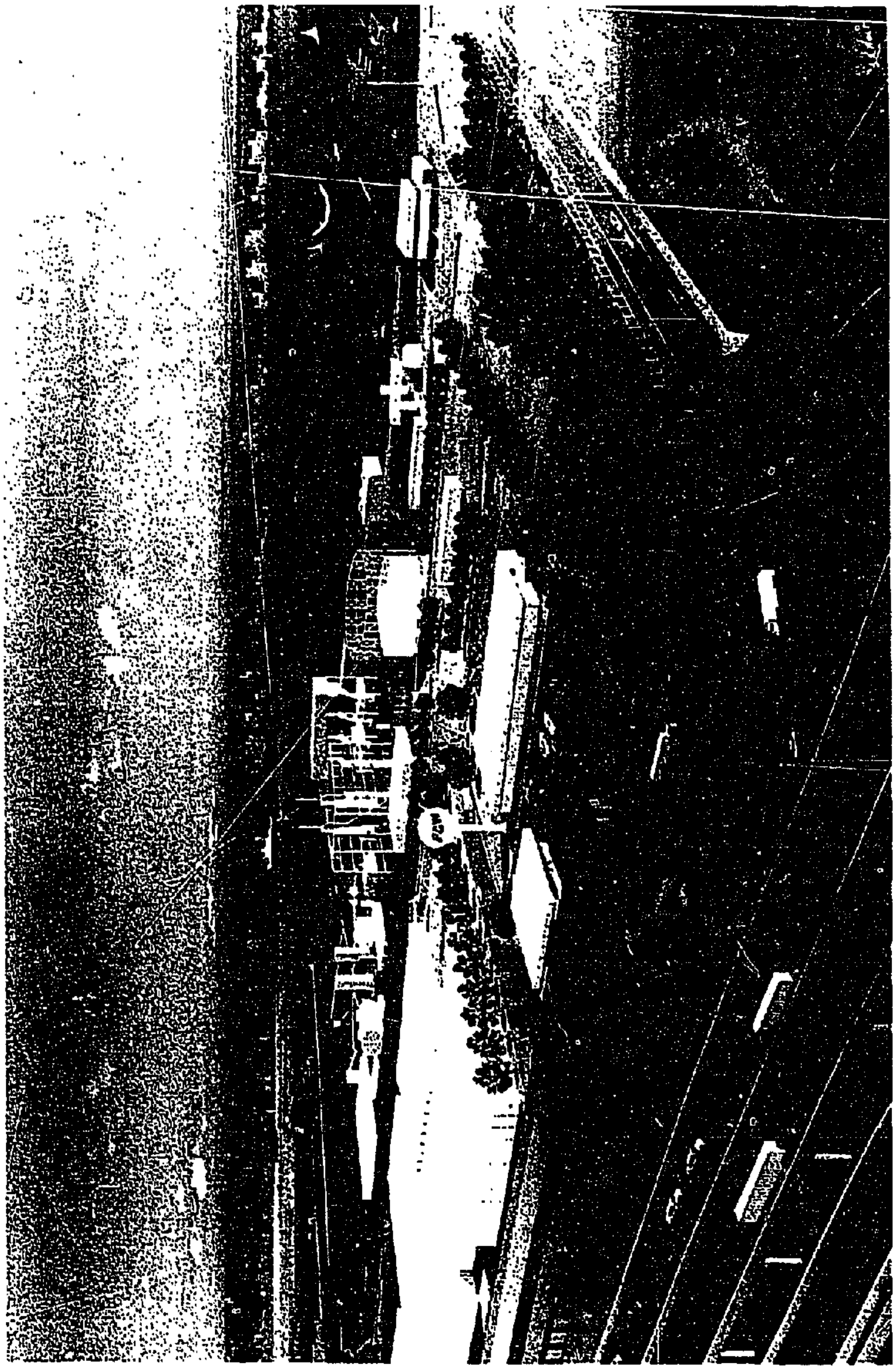

FRONTISPIECE

EXECUTIVE SUMMARY

INTRODUCTION

The energy crisis and the loss of industries in the City of Philadelphia have been the driving forces behind this project to build a central coal gasification facility in the city for producing medium-Btu gas for industrial usage.

The energy crisis has created a situation in which low sulfur fuel oil has become scarce and expensive. Domestic natural gas has also become scarce and has either not been available to large industrial consumers of energy or has been available on an inconvenient and interruptible basis.

The City of Philadelphia has been losing jobs because industry is moving away from the area for a variety of reasons, including the difficulty in obtaining a clean burning fuel. The making of a fuel, such as environmentally acceptable coal gas, available to industries would be a factor helping to allow for industrial expansion and enticing new industries to the area.

The Industrial Fuel Use Act of 1978 was enacted to prohibit, with exceptions, the use of petroleum and natural gas in new, large industrial and utility boilers and provided for possible extension to other industrial processes. The U.S. Department of Energy developed a major national policy of conversion from fuel oil and natural gas to the more abundant coal resources.

Although there are numerous low- and medium-Btu gasification plants operating overseas, there are only limited commercial users of low-Btu coal gas and no medium-Btu commercial plants in the United States today. Modern technology has resulted in the coal gasification process available today which can manufacture clean burning coal-derived gas in an environmentally acceptable manner.

On March 15, 1979, the United States Department of Energy released a Program Interest Notice (PIN) on a low/medium-Btu coal gasification assessment program for potential users in order to reach a "realistic assessment of the feasibility (from the owner/user's point of view) of utilizing low- or medium-Btu gas from coal in a variety of industrial applications and/or commercial gasification systems."

Because Philadelphia Gas Works is vitally interested in exploring the feasibility of using environmentally acceptable coal gas to help meet their charter for satisfying the city's demands for gas, they responded to the PIN and were awarded funds for a Phase I feasibility study in October 1979.

The feasibility study addressed market-analysis considerations, preliminary economic/operational analysis, heating value considerations, conceptual design of the gasification plant, and recommended economic/operational trade-offs.

The year-long study which culminated in a final report which was released in February 1981 concluded that the potential range of gas costs compared favorably with No. 6 fuel oil as an energy source; however, the cost was very dependent on coal costs.

Additional funds were awarded to PGW in October 1980 from the U.S. DOE under Public Law 96-126 for a 12-month study to define the means by which they would proceed toward construction and operation, considering the following factors:

a. Technical and economic feasibility,
b. Financing alternatives,
c. Resource assessment and availability, and
d. Ability to construct and operate a commercial plant in an environmentally acceptable manner on a selected site.

As part of the feasibility study and in accordance with the National Environmental Policy Act which stipulates that an environmental assessment shall be prepared for Federally funded projects, an environmental assessment of the project was prepared to evaluate the positive and negative impacts, and when potentially negative impacts could occur, to explain the mitigative measures which would be taken to avoid or minimize them. This document, which describes the results of the environmental assessment, contains the following sections: (1) Project Description; (2) Description of the Environment; (3) Environmental Impacts of the Proposed Project; (4) Alternatives to the Proposed Action and Their Impacts; (5) Agencies and Companies Contacted; and an Appendix which contains letters of endorsement from agencies and companies contacted.

PROJECT PHILOSOPHY

The underlying philosophy behind the project is to design a coal gasification plant in Philadelphia using state-of-the-art pollution control technology and process equipment for producing a clean medium-Btu gas which can be both produced by the facility and burned by industrial users in an environmentally acceptable manner by complying with all applicable Philadelphia, Pennsylvania, and Federal environmental regulations. The coal gas will replace 198,388 gpd of No. 6 fuel oil which the industries would otherwise use as fuel. An architectural rendering of the proposed facility is shown in the frontispiece.

ENVIRONMENTAL IMPACTS

The overall environmental impact of the project is a positive one. The facility will have the capacity to produce 20.58×10^9 Btu per day of clean burning medium-Btu gas (HHV = 290 Btu per cu ft). This will replace 198,388 gpd of low sulfur No. 6 fuel oil which the industries would otherwise use as fuel. The project will have a stimulatory impact on the economy. Plant construction will boost total city employment by a high of 715 jobs in 1984. Plant operation will increase total city employment to 105 jobs. The major economic effects of the plant will begin to occur in 1987, as a result of the retention of the 1,500 manufacturing jobs. After accounting for ripple effects, city employment will be higher by 2,262 in 1987 and by 2,695 in 1990 because of the coal gasification plant. By 1990, the gross city product will be increased by $110.85 million annually, personal income will be increased by

$47 million, and the city wage and earnings tax will be increased by $2.3 million. During the construction period, an estimated 500 construction jobs created by the project will have a positive effect on the Philadelphia economy for several calendar quarters. The operating facility is projected to provide 105 full time jobs. The increased demand on the Pennsylvania coal industry to supply 329,376 tpy of coal will benefit that industry. Philadelphia industries which are presently operating on fuel oil or interruptable natural gas would potentially close down or move away from the city if their conventional sources of energy were to become unavailable or too expensive. This trend could severely impact the city's economy at a time when there is an active program to attract new industry to Philadelphia. The facility will provide a reliable source of fuel to these industries.

The coal gasification plant will occupy a 43-acre site, known as the Riverside Site, which is located along the Delaware River next to Port Richmond between the Betsy Ross and Benjamin Franklin Bridges. The cleared site was previously used for industrial purposes and has a G-2 industrial zoning.

Adverse impacts during the construction phase of the project are not expected to be significantly different than those occurring during any major industrial construction project. Adverse impacts will be avoided or minimized whenever possible through the use of good engineering practices.

During operation of the coal gasification facility, specific mitigative measures have been designed into the facility to avoid adverse environmental impacts wherever possible. In addition to these extensive engineering safeguards, elaborate monitoring and control instrumentation shall be used.

The GKT entrained bed, oxygen-blown gasification process provided by Krupp/Koppers was selected because it is a commercially proven system and because of its positive environmental characteristics such as its ability to gasify many coal types and the fact that it does not produce tars, phenols, or ammonia. During gasification of the coal, pollutants such as heavy metals in the coal are concentrated into the slag and ash. None of these pollutants are found in the product gas.

The facility will produce 250 tpd of non-hazardous slag and fly ash. The proportion of this which is fly ash will be reduced to a minimum by returning to the gasifier a portion of the unburned carbon in the recovered fly ash. The combined slag and fly ash will occupy 347 cubic yards per day of landfill volume. Available haulers and landfills have been identified. Other methods for solid waste disposal, including returning the solid waste to the mines from which the coal came, are being explored.

Process water requirements (1,396,000 gpd) will be supplied directly from the Delaware River. This is a very small percentage of the total flow of the river. Cooling tower blowdown, treated wastewater, and treated coal pile runoff (360,000 gpd) will be returned to the river. Twenty-five percent of the water removed from the river will be returned to the river. The total quantity of Delaware River water consumed because of evaporation and process utilization will be 1,057,300 gpd. City of Philadelphia water will be used at the rate of 11,000 gpd for potable, sanitary, and miscellaneous uses and then returned to the city sanitary system.

The K-T gasifier has an uninterrupted history of safe operation. In an emergency such as loss of the coal feed system or a change in oxygen pressure the gasifiers can be shut down almost instantaneously.

A sophisticated health and safety program shall be required by the operator of the facility. This will include appropriate monitoring instruments for CO, H_2, H_2S, polynuclear aromatic hydrocarbons, organic compounds, and coal dust.

Air emissions from operation of the coal gasification plant are not considered significant. During start-up, product gas will be flared. Overall air impacts of the facility have been examined by comparing air emissions which would result if the four industries were to burn medium-Btu gas and No. 6 fuel oil (0.5 percent S). Sulfur dioxide emissions resulting from burning low sulfur oil and medium-Btu gas will be approximately the same; and, less than 70 percent of the maximum permitted by city air quality standards for burning the quantity of fuel which will be produced. None of the proposed industrial users of the medium-Btu gas is in a non-attainment area for SO_2.

Conversion to medium-Btu gas will result in a decrease in both nitrogen dioxide and particulate emissions. Nitrogen dioxide emissions will decrease from 10,667 lbs per day to 4,600 lbs per day, and particulates will decrease from 3,067 lbs per day to 360 lbs per day.

Conversion to burning of the medium-Btu gas from fuel oil by the four industrial users should cause a decrease of 283 tons per year of total suspended particulate emissions and a decrease of 1,001 tons per year of nitrogen oxide emissions.

Air emissions from the cooling tower will consist of water vapor. The cooling towers will make a minimal contribution to the water vapor already in the atmosphere and will cause no additional fogging or icing conditions in the vicinity of the plant. Air emissions from the plant flare and from vents located on various process units will consist primarily of water, air, and possible trace amounts of other gases which should neither be able to be smelled beyond the immediate area of the vents nor create a health or safety hazard to workers or the community.

Dust control systems have been designed into the facility to minimize fugitive dust emissions so that they comply with the City of Philadelphia air regulations for fugitive and nuisance dusting. Water and polymer sprays shall be utilized to control dust at the coal piles. A wind, time-activated spray system shall be used on the reserve coal pile. At other points where coal dust could be generated, such as at the delumpers, silos, and pneumatic conveyors, highly efficient fabric filters shall be used to prevent coal dust particles larger than 0.04 microns from entering the atmosphere. All coal conveyors shall be shrouded. Slag and ash shall be stored in covered hoppers and a spray system shall be used to minimize dusting when the material is transferred to covered trucks.

Other than medium-Btu gas the only recycleable by-products which will be recovered from the facility will be saleable elemental sulfur, and slag and fly ash which may be saleable. Buyers for the sulfur have been identified.

The Stretford plant, used to recover sulfur from the raw product gas, will use a Nittetu reductive incineration process to decompose the purge stream which would otherwise constitute a wastewater disposal problem.

Noise from operating the gasification facility will be minimized by using acoustical insulation and noise is not expected to be discernible among the background of industrial and highway noises already heard at the residential areas near the site.

Rail traffic through Port Richmond will increase by one 70-car train per week which will unload during a two or three day period. Thirteen 23-ton truck loads of slag/ash will leave the facility five days per week. The train traffic resulting from supplying coal to the gasification facility is less than three percent of the traffic which will be generated from the scheduled expansion of adjacent Port Richmond so that it can serve as a major coal exporting yard.

Quick access to Interstate Route 95 from the site should not cause a discernible increase in either traffic or noise in the area. Increased traffic because of employees is also not expected to cause a substantial difference in traffic flow near the site. On-site parking will be provided.

ALTERNATIVES

Several alternatives were considered in the study. The Riverside site was selected from more than 16 sites examined because it was the only available environmentally acceptable site of sufficient size for the facility near potential users of the gas within the City of Philadelphia.

Medium-Btu gas was selected as the coal derived fuel of choice because it can be transported a short distance to designated industrial users from a central plant in Philadelphia at a price which is projected to be lower than the price of No. 6 fuel oil in 1985, minimal retrofit expense is required by industrial users of the gas, and environmental considerations are restricted to a single facility.

The KT gasifier was selected from three alternative gasifiers because it is commercially proven and because of its unique ability to gasify many coals and because of the fact that it does not produce tars, phenols, or ammonia and is, therefore, an environmentally cleaner plant.

A Stretford desulfurization unit was selected from alternative systems because of its low capital cost for small capacity plants. The molten sulfur configuration was selected because it produces a saleable product and results in no solid or liquid waste.

The alternative of taking no action was rejected at the start of the feasibility study whose purpose was to explore the use of coal gas as a substitute for fuel oil and natural gas.

AGENCIES AND COMPANIES CONTACTED

The following agencies or companies have been contacted concerning the project and in some cases have already provided letters supporting the project:

Delaware River Basin Commission,
Pennsylvania Department of Environmental Resources,
Philadelphia Department of Licenses and Inspection,
Philadelphia Air Management Services,
Philadelphia Water Department,
Philadelphia Port Corporation,
Philadelphia Industrial Development Corporation,
Philadelphia Planning Commission,
United States Environmental Protection Agency,
U.S. Army Corps of Engineers,
U.S. Energy Management Agency,
Conrail,
Danella Bros., Inc.
Lanchester Corporation,
Arco Chemical Co., and
Essex Chemical Corporation.

1.0 PROJECT DESCRIPTION

1.1 INTRODUCTION

The energy crisis and the loss of industries in the City of Philadelphia have been the driving forces behind this project to build a central coal gasification facility in the city for producing medium-Btu gas for industrial usage.

The energy crisis has created a situation in which low sulfur fuel oil has become scarce and expensive. Domestic natural gas has also become scarce and has either not been available to large industrial consumers of energy or has been inconveniently available on an interruptible basis.

The City of Philadelphia has been losing jobs because industry is moving away from the area for a variety of reasons, including the inability to obtain a clean burning fuel. The making of a fuel, such as environmentally acceptable coal gas, available to industries would be a factor in helping to allow for industrial expansion and enticing new industries to the area.

The Industrial Fuel Use Act of 1978 was enacted to prohibit, with exception, the use of petroleum and natural gas in new large industrial and utility boilers and provided for possible extension to other industrial processes. The U.S. Department of Energy developed a major national policy of conversion from fuel oil and natural gas to the more abundant coal resources.

Although there are numerous low and medium-Btu gasification plants operating overseas, there are only limited commercial users of low-Btu coal gas and no medium-Btu commercial plants in the United States today. Gas derived from coal lit the streets of Philadelphia before natural gas became available; however, the process used to produce the gas then would not be acceptable with today's strict environmental standards. Modern technology has resulted in the coal gasification process available today which can manufacture clean burning coal-derived gas in an environmentally acceptable manner. Other, larger coal gasification plants using technology similar to that proposed for the Philadelphia project are being planned by the Tennessee Valley Authority in Murphy Hill, Alabama, and by the City of Memphis, Tennessee.

On March 15, 1979, the United States Department of Energy released a Program Interest Notice (PIN) on a low/medium-Btu coal gasification assessment program for potential users in order to reach a "realistic assessment of the feasibility (from the owner/user's point of view) of utilizing low or medium Btu gas from coal in a variety of industrial applications and/or commercial gasification systems."

Because the Philadelphia Gas Works is vitally interested in exploring the feasibility of using environmentally acceptable coal gas to help meet their charter for satisfying the city's demands for gas they responded to the PIN and were awarded funds for the Phase I feasibility study in October of 1978.

The feasibility study addressed market-analysis considerations, preliminary economic/operational analysis, heating value considerations, conceptual design of the gasification plant, and recommended economic/operational trade-offs.

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Additional funds were awarded to PGW in October 1980 under Public Law 96-126 from the U.S. DOE for a 12-month study to define the means by which they would proceed toward construction and operation, considering:

a. Technical and economic feasibility,
b. Financing alternatives,
c. Resource assessment and availability, and
d. Ability to construct and operate a commercial plant in an environmentally acceptable manner on a selected site.

As part of the feasibility study and in accordance with the National Environmental Policy Act an Environmental Assessment contained in the following document was prepared to demonstrate how the facility will be constructed and operated in an environmentally acceptable manner.

1.2 BASIS FOR DESIGN

The underlying philosophy behind the project is to design a coal gasification plant in Philadelphia using state-of-the-art pollution control technology and process equipment for producing a medium-Btu gas which can be both produced by the facility and burned by industrial users in an environmentally acceptable manner. The coal gas will replace 198,388 gpd of No. 6 fuel oil which the industries would otherwise use as fuel. Specific features of the project are listed as follows:

Type of Plant: Coal gasification plant producing medium-Btu gas for industrial users.

Plant Site: City of Philadelphia on the Delaware River at the Riverside site located between the Benjamin Franklin and Betsy Ross Bridges.

Plant Size: Two gasifiers with a capacity of producing 20.58 x 10^9 Btu/day of medium-Btu gas for distribution to industry.

Coal Feed: 1,128 tpd (329,376 tpy) of Pittsburgh No. 8 and/or other eastern bituminous coals. Characteristics of the coal are shown in Table 1-1.

Coal Storage: Live storage; 10,000 tons. Dead storage; 56,000 tons.

Gasification Process: GKT gasification process provided by Krupp/Koppers.

Sulfur Removal and Recovery: Stretford plant designed to remove essentially all H_2S from product gas. COS is not removed from gas, resulting in 0.1 mole percent sulfur in product gas. 27.2 tons per day of pure elemental molten sulfur will be produced for sale to the chemical market.

Make-up Water Supply: Potable water (11,000 gpd) is to be supplied from the City of Philadelphia Water Department. Plant water requirements (1,396,000 gpd) are supplied directly from the Delaware River.

Wastewater Disposal: Sanitary wastewater (11,000 gpd) discharged to the City of Philadelphia Sanitary System; cooling water blowdown, treated wastewater, and treated coal pile runoff (360,000 gpd) discharged into the Delaware River. Twenty-five percent of the water removed from the river will be returned to the river at the facility.

Solid Waste Disposal: Non-hazardous fly ash from gas scrubbing (202 tpd) and slag from gasifier bottoms (48 tpd) picked up at the plant gate by a contracted hauler and transported to a licensed landfill. The volume of solid waste produced will be 347 cubic yards per day.

Health and Safety: A health safety program for worker protection includes monitors and alarms for H_2S, CO, H_2, dust, polynuclear aromatic hydrocarbons, and organic compounds. Almost instantaneous shutdown of the gasifier is possible in the event of an emergency such as loss of the coal feed system or a change in oxygen pressure.

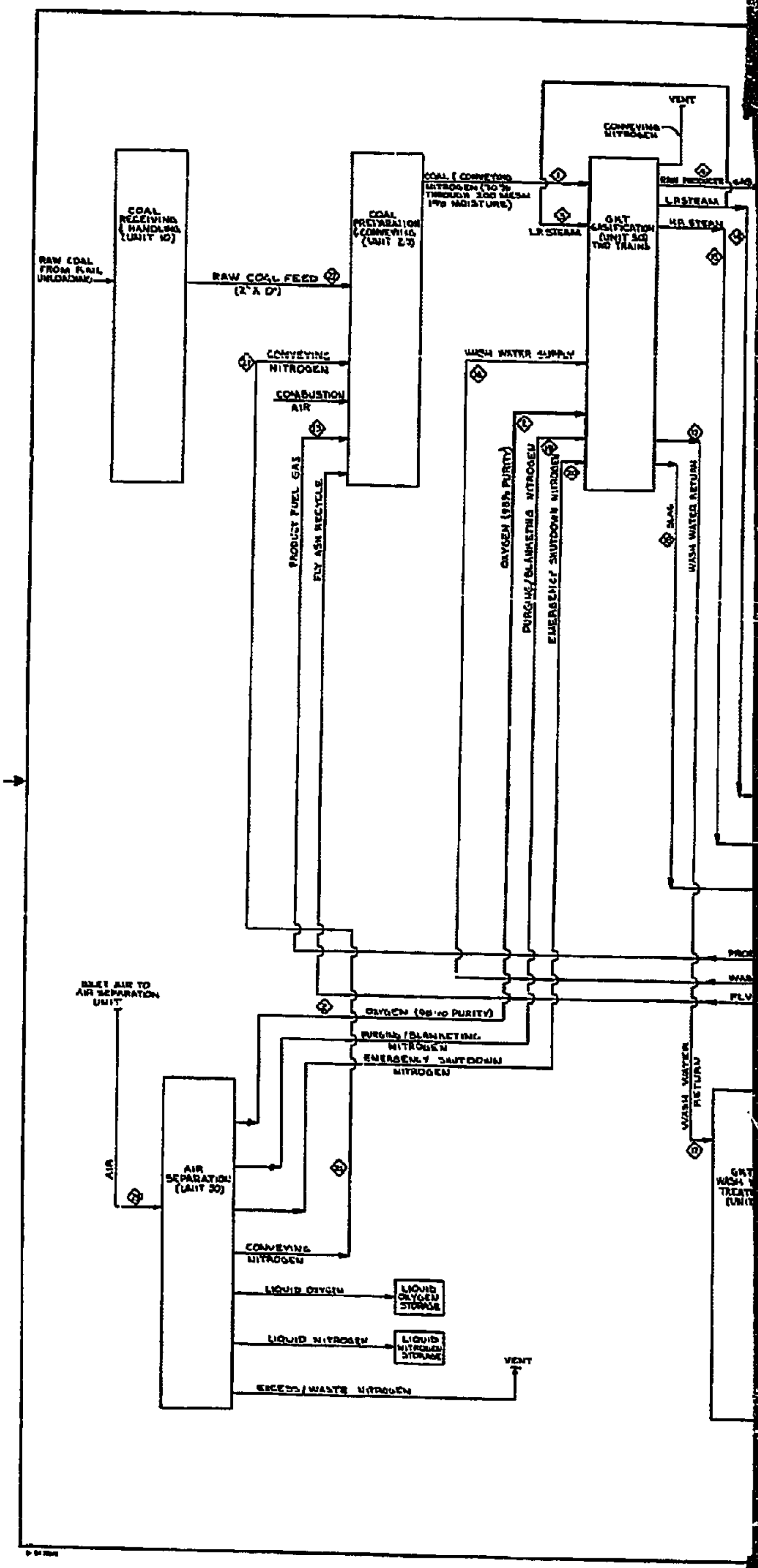
Dust Control: Dust control and filters, sprays, and enclosed structures used to control dust during storage and handling of coal, ash, and slag.

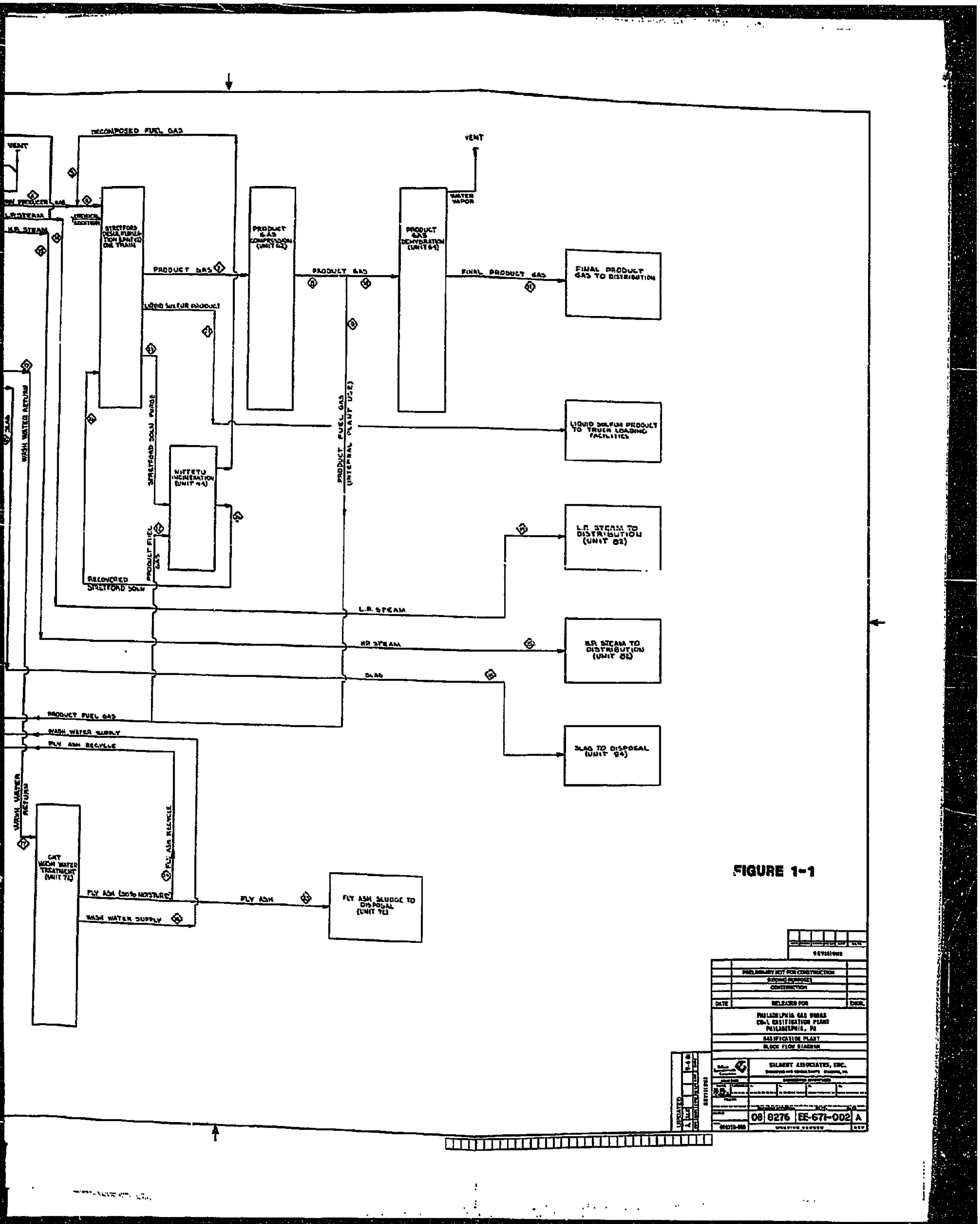
Noise: Enclosed buildings, accoustical shrouding, and insulation specified at major sources of noise such as at the coal unloading area and coal crushers.

1.3 OVERALL PROCESS DESCRIPTION

The preliminary design completed during Phase II of the PGW Coal Gasification Project is based on the gasification process offered by GKT. The GKT Gasification Unit consists of two parallel gasification and clean-up trains. No spare trains are provided in the present design. An overall process block diagram of the PGW gasification plant is shown in Figure 1-1. The gasification plant basically consists of the following units:

Unit No.	
10	Coal Receiving and Handling
15	Coal Dust Supression
20	Coal Preparation and Conveying
30	GKT Gasification
40	Sulfur Removal and Recovery
42	Stretford Desulfurization
44	Nittetu Incineration
50	Air Separation


COAL RECEIVING & HANDLING (UNIT 10)
RAW COAL FROM RAIL UNLOADING
RAW COAL FEED
COAL PREPARATION & CONVEYING
CONVEYING NITROGEN
COMBUSTION AIR
PRODUCT FUEL GAS
FLY ASH RECYCLE
VENT
CONVEYING NITROGEN
L.P. STEAM
H.P. STEAM
WASH WATER SUPPLY
OXYGEN (98% PURITY)
PURGING/BLANKETING NITROGEN
EMERGENCY SHUTDOWN NITROGEN
SLAG
WASH WATER RETURN
INLET AIR TO AIR SEPARATION UNIT
AIR
AIR SEPARATION (UNIT 30)
CONVEYING NITROGEN
LIQUID OXYGEN
LIQUID OXYGEN STORAGE
LIQUID NITROGEN
LIQUID NITROGEN STORAGE
VENT
EXCESS/WASTE NITROGEN
WASH WATER RETURN



DECOMPOSED FUEL GAS
VENT
WATER VAPOR
STRETFORD DESULFURIZATION UNIT(S) ONE TRAIN
PRODUCT GAS COMPRESSION (UNIT 62)
PRODUCT GAS DEHYDRATION (UNIT 64)
PRODUCT GAS
FINAL PRODUCT GAS
FINAL PRODUCT GAS TO DISTRIBUTION
LIQUID SULFUR PRODUCT
STRETFORD SOLN PURGE
NITTETU INCINERATION (UNIT 44)
PRODUCT FUEL GAS (INTERNAL PLANT USE)
LIQUID SULFUR PRODUCT TO TRUCK LOADING FACILITIES
L.P. STEAM TO DISTRIBUTION (UNIT 82)
RECOVERED STRETFORD SOLN
PRODUCT FUEL GAS
L.P. STEAM
HP STEAM
H.P. STEAM TO DISTRIBUTION (UNIT 82)
SLAG
SLAG TO DISPOSAL (UNIT 94)
WASH WATER RETURN
WASH WATER SUPPLY
FLY ASH RECYCLE
GKT WASH WATER TREATMENT (UNIT 72)
FLY ASH (30% MOISTURE)
FLY ASH
FLY ASH SLUDGE TO DISPOSAL (UNIT 92)
PHILADELPHIA GAS WORKS
COAL GASIFICATION PLANT
PHILADELPHIA, PA
GASIFICATION PLANT
BLOCK FLOW DIAGRAM
GILBERT ASSOCIATES, INC.
08 8276 EE-671-002 A

FIGURE 1-1

Unit No.	
60	Product Gas Handling
62	Gas Compression
64	Gas Dehydration
70	Water Treatment
72	GKT Wash Water
74	Waste Water
80	Utilities
81	Cooling Water
82	Steam, BFW, and Condensate Return
83	Firewater
84	Plant & Potable Water
85	Plant and Instrument Air
86	Sewer and Sanitary Drain
87	Boiler
90	Offsites
91	Main Process Flare & Relief
92	Fly Ash Removal and Storage
94	Slag Removal and Storage

For the GKT gasification plant 2.0 in. by 0 in. sized coal is delivered by unit train via in-plant tracks to the Coal Receiving and Handling Unit. In this unit the coal is unloaded from the unit train to the storage area, where a stock pile is formed by a lowering well. From the storage area, belt conveyors deliver the coal to bunkers for coal preparation at the rate of approximately 1200 tons per day (as received, without loss).

In the Coal Preparation and Conveying Unit the coal is fed from the bunkers to pulverizers where the coal is dried and pulverized to the following GKT gasifier feed requirements:

- Size - 90 percent through 170 mesh and 70 percent through 200 mesh
- Moisture Content - one percent

An air heater which uses medium-Btu product gas is used to heat air for the purpose of reducing the coal inlet moisture to one percent in the pulverizer. The heated air pneumatically carries the coal from the pulverizer to a particulate removal system. Coal dust (pulverized coal) from the removal system is collected and pneumatically conveyed via by-product nitrogen from an air separation plant to service bins within the GKT Gasification Unit battery limits.

In the entrained bed gasifiers, the coal dust is oxidized by oxygen in the presence of steam. Coal, oxygen, and steam are brought together and distributed to four gasifier burner heads which are 90° apart. Reaction temperature at the burner head discharge is 3300-3500°F and the operating pressure is slightly above atmospheric. The coal is gasified almost completely and immediately. Under the process conditions prevailing in the gasifer, carbon and hydrocarbons contained in the coal are converted to carbon monoxide, hydrogen, and carbon dioxide.

The gasifier is a refractory lined steel shell equipped with a water jacket for producing low-pressure process steam at 28 psig. The low pressure steam from the jacket is more than enough to meet the gasifier's needs.

Oxygen for the gasification reaction is provided by an air separation plant. The air separation plant will be a turnkey facility, and engineering and design services will be furnished by a contractor experienced in this field. The oxygen purity for the plant is 98 vol percent with 2 percent inerts (mostly argon). By-product nitrogen (98 vol percent purity) from the plant is used for coal dust conveying and gasification system purging and blanketing.

In the gasifier, approximately 30 percent of the coal ash particles coalesce and drop out as slag into a slag quench and removal system.

The slag is removed by belt conveyor to temporary slag storage facilities (Unit 94) prior to rail loading for disposal.

The remaining 70 percent of the fine ash particulates are carried overhead out of the gasifier as fly ash entrained with unburned carbon and are removed downstream by the gas clean-up train.

The medium-Btu product exits the gasifier at approximately 2700°F. The gas passes through a waste heat boiler which produces 925 psig saturated steam. At the exit of the waste heat boiler the gas temperature is reduced to 600°F. The gas then passes through a clean-up train where the temperature of the gas is subsequently reduced to 95°F and the majority of the entrained fly ash and carbon particulates are removed.

In the clean-up train the fly ash is removed via a circulating wash water system which scrubs the gas. The wash water stream ladden with fly ash and unburned carbon is sent to the GKT Wash Water Treatment (Unit 72). In the wash water treatment the entering wash water stream is sent to two rectangular settling ponds. The fly ash sludge from the settling ponds is sent to a common thickener. The underflow of the thickener is pumped to rotary vacuum filter where the moisture is reduced to 50 percent. The fly ash filter cake is then sent via belt conveyor to temporary storage facilities (Unit 92) prior to disposal by rail or truck. The amount of fly ash to disposal for a typical Pittsburgh No. 8 coal at the plant design production rate is 345 tpd.

To reduce the sludge disposal problems, and also to reutilize some of the carbon in the fly ash cake, recycling of up to 50 percent of the sludge cake to the gasifiers is incorporated in the present design. Recycle of 50 percent of the fly ash cake will increase the gasifier carbon conversion from 88.0 to 93.6 percent while reducing the raw coal feed by 6 percent. The recycle of sludge to the gasifier is limited to 50 percent, since the pulverizer and air heater design is currently limited to a maximum of 12 percent moisture. Recycle of 50 percent of the sludge cake to the gasifier will not significantly affect the gasifier gas production or composition, since the hydrogen, oxygen, nitrogen, and sulfur to carbon ratios in the mixed feed are essentially the same as the raw coal feed.

Summarized in Table 1-1 is the material balance for the recycle of sludge cake cases. The material balance represents a product gas production rate of 20.58 billion Btu/day at the plant battery limits (high heating value, no sensible heat credit basis).

Downstream of the gas clean-up train the two gasification trains join together to form a single train. The gas then passes through a gas holder and an electrostatic precipitator for final particulate removal before exiting the GKT battery limits. The composition and conditions of the product gas exiting the GKT battery limits are shown below:

Component	Mole%
H_2	27.29
N_2	0.92
Ar	0.57
CO_2	6.36
CO	58.61
CH_4	0.01
H_2S	0.85
COS	0.09
HCN	75 PPMV
H_2O	5.30
TOTAL	100.00
Temperature, °F	95
Pressure, in. W.C.	22

TABLE 1-1

PGW GASIFICATION PLANT OVERALL MATERIAL BALANCE
DESIGN PRODUCT GAS PRODUCTION (20.58×10^9 BTU/DAY), ASH RECYCLE CASE

STREAM NO.[1]	1		2		3	4		5		6	
STREAM DESCRIPTION	DRIED COAL FEED TO GKT UNIT		OXYGEN FEED TO GKT UNIT		L.P.STEAM INPUT TO GKT GASIFIERS	PRODUCT GAS OUTLET GKT BATTERY LIMITS		DECOMPOSED FUEL GAS FROM NITTETU INCINERATION		PRODUCT GAS INLET STRETFORD UNIT	
TOTAL FLOW, LB/HR	99,137 (1189.6 TPD)		94,910 (1139 TPD)		8843	179,794		7,420		186,069	
VAPOR FLOW, SCFM	-		18,662		-	52,781		1,581		53,958	
LIQUID FLOW, GPM	-		-		-	-		-		-	
VAPOR MOLECULAR WT.	-		32.16		-	21.54		29.69		21.81	
TEMPERATURE, °F	60		100		274	95		120		101	
PRESSURE, PSIG (IN W.C.)	ATM		0.4 (12)		28	0.8 (22)		0.8 (22)		5.8	
COMPONENTS	LB/HR	WT %	LB/HR	MOLE %	LB/HR	LB/HR	MOLE %	LB/HR	MOLE %	LB/HR	MOLE %
S	2,370	2.39	-	-	-	-	-	-	-	-	-
C	74,180	74.83	-	-	-	-	-	-	-	-	-
H_2	4,739	4.78	-	-	-	4,556	27.29	22	4.45	4,578	26.82
O_2	4,250	4.29	92,556	98.00	-	-	-	-	-	-	-
N_2	1,279	1.39	-	-	-	2,150	0.92	3,392	48.38	5,538	2.32
Ar	-	-	2,354	2.00	-	1,900	0.57	-	-	1,900	0.56
CO_2	-	-	-	-	-	23,358	6.36	2,677	24.33	26,035	6.93
CO	-	-	-	-	-	136,980	58.61	672	9.59	137,652	57.62
CH_4	-	-	-	-	-	13	0.01	-	-	13	.0.01
H_2S	-	-	-	-	-	2,417	0.85	137	1.61	2,554	0.88
COS	-	-	-	-	-	451	0.09	-	-	451	0.09
HCN	-	-	-	-	-	17	75 PPMV	-	-	17	74 PPMV
H_2O	995	1.00	-	-	8843	7,952	5.30	524	11.64	7,331	4.77
STRETFORD SOLN.	-	-	-	-	-	-	-	-	-	-	-
ASH	11,324	11.42	-	-	-	-	-	-	-	-	-
SLAG	-	-	-	-	-	-	-	-	-	-	-
TOTAL	99,137	100.00	94,910	100.00	8843	179,794	100.00	7,420	100.00	186,069	100.00

(1) Stream numbers correspond to those shown on Gasification Block Flow Diagram, Figure 1-1.

TABLE 1-1 (Cont'd)

STREAM NO.	7		8		9		10		11		12	
STREAM DESCRIPTION	PRODUCT GAS OUTLET STRETFORD UNIT		PRODUCT GAS OUTLET GAS COMPRESSION UNIT		PLANT PRODUCT FUEL GAS USAGE		PRODUCT GAS DEHYDRATION UNIT INLET		PRODUCT GAS PLANT BATTERY LIMITS OUTLET		PRODUCT FUEL GAS TO NITTETU INCINERATION	
TOTAL FLOW, LB/HR	186,150		178,188		5,147		173,041		170,683		2,935	
VAPOR FLOW, SCFM	54,517		51,719		1,485		50,234		49,385		852	
LIQUID FLOW, GPM	-		-		-		-		-		-	
VAPOR MOLECULAR WT.	21.60		21.79		21.78		21.78		21.85		21.78	
TEMPERATURE, °F	105		100		100		100		160		100	
PRESSURE, PSIG (IN W.C.)	1.5 (41.6)		40.3		40.3		40.3		35.3		40.3	
COMPONENTS	LB/HR	MOLE %	LB/HR	MOLE %	LB/HR	MOLE %	LB/HR	MOLE %	LB/HR	MOLE %	LB/HR	MOLE %
S	-	-	-	-	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-	-	-	-	-
H_2	4,575	26.53	[illegible],575	27.98	129	27.98	4,446	27.98	4,446	28.45	74	27.98
O_2	-	-	-	-	-	-	-	-	-	-	-	-
N_2	5,538	2.29	5,538	2.41	177	2.41	5,361	2.41	5,361	2.45	101	2.41
Ar	1,900	0.55	1,900	0.58	58	0.58	1,842	0.58	1,842	0.59	33	0.58
CO_2	25,549	6.74	25,549	7.10	733	7.10	24,816	7.10	24,816	7.22	418	7.10
CO	137,565	56.99	137,565	60.07	3,949	60.07	133,616	60.07	133,616	61.08	2,251	60.07
CH_4	13	0.01	13	0.01	-	0.01	13	0.01	13	0.01	-	0.01
H_2S	-	-	-	-	-	-	-	-	-	-	-	-
COS	451	0.09	451	0.09	25	0.09	426	0.09	426	0.09	14	0.09
HCN	6	27 PPMV	6	28 PPMV	1	28 PPMV	5	28 PPMV	5	26 PPMV	0.6	28 PPMV
H_2O	10,553	6.80	2,591	1.76	75	1.76	2,516	1.76	158	0.11	43	1.76
STRETFORD SOLN.	-	-	-	-	-	-	-	-	-	-	-	-
ASH	-	-	-	-	-	-	-	-	-	-	-	-
SLAG	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	186,150	100.00	178,188	100.00	5,147	100.00	173,041	100.00	170,683	100.00	2,934.6	100.00

TABLE 1-1 (Cont'd)

STREAM NO.	13		14	15	16	17	18		19
STREAM DESCRIPTION	PRODUCT FUEL GAS TO COAL PREPARATION		GKT GASIFICATION L.P. STEAM TO DISTRIBUTION	GKT GASIFICATION H.P. STEAM TO DISTRIBUTION	GKT UNIT WASH WATER SUPPLY	GKT UNIT WASH WATER RETURN	GKT UNIT SLAG TO DISPOSAL		PURGING/BLANKETING NITROGEN TO GKT UNIT
TOTAL FLOW, LB/HR	2,212		101,062	111,093	2,088,407	2,090,143	3,997 (48 TPD)		10,990
VAPOR FLOW, SCFM	642		-	-	-	-	-		2,482
LIQUID FLOW, GPM	-		-	-	4,178	4,182	-		-
VAPOR MOLECULAR WT.	21.78		-	-	-	-	-		28
TEMPERATURE, °F	100		274	453	113	158	70		100
PRESSURE, PSIG (IN W.C.)	40.3		28	925	100	10	ATM		10
COMPONENTS	LB/HR	MOLE %	LB/HR	LB/HR	LB/HR	LB/HR	LB/HR	WT%	LB/HR
S	-	-	-	-	-	-	-		-
C	-	-	-	-	-	-	-	-	-
H_2	55	27.98	-	-	-	-	-	-	-
O_2	-	-	-	-	-	-	-	-	-
N_2	76	2.41	-	-	-	-	-	-	-
Ar	25	0.58	-	-	-	-	-	-	-
CO_2	315	7.10	-	-	-	-	-	-	-
CO	1,698	60.07	-	-	-	-	-	-	-
CH_4	-	0.01	-	-	-	-	-	-	-
H_2S	-	-	-	-	-	-	-	-	-
COS	11	0.09	-	-	-	-	-	-	-
HCN	0.4	28 PPMV	-	-	-	-	-	-	-
H_2O	32	1.76	101,062	111,093	2,088,407	2,090,143	600	15.00	-
STRETFORD SOLN.	-	-	-	-	-	-	-	-	-
ASH	-	-	-	-	-	-	3,397	85.00	-
SLAG	-	-	-	-	-	-	-	-	-
TOTAL	2,212.4	100.00	101,062	111,093	2,088,407	2,090,143	3,997	100.00	10,990

TABLE 1-1 (Cont'd)

STREAM NO.	20	21	22		23		24	
STREAM DESCRIPTION	EMERGENCY SHUTDOWN NITROGEN TO GKT UNIT	CONVEYING NITROGEN TO COAL PREPARATION UNIT	RAW COAL FEED TO COAL PREPARATION UNIT		FLY ASH TO DISPOSAL		FLY ASH RECYCLE TO COAL PREPARATION UNIT	
TOTAL FLOW, LB/HR	65,940	13,736	2,000,000 (1000 TPH)(1)		16,826 (201.9 TPD)		16,826 (201.9 TPD)	
VAPOR FLOW, SCFH	14,891	3,102	-		-		-	
LIQUID FLOW, GPH	-	-	-		-		-	
VAPOR MOLECULAR WT.	28	28	-		-		-	
TEMPERATURE, °F	100	100	60		70		70	
PRESSURE, PSIG (IN W.C.)	15	35	ATM		ATM		ATM	
COMPONENTS			LB/HR	WT %	LB/HR	WT %	LB/HR	WT %
S	-	-	50,400	2.52	-	-	-	-
C	-	-	1,483,000	74.15	4,452	26.46	4,452	26.6
H_2	-	-	100,800	5.04	-	-	-	-
O_2	-	-	90,400	4.52	-	-	-	-
N_2	-	-	27,200	1.36	-	-	-	-
Ar	-	-	-	-	-	-	-	-
CO_2	-	-	-	-	-	-	-	-
CO	-	-	-	-	-	-	-	-
CH_4	-	-	-	-	-	-	-	-
H_2S	-	-	-	-	-	-	-	-
COS	-	-	-	-	-	-	-	-
HCN	-	-	-	-	-	-	-	-
H_2O	-	-	91,600	4.58	8,413	50.00	8,413	50.0
STRETFORD SOLN.	-	-	-	-	-	-	-	-
ASH	-	-	156,600	7.83	3,961	23.54	3,961	23.6
SLAG	-	-	-	-	-	-	-	-
TOTAL	65,940	13,736	2,000,000	100.00	16,826	100.00	16,826	100.0

(1) Maximum 1 shift per day operation

TABLE 1-1 (Cont'd)

STREAM NO.	25		26		27
STREAM DESCRIPTION	STRETFORD SOLN. PURGE TO NITTETU INCINERATION		RECOVERED STRETFORD SOLUTION FROM NITTETU INCINERATION		LIQUID PRODUCT SULFUR FROM DESULFURIZATION UNIT
TOTAL FLOW, LB/HR	3,500		3,540		2279 (27.3 TPD)
VAPOR FLOW, SCFH	-		-		-
LIQUID FLOW, GPM	6.17		6.1		-
VAPOR MOLECULAR, WT.	-		-		-
TEMPERATURE, °F	105		195		280
PRESSURE, PSIG (IN W.C.)	110		30		ATM
COMPONENTS	LB/HR	WT %	LB/HR	WT %	LB/HR
S	-	-	-	-	2,279
C	-	-	-	-	-
H_2	-	-	-	-	-
O_2	-	-	-	-	-
N_2	-	-	-	-	-
Ar	-	-	-	-	-
CO_2	-	-	-	-	-
CO	-	-	-	-	-
CH_4	-	-	-	-	-
H_2S	-	-	-	-	-
COS	-	-	-	-	-
HCN	-	-	-	-	-
H_2O	2,484	70.97	2,775	78.38	-
STRETFORD SOLN.	1,016	29.03	765	21.62	-
ASH	-	-	-	-	-
SLAG	-	-	-	-	-
TOTAL	3,500	100.00	3,540	100.00	2,279

From the GKT Gasification Unit the gas is compressed to approximately 6 psig prior to entering the Desulfurization Unit. The desulfurization unit is a Stretford process which removes H_2S present in the raw gas by converting it to recoverable elemental sulfur. The Stretford process is a low temperature absorption-direct oxidation desulfurization process. The raw gas from the GKT gasifier contains about 0.90 and 0.09 percent of H_2S and COS, respectively, on a dry gas volume basis. To comply with the EPA environmental regulations set by the City of Philadelphia (500 PPMV or 0.86 lb $SO_2/10^6$ Btu input), the raw gas must be cleaned before being utilized in the boilers. The Stretford desulfurization process removes almost all H_2S from the gas. COS in the gas is not removed; however, its content is low and burning the gas will produce only 350 PPMV SO_2.

The Stretford process basically consists of an absorber, oxidizers, a sulfur removal system, an incineration unit for handling Stretford purge solution, and associated pumps, air blowers, and solution makeup equipment. Removal of H_2S occurs in the Stretford absorber mixer and reaction vessel where the product gas stream contacts the lean Stretford solution. The clean gas exiting the reaction vessel is delivered to the Gas Compression and Dehydration Units at 105°F and 2 psig.

The sulfur removal system employed for the Stretford process produces a saleable molten sulfur product. The molten sulfur is stored in a storage pit prior to rail loading. The molten sulfur produced at design gasification plant capacity for a typical Pittsburgh No. 8 coal is 27.3 TPD.

In the Stretford process, salts (Na_2SO_4, $Na_2S_2O_3$, & NaSCN) are produced during the absorption and oxidation steps. The salts accumulate in the Stretford solution and the free alkali portion of the working solution is suppressed. To remedy this, a purge stream from the Stretford solution containing salts formed during the process is sent to a Nittetu Incineration Plant (Unit 44) to decompose the salts via reductive incineration. In the Nittetu unit the purge solution is vaporized and the salts decomposed in a furnace. Reformed molten salts are then quenched and the solution returned to the Stretford process. Decomposed gases (containing H_2S) formed during the quench operation are sent to the inlet of the Stretford absorber where they are mixed with the raw product gas from the GKT plant.

From the Desulfurization Unit the desulfurized product gas is compressed to 35 psig in a set of parallel compressors. The two compressors are centrifugal machines with aftercoolers and are driven by condensing steam turbines using excess low pressure steam from the gasifier jacket. A third compressor driven by electric motor will provide a 50 percent standby capability for startup and emergency situations.

From the Gas Compression Unit (Unit 62) the product gas enters the Gas Dehydration Unit. In the gas dehydration unit, excess water from the compressed gas (40 psig) is removed to meet the selected product gas water content. Most natural gas pipelines specifications require a water content not to exceed 7.0 lb H_2O)/MM SCF due to long pipeline distances and pressures up to 1000 psia. The PGW application requires transmission distances of only five miles and a discharge pressure of 35 psig. Therefore, a low gas water content specification is not necessary and economic considerations have led to the selection of 53.3 lb H_2O/MM SCF (or 20°F dew point). The wet compressed gas at 40 psig and dew point of 100°F has a water content of 851.1 lb/MM SCF. The dehydration unit will remove the excess water (797.8 lb/MM SCF) to prevent gas freeze-ups and gas transmission problems such as pipe line corrosion. A standard triethylene glycol system is employed for the Dehydration Unit (Unit 64).

From the gas dehydration unit the product gas is metered prior to exiting the plant battery limits and entering the product gas distribution system. The composition and conditions of the product gas exiting the plant battery limits are shown below:

Component	Mole%
H_2	28.45
N_2	2.45
Ar	0.59
CO_2	7.22
CO	61.08
CH_4	0.01
H_2S	-
COS	0.09
HCN	26 PPMV
H_2O	0.11
	100.00
Temperature, °F	160
Pressure, psig	35
HHV, Btu/SCF	289.5

The design heat duty of the medium Btu gas delivered from the gasification battery limits to the users is 20.58 billion Btu/day (HHV basis). The cold gas efficiency is 66.7% based on the following definition:

$$\text{Cold Gas Efficiency, \%} = \frac{\text{(HHV of Product Gas at 60°F at GKT battery limits)}}{\text{(HHV of A.R. Coal Feed)}} \times 100$$

1.4 COAL RECEIVING AND HANDLING

Complete coal handling facilities are provided for receiving and storing coal delivered by rail and transferring the coal to the plant. Two trains are provided for coal unloading, and one train for stacking, reclaiming and conveying equipment. A process flow diagram for the Coal Receiving and Handling Unit (Unit 10) is shown in Figure 1-2. Although the receiving and handling facilities are designed for Pittsburgh No. 8, the storage and conveying facilities are capable of handling other eastern bituminous coals selected as possible candidates.

Coal Receiving

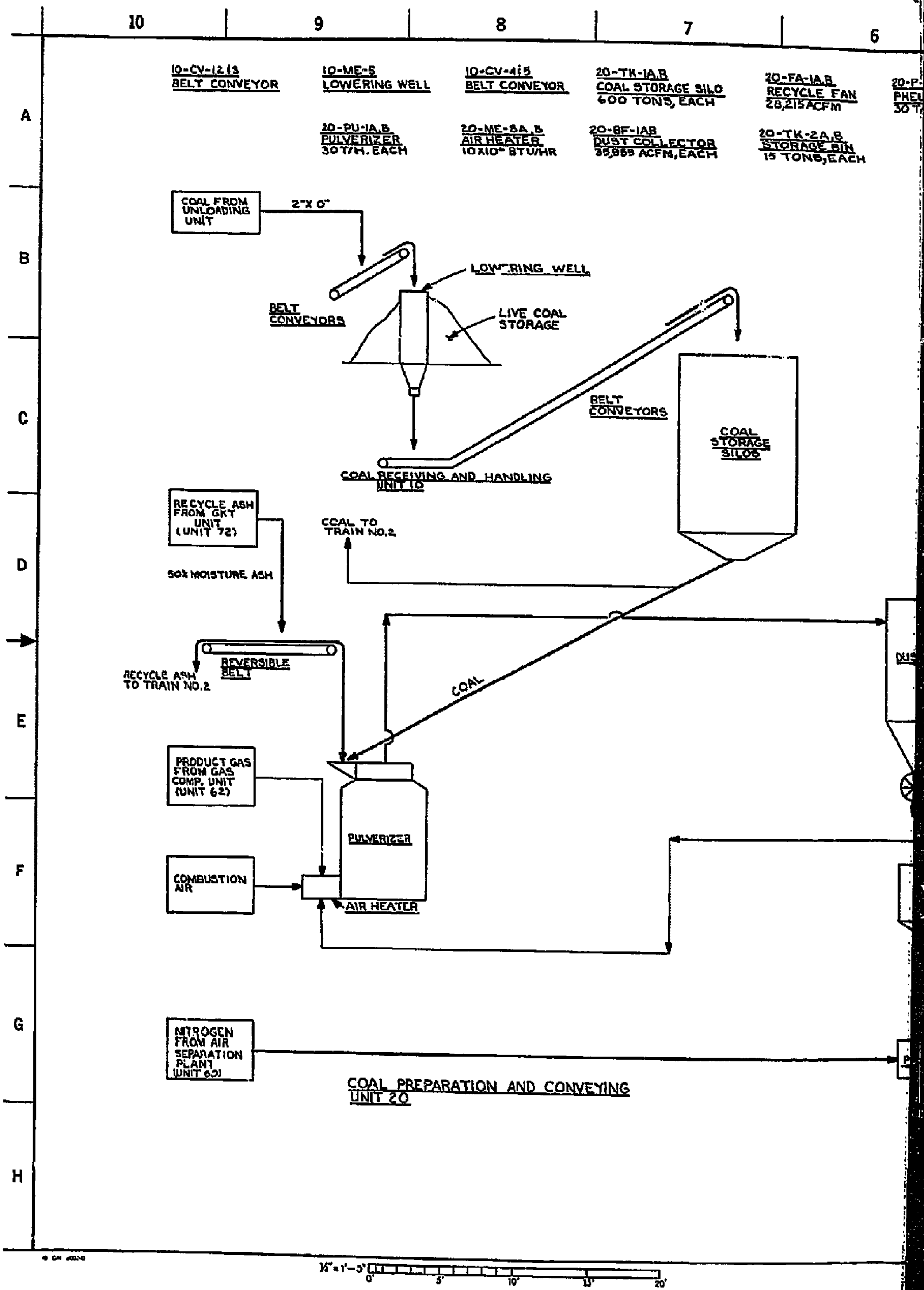
Washed coal is delivered to the plant by unit trains consisting of seventy 100-ton bottom dump cars (or their equivalent). The design coal has a nominal size of 2-inches x 0-inches, weighs 50 pounds per cubic foot, and has an angle of repose of 38 degrees. Allowance is made, however, for accepting reasonable variations in these parameters.

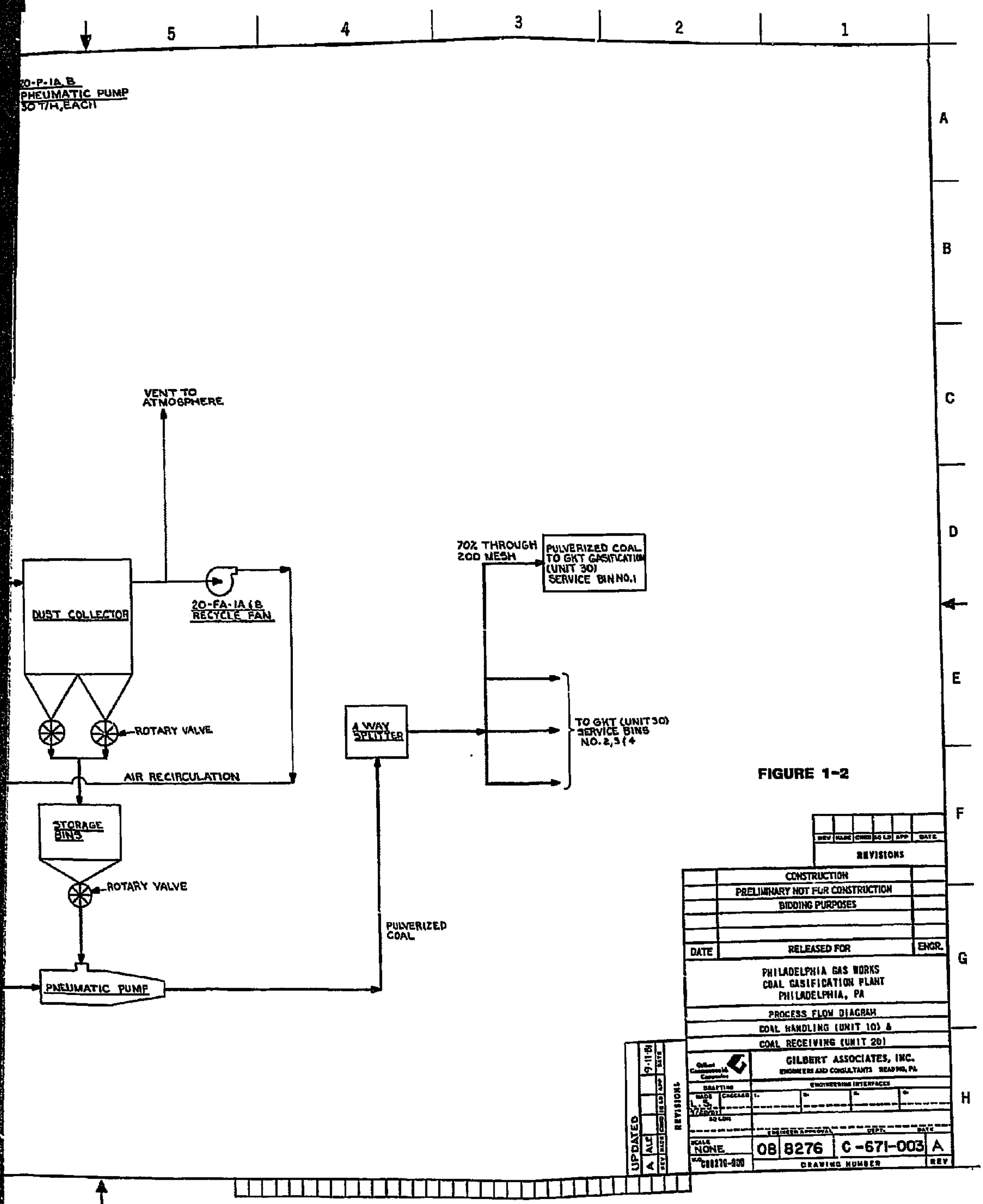
Coal is received at two parallel track unloading hoppers. An enclosure is provided over each hopper, incorporating thaw shed and a manually operated car shaker to assist in unloading wet or frozen coal. Dust suppression and collection systems are provided to control the fugitive dust emissions generated by the unloading operation (Unit 15).

Each unloading hopper with a capacity of 100 tons has manually operated shutoff gate and four vibrating feeders. The vibrating feeders discharge to the two parallel unloading conveyors, each 48 inches wide. Coal unloading from the unit train is completed in two days, based on one shift (8 hours) per day.

Conveying to Storage, Weighing, and Sampling

The hooded coal unloading transfer conveyor is 48 inches wide and has a capacity of 1000 TPH. It conveys coal from the hopper unloading conveyors to a live storage pile (10,000 tons) via a lowering well (stacking tube).


10-CV-12,13
BELT CONVEYOR
10-ME-5
LOWERING WELL
10-CV-4,5
BELT CONVEYOR
20-TK-1A,B
COAL STORAGE SILO
600 TONS, EACH
20-FA-1A,B
RECYCLE FAN
28,215 ACFM
20-PU-1A,B
PULVERIZER
30 T/H, EACH
20-ME-8A,B
AIR HEATER
10X10⁶ BTU/HR
20-BF-1AB
DUST COLLECTOR
35,859 ACFM, EACH
20-TK-2A,B
STORAGE BIN
15 TONS, EACH
COAL FROM UNLOADING UNIT
2"X 0"
BELT CONVEYORS
LIVE COAL STORAGE
BELT CONVEYORS
COAL STORAGE SILOS
COAL RECEIVING AND HANDLING UNIT 10
RECYCLE ASH FROM GKT UNIT (UNIT 72)
COAL TO TRAIN NO.2
50% MOISTURE ASH
REVERSIBLE BELT
RECYCLE ASH TO TRAIN NO.2
COAL
PRODUCT GAS FROM GAS COMP. UNIT (UNIT 62)
PULVERIZER
COMBUSTION AIR
AIR HEATER
NITROGEN FROM AIR SEPARATION PLANT (UNIT 69)
COAL PREPARATION AND CONVEYING UNIT 20



20-P-1A,B
PNEUMATIC PUMP
30 T/H, EACH
VENT TO
ATMOSPHERE
DUST COLLECTOR
20-FA-1A & B
RECYCLE FAN
ROTARY VALVE
AIR RECIRCULATION
STORAGE
BINS
ROTARY VALVE
PNEUMATIC PUMP
PULVERIZED
COAL
4 WAY
SPLITTER
70% THROUGH
200 MESH
PULVERIZED COAL
TO GKT GASIFICATION
(UNIT 30)
SERVICE BIN NO.1
TO GKT (UNIT 30)
SERVICE BINS
NO. 2, 3 & 4
REVISIONS
CONSTRUCTION
PRELIMINARY NOT FOR CONSTRUCTION
BIDDING PURPOSES
DATE
RELEASED FOR
ENGR.
PHILADELPHIA GAS WORKS
COAL GASIFICATION PLANT
PHILADELPHIA, PA
PROCESS FLOW DIAGRAM
COAL HANDLING (UNIT 10) &
COAL RECEIVING (UNIT 20)
GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS READING, PA
UPDATED
A
ALF
9-11-81
REVISIONS
NONE
08 8276
C-671-003
A
DRAWING NUMBER
REV

FIGURE 1-2

As the conveyor leaves the unloading hopper tunnel, at a point just above grade elevation, a self-contained weigh scale is provided. The weigh scale is capable of determining flow rate and total integrated accumulated flow, and has provisions for periodic calibration.

The unloading transfer conveyor head pulley is located in the sampling system enclosure. A magnetic separator is provided to remove tramp iron from the coal stream. The rejects are chuted outside of the sampling enclosure to a tote box at grade. Periodic truck removal of tramp iron is made.

A sampling system is installed to collect coal samples for laboratory analysis and coal supplier's use. The system enclosure is ventilated, and dust supression and collection systems are also installed (Unit 15).

Coal Storage

The coal is stored as a long pile, which is capable of storing 66,000 tons of coal. The coal storage area is sized for approxiatmely 60 day supply of coal. About 10,000 tons of coal or 10 days supply is placed in "live storage". The live storage pile is formed by a lowering well at one end of the pile, fed by the transfer conveyor.

Underneath the live pile are three reclaim hoppers, from which a belt conveyor of 200 TPH capacity and 30 inches wide conveys the coal to the two coal storage silos. Each storage silo is 25 feet diameter and has a live capacity of 600 tons. The top of each silo is at an elevation of approximately 123 feet above grade. The bottom of each silo has a power operated shutoff gate and a vibrating feeder with a variable capacity up to 50 TPH. The vibrating feeders discharge directly into the pulverizer assemblies.

The "dead storage" section of the pile (56,000 tons) is formed by moving the coal with a bulldozer. This coal is used only in case of supply interruptions. The pile is compacted and sprayed with an organic polymer crusting agent to minimize both dusting and rain erosion problems. The entire coal pile is diked and lined with a clay base to prevent seepage. Contaminated rainfall runoff is collected in a lined settling pond. Settled particles are periodically removed and sent back to the coal pile. The water from the pond is pumped to a waste treatment facility and neutralized before being discharged to the river.

1.5 COAL PREPARATION AND CONVEYING

In the coal preparation unit the bunker coal or a mixture of the bunker coal and recycled fly ash sludge cake (50 percent moisture from the GKT coal gasification plant) is dried and pulverized to the following GKT gasifier feed requirements:

- o Size - 90 percent through 170 mesh and 70 percent through 200 mesh
- o Moisture content - One percent

Pneumatic conveyors transport the dried and pulverized coal from the pulverized coal storage bin to the gasifier service bins. Compressed nitrogen from the air separation plant is used as the conveying medium.

It should be noted that the fly ash has a high carbon content and the recycle approach is selected for a higher carbon utilization. For the design coal (Pittsburgh No. 8) 50 percent of the filter cake recovered in the GKT gasification plant is recycled. However, depending upon the coal being processed, overall moisture removal and heat duty required in the pulverizer, the recycle rate can be varied. The equipment is designed to provide this flexibility. More discussion of the recycle of the filter cake and its effect on overall carbon utilization is given in Appendix B.

The complete system as shown in Figure 1-2 is designed to provide maximum in safety, reliability, and flexibility. Each train is designed to process 25 tph (600 TPD) of puliverized coal/filter cake mixture (dry basis).

The coal preparation unit consists of two 50 percent roller mills, and two 50-percent trains of associated ancilliary equipment such as bag collector, recycle fan and air heater. The pulverized coal conveying unit has two trains, each consisting of a storage silo, pneumatic pump and a conveying line feeding to the gasifier service bins.

The roller mills are designed to process coal with a Hardgrove Grindability Index of 50, and a maximum moisture content of 12.0 percent. Provisions are made to recycle up to 50 percent of the fly ash cake from the GKT unit with the base coal. For higher ash coals a smaller recycle percentage is recommended. For the design coal (4.6 percent moisture) with 50 percent filter cake recycle, the heating load required for the pulverizer heater is about 20.5 MM Btu/hr. For a 12 percent moisture raw coal feed the heating load increases to about 34.4 MM Btu/hr. A small portion of the clean product gas from the gasification unit will be utilized in a heater for producing the hot air for the pulverizers.

Each mill and its associated equipment, with the exception of the bag collector, are designed for 50 psig in accordance with the NFPA code. The bag type dust collector is suitably equipped with an explosion door which reseals - to prevent the infiltration of ambient air into the system after relieving. In addition, partial recirculation of gases from the clean side of the collector back to the roller mill further increases the safety and reliability of the pulverizing circuit. This recycle loop, containing less than 0.02 grains of particulate per actual cubic foot, insures a sufficiently low oxygen content in the system gases, which minimizes the hazardous nature of the finely pulverized coal. Each baghouse is sized for 36,000 ACFM and has an air/cloth ratio of 4.5/1.0.

Pulverized coal from each baghouse goes to a 15-ton capacity pulverized coal storage bin, which is 10 feet in diameter. The top of the bin is at an elevatin of approximately 28 feet above grade. The bottom of the bin has rotary air lock and discharges directly into the pneumatic pump inlet hopper. Compressed nitrogen (98 percent purity) at 35 psig is supplied from the air separation plant. The coal is conveyed via a carbon steel conveying pipe to the gasifier service bins through a 4-way splitter.

1.6 GKT COAL GASIFICATION AND WASH WATER TREATMENT

For the production of medium-Btu gas from coal, GKT's entrained bed coal gasification process has been selected for the PWG plant. Coal dust pulverized and conditioned to 70 percent through 200 mesh size and one percent water content from the Coal Preparation and Conveying Unit is processed through the gasifier and partially oxidized under exothermic conditions at pressures slightly above atmospheric. Process flow diagrams for the GKT Unit (Unit 30) are shown in Figures 1-3 and 1-4. The GKT Wash Water Treatment Unit (Unit 72) is shown in Figure 1-5.

To produce approximately 20 billion Btu per day of medium Btu gas from a typical bituminous coal, two four-headed GKT gasifiers are required. As feedstock to the gasifier, in principle, any kind of coal can be used. The efficiency, however, defined by the overall carbon conversion and the output of useful gas (carbon monoxide plus hydrogen) is to a certain degree dependent on the type and quality of the feedstock. For the PGW plant, a typical Pittsburgh No. 8 coal has been used as the design coal for the plant design. Enough flexibility, however, has been added to the gasification plant design to accommodate a variety of eastern bituminous coals.

The material balance for the GKT plant is shown in Table 1-2. The gasification plant is designed to handle 1200 tpd as-received coal (2 in. by 0 in.). Raw coal is dried and ground to the required size

TABLE 1-2

GKT GASIFICATION UNIT MATERIAL BALANCE
DESIGN PRODUCT GAS PRODUCTION (20.58 x 10^9 BTU/DAY)
NON-ASH RECYCLE CASE

STREAM NO.	1		2		3	4		5	6
	COAL FEED TO GKT GASIFIER NO. 1		OXYGEN FEED TO GASIFIER NO. 1		L.P. STEAM TO GASIFIER NO. 1	PRODUCT GAS EXITING GASIFIER NO. 1		SLAG FM GASIFIER NO. 1 TO DISPOSAL	GASIFIER NO. 1 H.P. & L.P. STEAM DRUM BLOWDOWN
TOTAL FLOW, LB/HR	48,230 (578.8 TPD)		47,455 (569.5 TPD)		4,422	91,584		1,383	1,100
VAPOR FLOW, SCFM	-		9,331		-	26,918		-	-
LIQUID FLOW, GPM	-		-		-	-		-	-
VAPOR MOLECULAR	-		32.16		-	21.52		-	-
TEMPERATURE, °F	60		100		274	2230		100	-
PRESSURE, PSIG (IN W.C.)	-		0.4 (12)		28	1.0		-	-
COMPONENTS	LB/HR	WT %	LB/HR	MOLE %	LB/HR	LB/HR	MOLE %	LB/HR	
S	1,259	2.61	-	-	-	-	-	-	-
C	37,103	76.93	-	-	-	-	-	-	-
H_2	2,523	5.23	-	-	-	2,272	26.69	-	-
O_2	2,262	4.69	46,278	98.00	-	-	-	-	-
N_2	680	1.41	-	-	-	1,075	0.90	-	-
Ar	-	-	1,777	2.00	-	950	0.37	-	-
CO_2	-	-	-	-	-	11,679	6.24	-	-
CO	-	-	-	-	-	68,490	57.46	-	-
CH_4	-	-	-	-	-	7	0.01	-	-
H_2S	-	-	-	-	-	1,208	0.83	-	-
COS	-	-	-	-	-	226	0.09	-	-
HCN	-	-	-	-	-	8	70PPMV	-	-
H_2O	482	1.00	-	-	4,422	5,569	7.40	207	1,100
STRETFORD SOLN.	-	-	-	-	-	-	-	-	-
ASH	3,921	8.13	-	-	-	-	-	-	-
SLAG	-	-	-	-	-	-	-	1,176	-
TOTAL	48,230	100.00	47,455	100.00	4,422	91,584	100.00	1,383	1,100

TABLE 1-2(Cont'd)

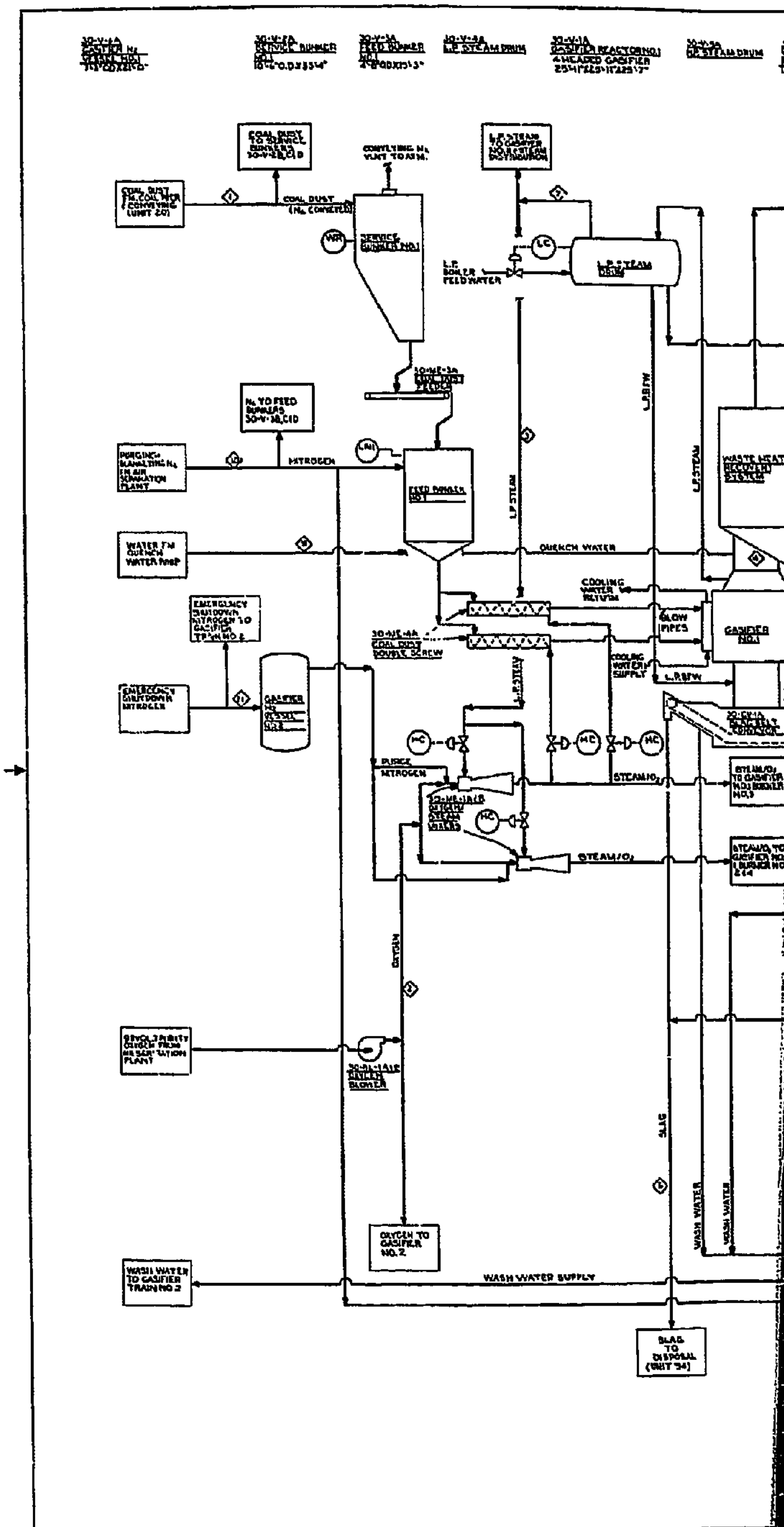
STREAM NO.	7	8	9	10	11	12	
STREAM DESCRIPTION	L.P. STEAM GENERATION FM GASIFIER NO. 1	H.P. STEAM GENERATION FM GASIFIER NO. 1	QUENCH WATER TO GASIFIER NO. 1	PURGING/ BLANKETING NITROGEN TO GASIFIER NO. 1	EMERGENCY SHUTDOWN NITROGEN TO GASIFIER NO. 1	PRODUCT GAS FM RAW GAS BLOWER NO. 1	
TOTAL FLOW, LB/HR	54,953	55,546	23,320	5,495	32,970	89,897	
VAPOR FLOW, SCFM	-	-	-	1,241	7,446	26,391	
LIQUID FLOW, GPM	-	-	46.6	-	-	-	
VAPOR MOLECULAR	-	-	-	28	28	21.54	
TEMPERATURE °F	274	453	70	100	100	95	
PRESSURE, PSIG (IN W.C.)	28	925	40	10	15	1.5 (42)	
COMPONENTS	LB/HR	LB/HR	LB/HR	LB/HR	LB/HR	LB/HR	MOLE %
S	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-
H_2	-	-	-	-	-	2,278	27.29
O_2	-	-	-	-	-	-	-
N_2	-	-	-	-	-	1,075	0.92
Ar	-	-	-	-	-	950	0.57
CO_2	-	-	-	-	-	11,679	6.36
CO	-	-	-	-	-	68,490	58.61
CH_4	-	-	-	-	-	7	0.01
H_2S	-	-	-	-	-	1,208	0.85
COS	-	-	-	-	-	226	0.09
HCN	-	-	-	-	-	8	75 PPMV
H_2O	54,953	55,546	23,320	-	-	3,976	5.30
STRETFORD SOLN.	-	-	-	-	-	-	-
ASH	-	-	-	-	-	-	-
SLAG	-	-	-	-	-	-	-
TOTAL	54,953	55,546	23,320	5,495	32,970	89,897	100.00

TABLE 1-2(Cont'd)

STREAM NO.	13		14		15	16	17	18
STREAM DESCRIPTION	PRODUCT GAS FM RAW GAS BLOWER NO. 2		PRODUCT GAS FM GKT UNIT-TRAINS 1 & 2		WASH WATER FM GKT WASH COOLERS - TRAINS 1 & 2	WASH WATER RETURN TO GKT WASH COOLERS - TRAINS 1 & 2	WASH WATER MAKE-UP TO SETTLING BASINS	EXCESS WASH WATER TO DISPOSAL
TOTAL FLOW, LB/HR	89,897		179,794		2,090,143	2,088,407	NORMALLY 0	5,470
VAPOR FLOW, SCFM	26,391		52,781		-	-	-	-
LIQUID FLOW, GPM	-		-		4,182	4,178	-	10.9
VAPOR MOLECULAR	21.54		21.54		-	-	-	-
TEMPERATURE, °F	95		95		158	113	-	158
PRESSURE, PSIG (IN. W.C.)	1.5 (42)		0.8 (22)		10	100	-	-
COMPONENTS	LB/HR	MOLE %	LB/HR	MOLE %	LB/HR	LB/HR	LB/HR	LB/HR
S	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-
H_2	2,278	27.29	4,556	27.29	-	-	-	-
O_2	-	-	-	-	-	-	-	-
N_2	1,075	0.92	2,150	0.92	-	-	-	-
Ar	950	0.57	1,900	0.57	-	-	-	-
CO_2	11,679	6.36	23,358	6.36	-	-	-	-
CO	68,490	58.61	136,980	58.61	-	-	-	-
CH_4	7	0.01	13	0.01	-	-	-	-
H_2S	1,208	0.85	2,417	0.85	-	-	-	-
COS	226	0.09	451	0.09	-	-	-	-
HCN	8	75 PPMV	17	75 PPMV	-	-	-	-
H_2O	3,976	5.30	7,952	5.30	2,090,143	2,088,407	-	5,470
STRETFORD SOLN.	-	-	-	-	-	-	-	-
ASH	-	-	-	-	-	-	-	-
SLAG	-	-	-	-	-	-	-	-
TOTAL	89,897	100.00	179,794	100.00	2,090,143	2,088,407	0	5,470

TABLE 1-2(Cont'd)

STREAM NO.	19		20	
STREAM DESCRIPTION	FLY ASH SLUDGE TO ROTARY FILTERS		FLY ASH SLUDGE TO DISPOSAL	
TOTAL FLOW, LB/HR	56,816		28,750 (345 TPD)	
VAPOR FLOW, SCFH	-		-	
LIQUID FLOW, GPH	-		-	
VAPOR MOLECULAR	-		-	
TEMPERATURE, °F	70		70	
PRESSURE, PSIG (IN W.C.)	-		-	
COMPONENTS	LB/HR	WT %	LB/HR	WT %
S	-	-	-	-
C	8,721	15.35	8,892	30.93
H_2	-	-	-	-
O_2	-	-	-	-
N_2	-	-	-	-
Ar	-	-	-	-
CO_2	-	-	-	-
CO	-	-	-	-
CH_4	-	-	-	-
H_2S	-	-	-	-
COS	-	-	-	-
HCN	-	-	-	-
H_2O	42,612	75.00	14,375	50.00
STRETFORD SOLN.	-	-	-	-
ASH	5,483	9.65	5,483	19.07
SLAG	-	-	-	-
TOTAL	56,816	100.00	28,750	100.00



COAL DUST
L.P. STEAM DRUM
4 HEADED GASIFIER
COAL DUST TO SERVICE BUNKERS
CONVEYING N2 VENT TO ATM.
COAL DUST FM. COAL MILL & CONVEYING (UNIT 20)
SERVICE BUNKER NO.1
L.P. BOILER FEED WATER
N2 TO FEED BUNKERS
NITROGEN
FEED BUNKER NO.1
L.P. STEAM
L.P.BFW
WASTE HEAT RECOVERY SYSTEM
WATER FM QUENCH WATER PUMP
QUENCH WATER
COOLING WATER RETURN
BLOW PIPES
GASIFIER NO.1
COAL DUST DOUBLE SCREW
COOLING WATER SUPPLY
EMERGENCY SHUTDOWN NITROGEN
PURGE NITROGEN
STEAM/O2
OXYGEN
OXYGEN TO GASIFIER NO. 2
SLAG
WASH WATER
WASH WATER SUPPLY
WASH WATER TO GASIFIER TRAIN NO 2
SLAG TO DISPOSAL (UNIT 54)

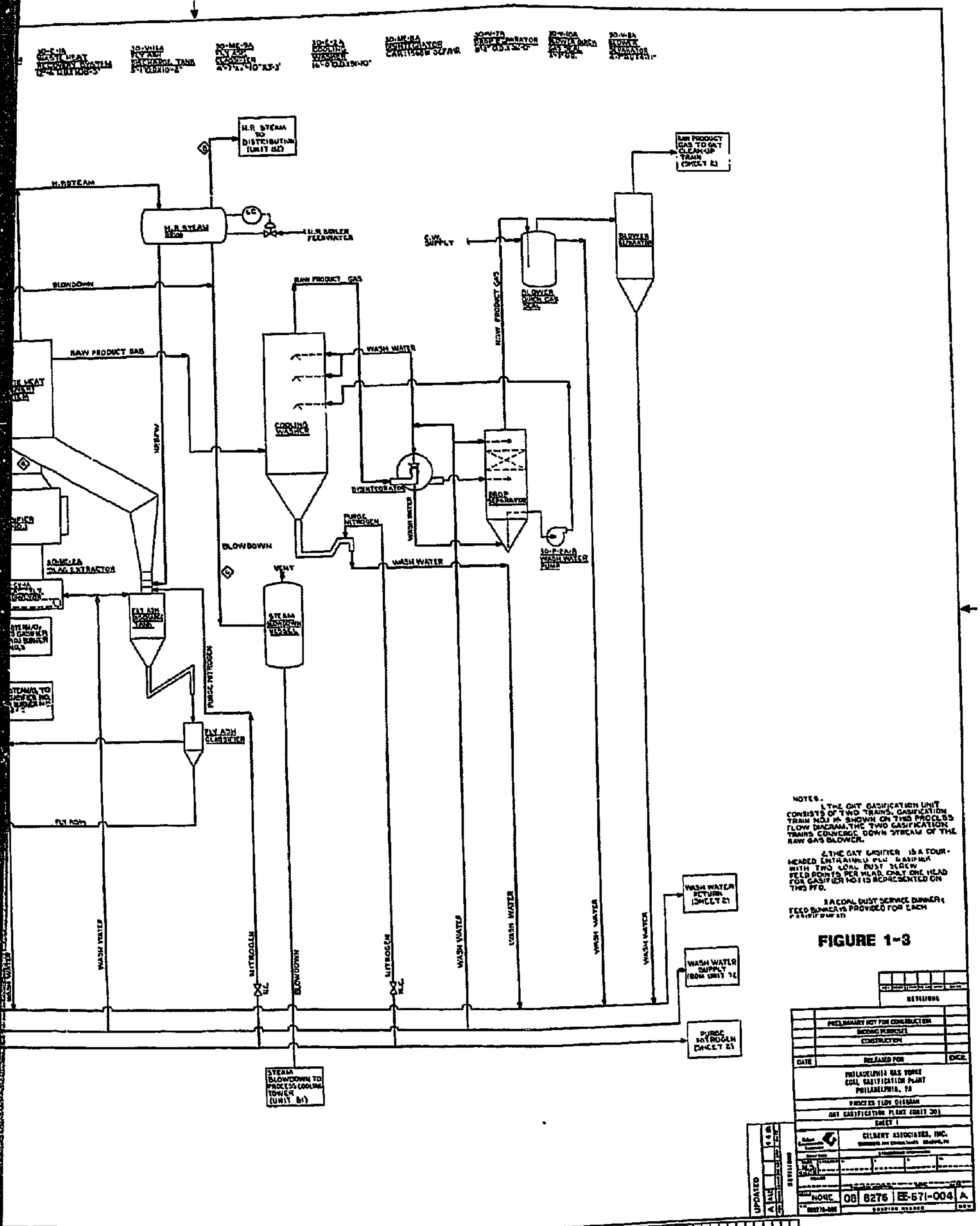
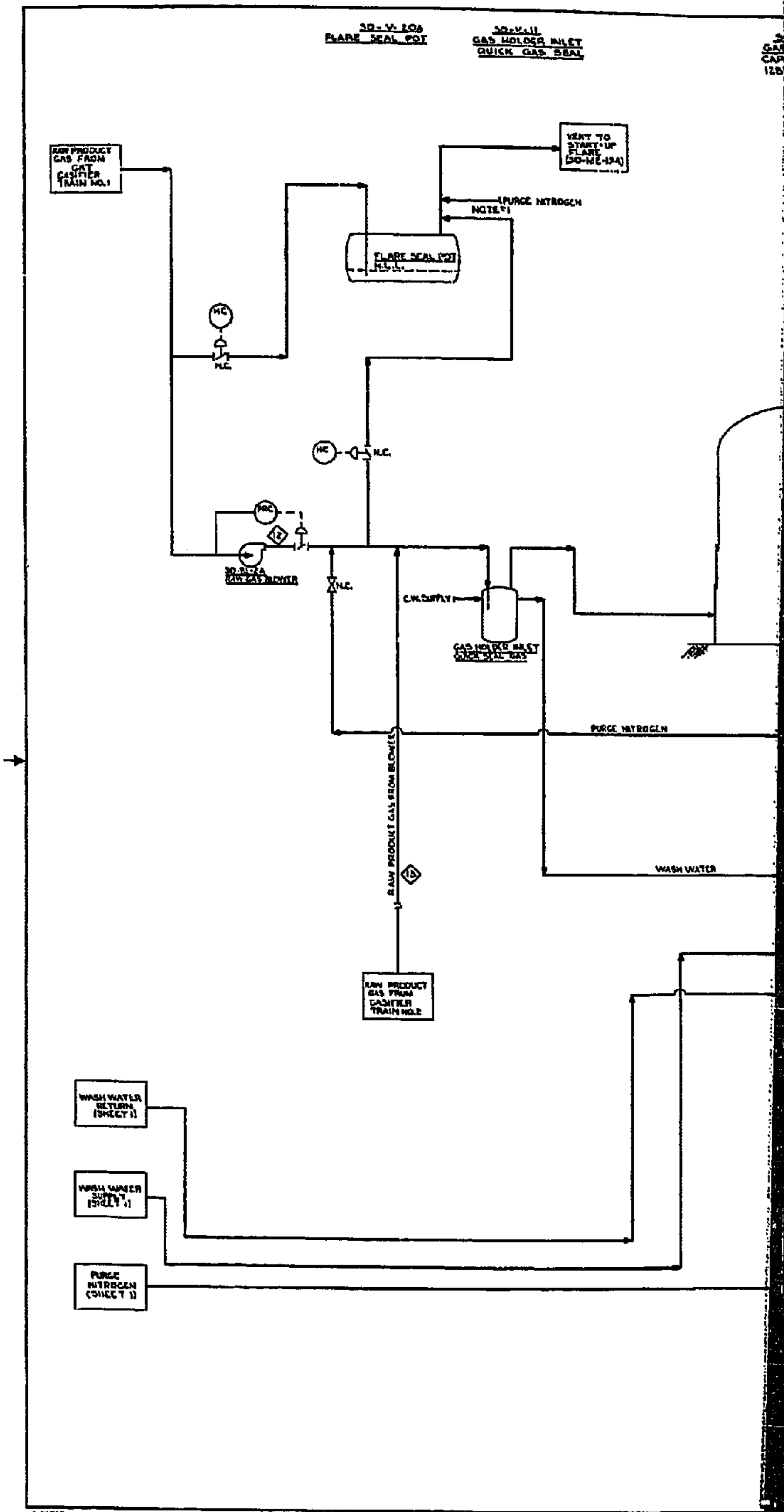
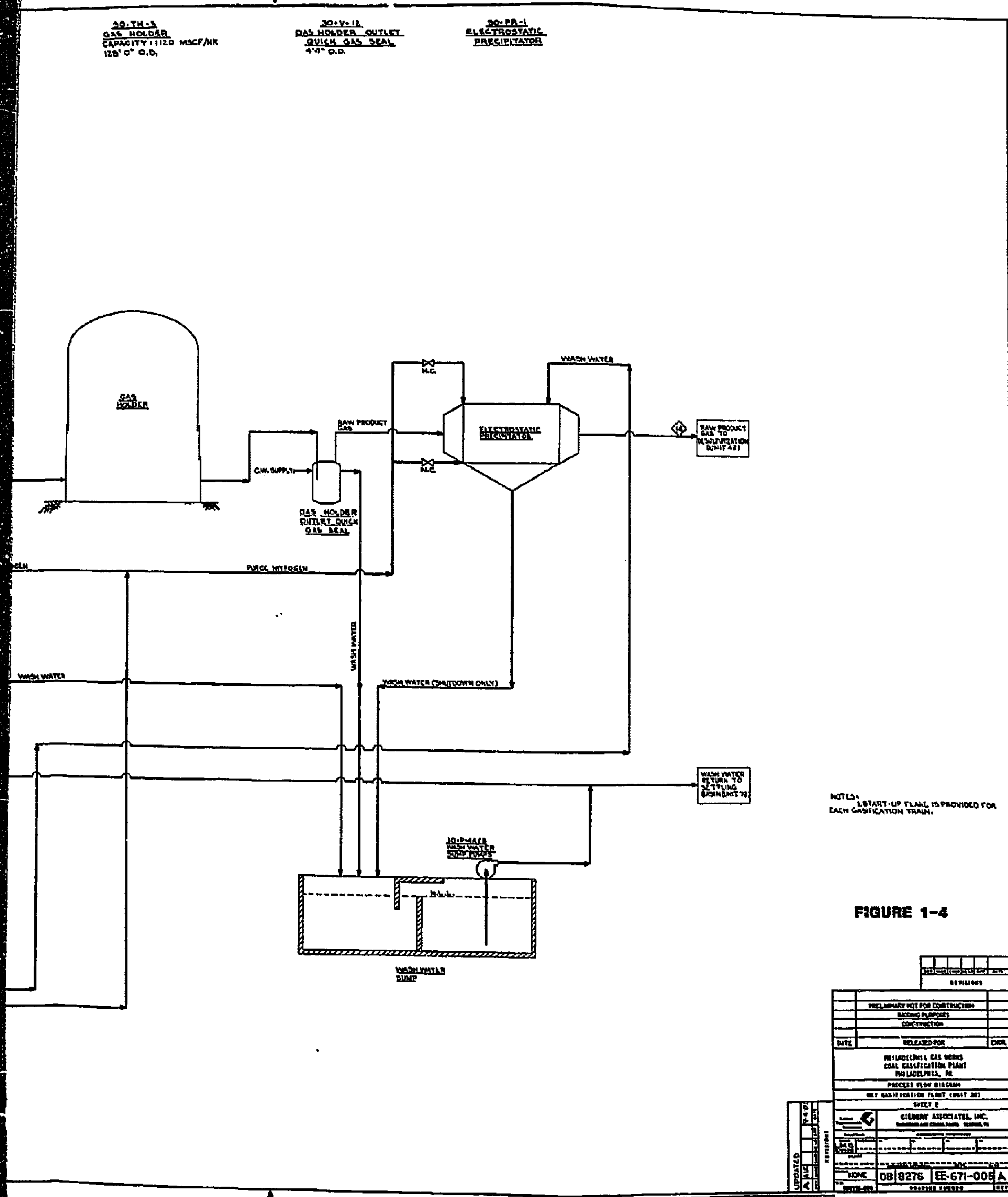

H.P. STEAM TO DISTRIBUTION (UNIT 82)
RAW PRODUCT GAS TO GKT CLEAN-UP TRAIN (SHEET 2)
H.P. STEAM
H.P. STEAM DRUM
H.P. BOILER FEEDWATER
C.W. SUPPLY
BLOWDOWN
RAW PRODUCT GAS
RAW PRODUCT GAS
WASH WATER
COOLING WASHER
DISINTEGRATOR
DROP SEPARATOR
BLOWER
PURGE NITROGEN
SLAG EXTRACTOR
FLY ASH CLASSIFIER
FLY ASH
VENT
STEAM BLOWDOWN VESSEL
WASH WATER RETURN (SHEET 2)
WASH WATER SUPPLY (FROM UNIT 74)
PURGE NITROGEN (SHEET 2)
STEAM BLOWDOWN TO PROCESS COOLING TOWER (UNIT 81)
NITROGEN
WASH WATER
NOTES.
1. THE GKT GASIFICATION UNIT CONSISTS OF TWO TRAINS. GASIFICATION TRAIN NO.1 IS SHOWN ON THIS PROCESS FLOW DIAGRAM. THE TWO GASIFICATION TRAINS CONVERGE DOWN STREAM OF THE RAW GAS BLOWER.
2. THE GKT GASIFIER IS A FOUR-HEADED ENTRAINED FLOW GASIFIER WITH TWO COAL DUST SCREW FEED POINTS PER HEAD. ONLY ONE HEAD FOR GASIFIER NO.1 IS REPRESENTED ON THIS PFD.
3. A COAL DUST SERVICE BUNKER & FEED BUNKER IS PROVIDED FOR EACH GASIFIER HEAD.
PHILADELPHIA GAS WORKS
COAL GASIFICATION PLANT
PHILADELPHIA, PA
PROCESS FLOW DIAGRAM
GKT GASIFICATION PLANT (UNIT 30)
SHEET 1
GILBERT ASSOCIATES, INC.
NONE
08
8276
EE-571-004
A
UPDATED

FIGURE 1-3

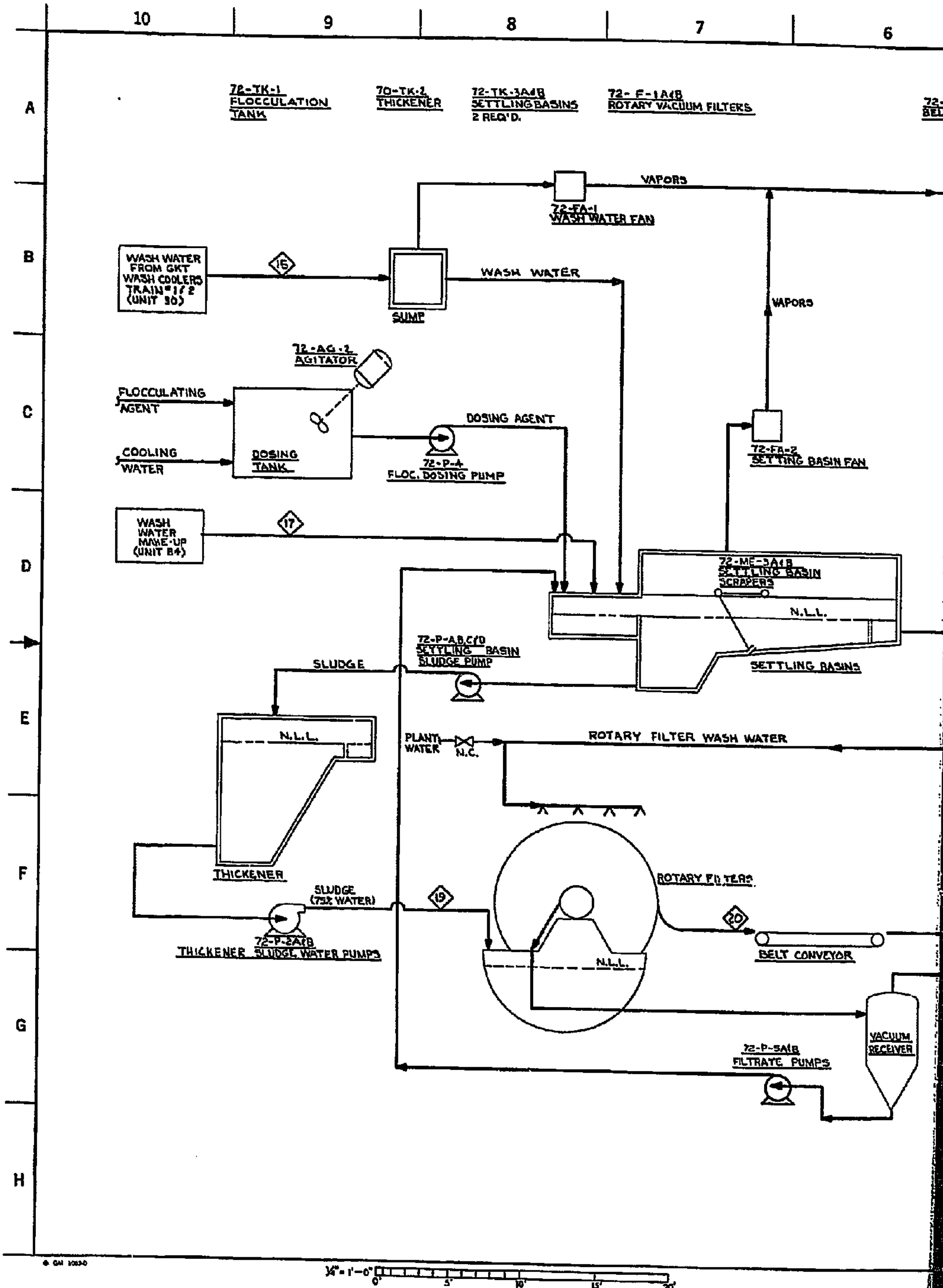


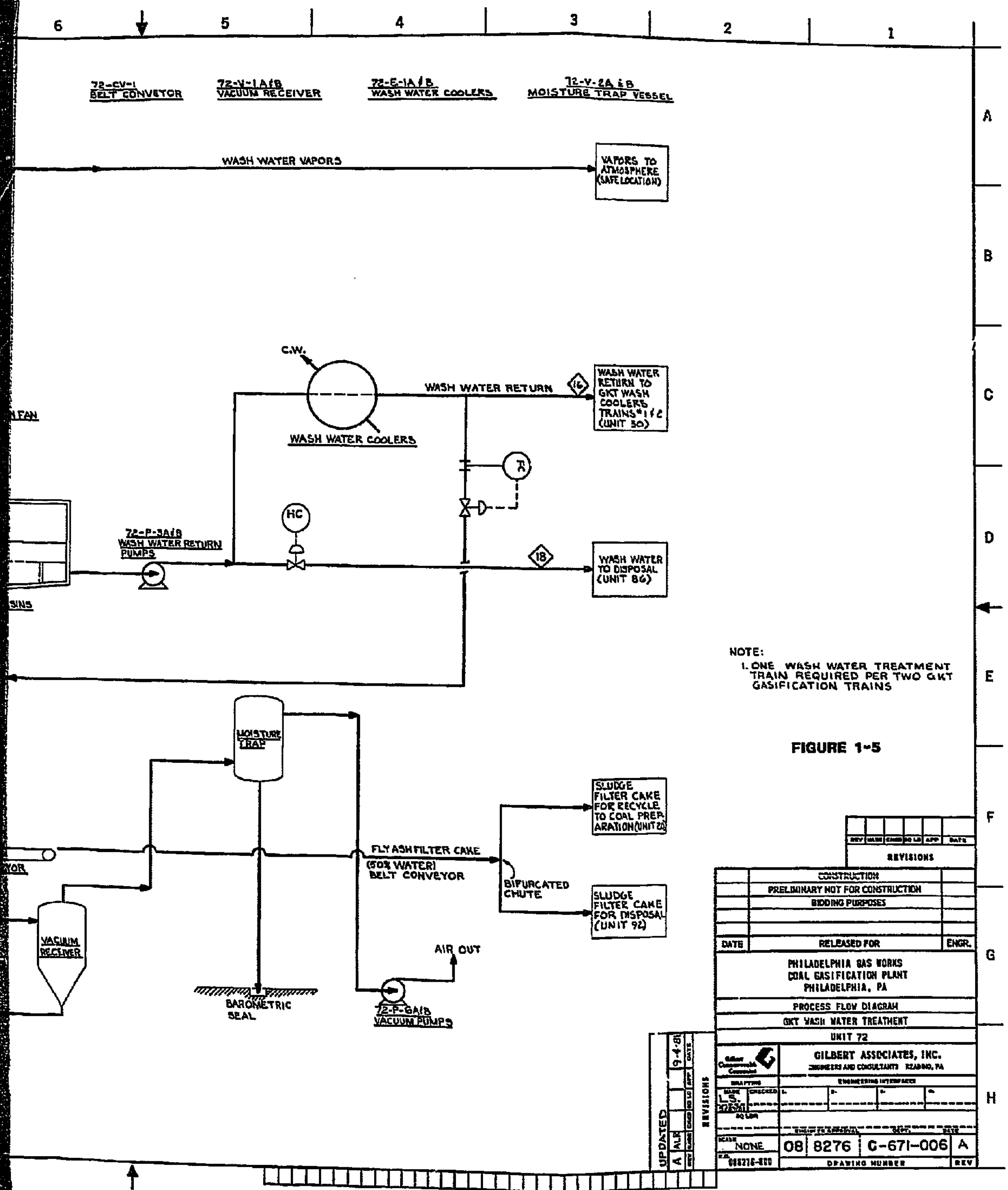
30-V-206
FLARE SEAL POT
30-V-11
GAS HOLDER INLET
QUICK GAS SEAL
RAW PRODUCT GAS FROM GAS GASIFIER TRAIN NO.1
VENT TO START-UP FLARE (30-ME-19A)
PURGE NITROGEN
NOTE 1
FLARE SEAL POT
HC
N.C.
HC
N.C.
PRC
12
30-BL-2A
RAW GAS BLOWER
N.C.
C.W. SUPPLY
GAS HOLDER INLET QUICK SEAL GAS
PURGE NITROGEN
RAW PRODUCT GAS FROM BLOWER
13
WASH WATER
RAW PRODUCT GAS FROM GASIFIER TRAIN NO.2
WASH WATER RETURN (SHEET 1)
WASH WATER SUPPLY (SHEET 1)
PURGE NITROGEN (SHEET 1)



30-TH-3
GAS HOLDER
CAPACITY 1120 MSCF/HR
128' 0" O.D.
30-V-12
GAS HOLDER OUTLET
QUICK GAS SEAL
4'4" O.D.
30-PR-1
ELECTROSTATIC
PRECIPITATOR
GAS HOLDER
C.W. SUPPLY
RAW PRODUCT GAS
GAS HOLDER OUTLET QUICK GAS SEAL
N.C.
N.C.
WASH WATER
ELECTROSTATIC PRECIPITATOR
14
RAW PRODUCT GAS TO DESULFURIZATION (UNIT 43)
PURGE NITROGEN
WASH WATER
WASH WATER
WASH WATER (SHUTDOWN ONLY)
WASH WATER RETURN TO SETTLING BASIN (UNIT 73)
30-P-4A&B
WASH WATER
SUMP PUMPS
WASH WATER
SUMP
NOTES:
1. START-UP FLARE IS PROVIDED FOR EACH GASIFICATION TRAIN.
REVISIONS
PRELIMINARY NOT FOR CONSTRUCTION
BIDDING PURPOSES
CONSTRUCTION
DATE
RELEASED FOR
CHKD.
PHILADELPHIA GAS WORKS
COAL GASIFICATION PLANT
PHILADELPHIA, PA
PROCESS FLOW DIAGRAM
WET GASIFICATION PLANT (UNIT 30)
SHEET 2
GILBERT ASSOCIATES, INC.
UPDATED
A
REVISIONS
NONE
08
8276
EE-671-005
A

FIGURE 1-4


10
9
8
7
6
A
B
C
D
E
F
G
H
72-TK-1 FLOCCULATION TANK
70-TK-2 THICKENER
72-TK-3A&B SETTLING BASINS 2 REQ'D.
72- F-1A&B ROTARY VACUUM FILTERS
VAPORS
72-FA-1 WASH WATER FAN
WASH WATER FROM GKT WASH COOLERS TRAIN#1&2 (UNIT 30)
15
SUMP
WASH WATER
VAPORS
72-AG-2 AGITATOR
FLOCCULATING AGENT
COOLING WATER
DOSING TANK
DOSING AGENT
72-P-4 FLOC. DOSING PUMP
72-FA-2 SETTLING BASIN FAN
WASH WATER MAKE-UP (UNIT 84)
17
72-ME-3A&B SETTLING BASIN SCRAPERS
N.L.L.
72-P-A,B,C&D SETTLING BASIN SLUDGE PUMP
SLUDGE
SETTLING BASINS
N.L.L.
PLANT WATER
N.C.
ROTARY FILTER WASH WATER
THICKENER
SLUDGE (75% WATER)
19
ROTARY FILTERS
20
72-P-2A&B THICKENER SLUDGE WATER PUMPS
N.L.L.
BELT CONVEYOR
VACUUM RECEIVER
72-P-5A&B FILTRATE PUMPS
3/4" = 1'-0"
0'
5'
10'
15'
20'



6
5
4
3
2
1
A
B
C
D
E
F
G
H
72-CV-1 BELT CONVEYOR
72-V-1A&B VACUUM RECEIVER
72-E-1A&B WASH WATER COOLERS
72-V-2A&B MOISTURE TRAP VESSEL
WASH WATER VAPORS
VAPORS TO ATMOSPHERE (SAFE LOCATION)
C.W.
WASH WATER RETURN
16
WASH WATER RETURN TO GKT WASH COOLERS TRAINS #1&2 (UNIT 50)
WASH WATER COOLERS
HC
72-P-3A&B WASH WATER RETURN PUMPS
18
WASH WATER TO DISPOSAL (UNIT 86)
NOTE:
1. ONE WASH WATER TREATMENT TRAIN REQUIRED PER TWO GKT GASIFICATION TRAINS
MOISTURE TRAP
SLUDGE FILTER CAKE FOR RECYCLE TO COAL PREPARATION (UNIT 20)
FLY ASH FILTER CAKE (50% WATER) BELT CONVEYOR
BIFURCATED CHUTE
SLUDGE FILTER CAKE FOR DISPOSAL (UNIT 92)
VACUUM RECEIVER
AIR OUT
BAROMETRIC SEAL
72-P-6A&B VACUUM PUMPS
REVISIONS
CONSTRUCTION
PRELIMINARY NOT FOR CONSTRUCTION
BIDDING PURPOSES
DATE
RELEASED FOR
ENGR.
PHILADELPHIA GAS WORKS
COAL GASIFICATION PLANT
PHILADELPHIA, PA
PROCESS FLOW DIAGRAM
GKT WASH WATER TREATMENT
UNIT 72
GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS READING, PA
NONE
08 8276 C-671-006 A
DRAWING NUMBER
REV
UPDATED
A ALR 9-4-81

FIGURE 1-5

in the Coal Preparation Unit. Pulverized coal is then pneumatically transported from the Coal Preparation Unit to the GKT gasifier trains via conveying nitrogen supplied from the Air Separation Unit. The pulverized coal is routed via a flow splitter to service bins within the GKT battery limits. The conveying nitrogen is vented to the atmosphere through filters at the service bins. Pulverized coal flows by gravity from the service bind to the feed bins. Four service bins and four feed bins are provided for each gasifier. The service bins and feed bins provide a guaranteed supply of coal to the gasifiers in the event of an upstream emergency shut-down. The service and feed bins provide a total of approximately 15 minutes of storage for the gasifiers at design useage rates.

Controls regulate the intermittent feeding of coal from the service bins to the feed bins which are connected to twin variable-speed coal screw feeders. Four double coal screw feeders are provided per gasifier to supply pulverized coal to each burner head. The pulverized coal is continuously discharged from the twin screws into mixing nozzles where it is entrained in oxygen and low pressure steam. For each gasifier 48,230 lb/hr (579 TPD) of Pittsburgh No. 8 coal react with 47,455 lb/hr (569.5 TPD) of oxygen and 4422 lb/hr of steam for the production of 10 billion Btu per day of medium Btu gas (lower heating value basis). The mixture is then delivered through twin blow pipes to each burner head. Moderate temperature and high burner velocity prevents the reaction of coal and oxygen until they enter the gasification zone.

Oxygen/steam mixers are provided to insure complete mixing before injection into the blow pipes. Two oxygen/steam mixers are provided per gasifier. The normal oxygen/ coal ratio for a typical Pittsburgh No. 8 coal is 0.98 lb/lb and the normal steam/coal ratio is 0.09 lb/lb. The oxygen required for the partial oxidation reaction is provided at 98 vol. percent purity from an air separation plant. Approximately 54,950 lb/hr of low pressure steam at 28 psig is generated from each gasifier jacket.

In the gasifier, the coal dust is oxidized by oxygen in presence of steam. Under the process conditions prevailing in the gasifier, carbon and hydrocarbons contained in the coal are converted to carbon monoxide, hydrogen, and carbon dioxide. Besides these components, sulfur compounds in accordance with the sulfur content of the feedstock, and nitrogen resulting from the impurity of the oxygen and the feedstock, are contained in the generated gas. Traces of methane, not exceeding 0.01 percent by volume, are also produced. However, no hydrocarbons, phenols, aromatics, or any other organic compounds are generated in the GKT gasification process.

The gasification reaction (partial oxidation) of the coal is carried out in two four-headed gasifiers, each of which is connected to a waste heat recovery system for generation of high pressure steam (925 psig). The gasifier itself is a double-shell reactor, lined with refractory, and generates low-pressure steam (28 psig) within its shell. Endothermic reactions, occuring in the gasifier between carbon and steam, and radiation to the refractory walls substantially reduce the flame temperature from 3500°F to 2700°F.

Ash in the coal feed is liquified in the gasifier high temperature zone. Approximately 30 percent of the ash is dropped out of the gasifier as molten slag and is quenched and collected in a water seal type slag quench tank and recovery system at the bottom of the gasifier. The recovered granular slag is transported from the bottom of the slag recovery system, via a slag extractor (drag chain conveyor), where the slag is dewatered and delivered to a belt conveyor. Belt conveyors, in turn, deliver the slag to an on-site storage area prior to disposal.

The remainder of the ash and the unreacted carbon are entrained in the gas exiting the gasifier. Water sprays quench the gas to reduce the temperature below the ash fusion temperature to prevent slag particules from adhering to the tubes of the waste heat boiler mounted over the gasifier.

The raw gas from the gasifier passes through the waste heat boiler where 55,550 lb/hr of high pressure, saturated steam (925 psig) is generated per gasifier. After leaving the waste heat boiler, the gas at 600°F is cleaned and cooled in a gas clean-up system. The system consists of a cooling washer which removes the largest particulates and cools the gas to 100°F, followed by a "disintegrator" type scrubber which reduces the particulate content of the gas to approximately 0.004 grains per standard cubic feet.

To reduce the water droplets carried with the raw gas, a separator is linked downstream to the disintegrator by which the majority of the water is recovered. The collected water is recycled to the cooling washer. After leaving the separator, the gas passes through a second separator for final treatment and is routed to the raw gas blower which feeds a gas holder and an electrostatic precipitator. The gas blower pressurizes the raw product gas to a delivery pressure at the GKT Gasification Unit battery limits (downstream of electrostatic precipitator) to approximately 22 inches of water.

Downstream of the raw gas blowers the two gasification trains join together to form a single train. The combined pressurized raw product gas passes into a single gas holder. The capacity of the gas holder is approximately 1.117 MMSCF of raw product gas. The gas holder provides approximately 20 minutes of storage capacity at the design usage rate in the event of a short term upstream gasification system failure. The gas holder also helps to smooth out the product gas user demand fluctuations. From the gas holder the gas is discharged to an electrostatic precipitator which removes the remaining fine particles before the gas enters the Desulfurization Unit for final clean-up.

Particulate-laden water from the GKT gas cleaning and cooling system is channeled to settling basins in the GKT Wash Water Treatment Unit (Unit 72). A portion of the fly ash carried over from the gasifier will be collected at the fly ash sump and pumped as slurry to the waste water treatment settling basins. The major portion of the particles, however, are channeled with the circulating waste water which, after leaving the wash cooler, flows to settling basins for particulate removal.

In the Wash Water Treament Unit, two 33 ft by 197 ft settling basins are provided to separate the ash and carbon particles entrained in the wash water from the GKT Gasification Unit. The settling basins are designed with adequate residence time to allow the settling of particles to the bottom of the settling basins, from which they are pushed by scrapers to a collecting sump adjacent to the settling basins. The ash slurry from the collection sump is pumped to a thickener. From the underflow of the thickener, a slurry pump transports the ash sludge to rotary vacuum filters for water removal. Two rotary vacuum filters are provided to reduce the sludge water content to 50 percent.

The fly ash sludge from the rotary filters is transported to the ash storage area via belt conveyors for temporary on-site storage. For Pittsburgh No. 8 coal with an ash content of 7.83 percent this would result in an ash sludge production rate of 345 tpd at design capacity. To reduce the ash disposal problem the GKT gasification plant has been designed with the capability of recycling a maximum of 50 percent of the ash sludge to the pulverizers. (The recycled sludge cake is transported to the pulverizers in the Coal Preparation Unit via belt conveyors). The sludge, at 50 percent recycle, contains approximately 26 percent unused carbon and will increase the gasifier carbon conversion from 88.0 to 93.6 percent while reducing the raw coal feed by 6 percent. The mixed feed would contain approximately 11.5 percent moisture compared to 4.6 percent for the Pittsburgh No. 8 fresh feed coal. The pulverizer and the pulverizer air heater are sized to handle the ash recycle operation.

During start-up of the gasifiers, the off-spec product gas will be routed to start-up flares provided within the GKT battery limits. A start-up flare is provided for each GKT gasifier train. Product gas is diverted upstream of the raw gas blowers to each flare. The start-up of a gasifier from ambient to design conditions takes a maximum of ten hours. Restart of the gasifier after a short shut-down period (about one hour), however, takes only 30 minutes.

A single GKT gasifier can be turned down to approximately 70% of its full load capacity within a few minutes. The product gas output from the two-gasifier GKT plant can therefore be adjusted in the range of 35-100 percent.

1.7 SULFUR REMOVAL AND RECOVERY

The sulfur removal and recovery system consists of two units. The first unit consists of a Stretford desulfurization plant (Unit 42) which removes H_2S present in the raw gas by converting it to recoverable elemental sulfur. The Stretford plant generates a purge liquor stream containing insoluble Na_2SO_4, $Na_2S_2O_3$, and NaSCN salts. The purge stream has a high COD value and is decomposed in the second unit, the Nittetu reductive incineration plant (Unit 44). Part of the clean product gas from the Stretford plant is burned with substoichiometric air in the Nittetu plant to produce the hot reduced gas necessary for the decomposition of the salts. Sodium vanadate, a component of Stretford Solution, is recovered with caustic alkali in the Nittetu plant and is recycled to the Stretford plant. The decomposed gas produced in the Nittetu plant contains H_2S and is recycled to the Stretford plant to combine with the raw gas from GKT gasification plant for sulfur removal.

1.7.1 Stretford Desulfurization

The Stretford desulfurization process developed by the British Gas Board is a direct oxidation process. The Stretford Plant is designed to remove 90 percent of the sulfur contained in the product gas produced from the gasification of Pittsburgh No. 8 coal, which contains 2.64 percent sulfur by weight (dry basis). The product gas from the GKT gasification plant contains 0.90 percent H_2S and 0.09 percent COS on a dry volume basis. The Stretford plant removes almost all H_2S. COS is not removed from the gas; however, when burned it will produce only 350 ppmv SO_2 or 0.60 lb. $SO_2/10^6$ Btu heat input which is well below the 500 ppmv or 0.86 lb. $SO_2/10^6$ Btu limit set by the City of Philadelphia.

The Stretford plant can be designed to produce either filter cake or molten sulfur. The selection depends on the plant capacity, environmental restrictions, by-product sulfur credit and the filter cake disposal costs. The molten sulfur configuration generates a purge liquor stream which requires either on-site treatment by reductive incineration or disposal by hauling it to a hazardous waste treatment facility. Again the selection between the two depends on the size of the plant and economics. An economic evaluation of the above options was performed (see Appendix C) and the results favored the selection of the molten sulfur option with on-site reductive incineration.

Process Chemistry

The Stretford solution is an aqueous mixture of anthraquinonedisulfonic acid (ADA), sodium metavanadate, and sodium carbonate. The removal of H_2S and its conversion to elemental sulfur are represented by the following idealized reactions:

$$2H_2S + 2Na_2CO_3 \rightarrow 2NaHS + 2NaHCO_3$$
$$2NaHS + 4NaVO_3 + H_2O \rightarrow Na_2V_4O_9 + 4NaOH + 2S$$
$$Na_2V_4O_9 + 2\ NaOH + H_2O + 2ADA \rightarrow 4NAVO_3 + 2ADA(H_2)$$
$$2NaHCO_3 + 2NaOH \rightarrow 2Na_2CO_3 + 2H_2O$$
$$2ADA(H_2) + O_2 \rightarrow 2ADA + 2H_2O$$

where $ADA(H_2)$ represents the reduced form of ADA. Ionized forms of the reactants in aqueous solution are usually involved. The sum of the foregoing reactions gives the overall reaction

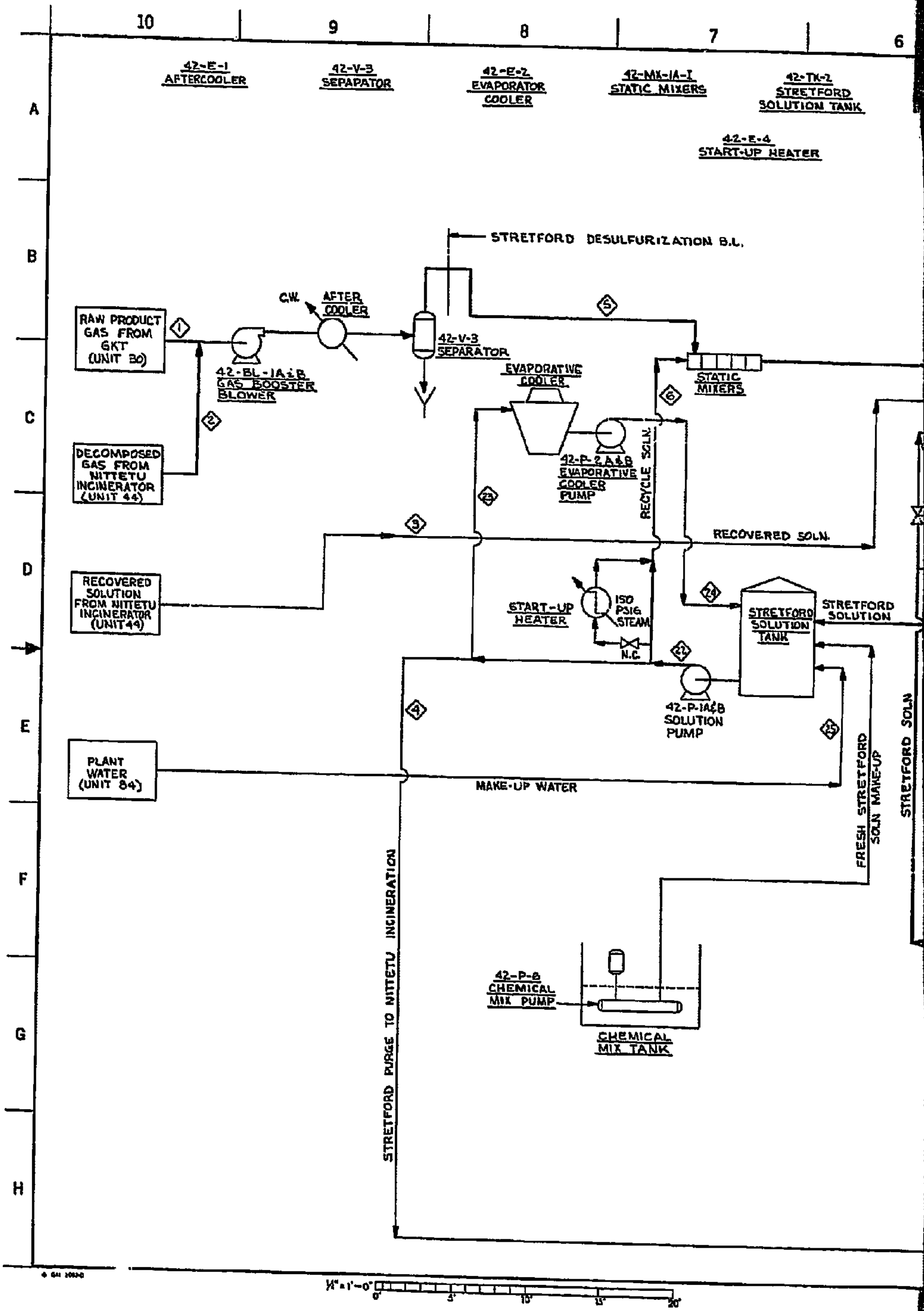
$$2H_2S + O_2 \rightarrow 2H_2O + 2S.$$

In this sequence of reactions, the hydrosulfide reaction product is oxidized to free elemental sulfur by reduction of vanadium from the pentavalent to the quadrivalent oxidation state, and the reduced vanadium is reoxidized by reduction of ADA. Air is blown through the solution in the oxidizer vessel to reoxidize the reduced ADA. Although the rate of H_2S absorption increases with the alkalinity of the solution, pH values above 9.5 are unfavorable for conversion to elemental sulfur.

Process Description

For the design coal (2.64 percent S, dry basis) the Stretford plant capacity is 27.3 tpd sulfur. Equipment sizing for the process is governed by the total quantity of sulfur in the fuel gas from the GKT gasification plant. The present design conservatively assumes that all the sulfur present in the coal appears in the gas. However, in the actual operation, some sulfur is retained in the ash. This allows a margin for using a higher sulfur coal.

Figure 1-6 shows the process flow and Table 1-3 gives the material balance for the Stretford plant. The raw gas from the GKT gasification plant at 95°F and 15.5 psia, and the decomposed gas from the Nittetu plant at 120°F and 15.5 psia are combined and compressed in the blower. The combined gas is cooled and washed in static mixers with the oxidized Stretford solution. The gas and the solution from the static mixers discharge into the reaction vessel which is sized to allow sufficient residence time for the sulfur forming reaction mechanism to go to completion.



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42-E-1 AFTERCOOLER
42-V-3 SEPARATOR
42-E-2 EVAPORATOR COOLER
42-MX-1A-I STATIC MIXERS
42-TK-2 STRETFORD SOLUTION TANK
42-E-4 START-UP HEATER
STRETFORD DESULFURIZATION B.L.
RAW PRODUCT GAS FROM GKT (UNIT 30)
DECOMPOSED GAS FROM NITTETU INCINERATOR (UNIT 44)
RECOVERED SOLUTION FROM NITTETU INCINERATOR (UNIT 44)
PLANT WATER (UNIT 84)
C.W.
AFTER COOLER
42-BL-1A&B GAS BOOSTER BLOWER
42-V-3 SEPARATOR
EVAPORATIVE COOLER
42-P-2A&B EVAPORATIVE COOLER PUMP
STATIC MIXERS
RECYCLE SOLN.
RECOVERED SOLN.
START-UP HEATER
150 PSIG STEAM
N.C.
STRETFORD SOLUTION TANK
STRETFORD SOLUTION
42-P-1A&B SOLUTION PUMP
MAKE-UP WATER
FRESH STRETFORD SOLN MAKE-UP
STRETFORD SOLN
STRETFORD PURGE TO NITTETU INCINERATION
42-P-8 CHEMICAL MIX PUMP
CHEMICAL MIX TANK
1/4" = 1'-0"
0'
5'
10'
15'
20'

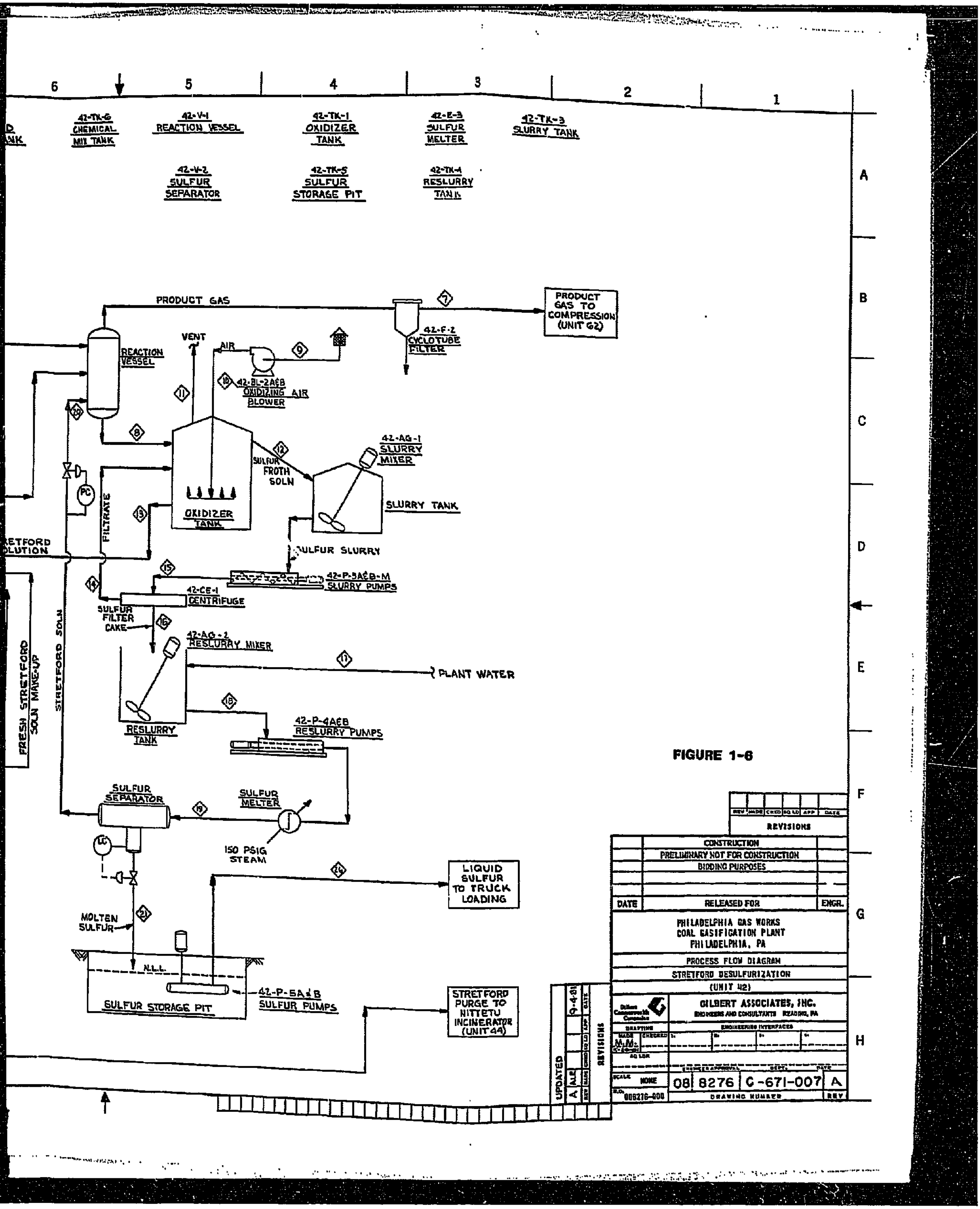
42-TK-6 CHEMICAL MIX TANK
42-V-1 REACTION VESSEL
42-TK-1 OXIDIZER TANK
42-E-3 SULFUR MELTER
42-TK-3 SLURRY TANK
42-V-2 SULFUR SEPARATOR
42-TK-5 SULFUR STORAGE PIT
42-TK-4 RESLURRY TANK
PRODUCT GAS
PRODUCT GAS TO COMPRESSION (UNIT 62)
42-F-2 CYCLOTUBE FILTER
VENT
AIR
REACTION VESSEL
42-BL-2A&B OXIDIZING AIR BLOWER
42-AG-1 SLURRY MIXER
SULFUR FROTH SOLN
SLURRY TANK
OXIDIZER TANK
FILTRATE
PC
STRETFORD SOLUTION
SULFUR SLURRY
42-P-3A&B-M SLURRY PUMPS
42-CE-1 CENTRIFUGE
SULFUR FILTER CAKE
42-AG-2 RESLURRY MIXER
PLANT WATER
RESLURRY TANK
42-P-4A&B RESLURRY PUMPS
FRESH STRETFORD SOLN MAKE-UP
STRETFORD SOLN
SULFUR SEPARATOR
SULFUR MELTER
150 PSIG STEAM
LC
LIQUID SULFUR TO TRUCK LOADING
MOLTEN SULFUR
N.L.L.
SULFUR STORAGE PIT
42-P-5A&B SULFUR PUMPS
STRETFORD PURGE TO NITTETU INCINERATOR (UNIT 44)
REVISIONS
CONSTRUCTION
PRELIMINARY NOT FOR CONSTRUCTION
BIDDING PURPOSES
DATE
RELEASED FOR
ENGR.
PHILADELPHIA GAS WORKS
COAL GASIFICATION PLANT
PHILADELPHIA, PA
PROCESS FLOW DIAGRAM
STRETFORD DESULFURIZATION
(UNIT 42)
GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS READING, PA
M.M.
NONE
08 8276 C-671-007 A
DRAWING NUMBER
UPDATED
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FIGURE 1-6

TABLE 1-3

FGW GASIFICATION PROJECT
STRETFORD PLANT PROCESS
MATERIAL AND ENERGY BALANCE

STREAM NO.	1	2	3	4	5	6	7	8	9	10	11	12	13
Temp, °F	95.0	120.0	135.0	105.2	101.0	105.2	105.2	105.2	91.0	304.1	105.2	105.2	105.2
Press, psia	15.5	15.5	44.7	124.7	20.5	46.7	16.2	16.7	14.7	35.86	14.7	14.7	14.7
Total Flow, lbs/hr	179794	7424	3540	3500	186069	6574634	186224	6583454	37974	37974	38542	31626	6578417
Liquid, gpm		0.0594	6.1	6.17		10117		10132				47.49	10124
Flowing, lbs/gal		8.25	9.67	9.45		10.831		10.83				11.10	10.83
Vapor Flow, ACFS	889.49	27.75			694.83		895.20		151.3	84.28	157.12		
Flowing, lbs/ft^3	0.0561	0.0743			0.0744		0.0578		0.070	0.125	0.068		
Vapor Mol. Wt	21.54	26.69			21.81		21.60		28.55	28.55	28.05		
ADA Soln (lbs/hr)			3540	3500		6574634		6580669				29347	6578417
Sulfur (lbs/hr)								2279				2279	
CO_2	530.87	60.84			591.71		580.66	11.05			11.05		
CO	4892.16	23.99			4916.15		4913.04	3.11			3.11		
H_2	2277.89	11.13			2289.02		2287.61	1.41			1.41		
H_2S	70.95	4.02			47.97		-						
COS	7.51				7.51		7.51						
HCN	0.63				0.63		0.23	0.40					
N_2	76.79	120.99			197.78		197.78		1023.04	1023.04	1023.04		
Ar	47.57				47.57		47.57						
CH_4	0.83				0.83		0.83						
H_2O	441.77	29.10	154.15	138.0	407.03	346995	586.26	347331	34.8	34.8	103.56	1547.74	347159
Sulfur								71.22				71.22	
O_2									271.95	271.95	231.88		
NaHS			4.30										
TOTAL	8346.97	250.07	158.45	138.0	8533.20	346995	8621.49	347418	1329.79	1329.79	1374.05	1618.66	347159

TABLE 1-3 (Cont'd)

STREAM NO.	14	15	16	17	18	19	20	21	22	23	24	25	26
Temp, °F	105.2	105.2	105.2	86.0	105.2	280	280	280	105.2	105.2	95.4	86.0	
Press, psia	30.0	64.7	30.0	64.7	79.7	74.7	16.7	14.7	124.7	100.0	30.0	64.7	
Total Flow, lbs/hr	27118.3	31644.9	4507.7		7450.7	7450.7	5171.7	2279	8527174	1949040	1936210	12542	
Liquid, gpm	41.73	47.3	5.71	5.9	11.49	12.13		2.55	13123	3000	2974	25.1	
Flowing, lbs/gal	10.83	11.1	13.15		10.65	10.08		14.9	10.83	10.83	10.85	8.33	
Vapor Flow, ACFS													
Flowing, lbs/ft^3													
Vapor Mol. Wt													
ADA Soln (lbs/hr)	21778.3	29365.9	2207.3		5171.7	5171.7	5171.7						
Sulfur (lbs/hr)		2279	2279		2279	2279		2279					91160
CO_2													
CO													
H_2													
H_2S													
COS													
HCN													
N_2													
Ar													
CH_4													
H_2O	1431.24	1548.74	116.50	163.5	281.16	281.16	281.16		450043	102910	102197	696.8	
Sulfur		71.22	71.22		71.22	71.22		71.22					2848.8
O_2													
NaHS													
TOTAL	1431.24	1619.96	187.72	163.5	352.38	352.38	281.16	71.22	450043	102910	102197	696.8	2848.8

The treated gas exits the top of the reaction vessel and enters the gas compression and dehydration units. The solution from the reaction zone in the reaction vessel flows to an oxidizer tank where an aerator disperses air supplied by the air blower. Sulfur slurry overflows from the oxidizer tank into the sulfur slurry tank by gravity. The oxidized solution is recycled from the pump tank to the static mixers. A cooling tower and circulating pump are provided with the pump tank to maintain the heat and water balance in the unit.

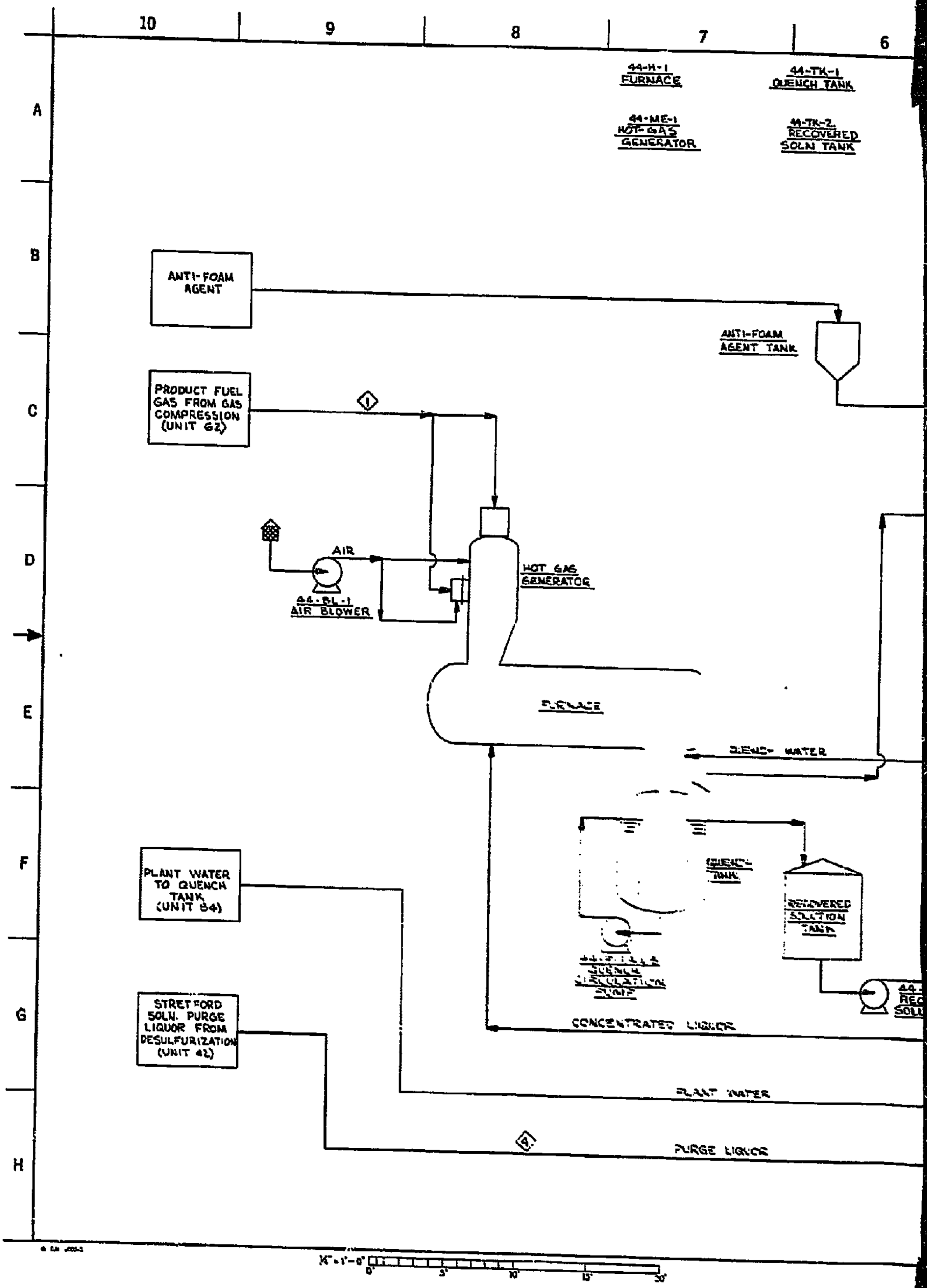
The sulfur slurry which flows to the slurry tank is agitated and, thus, deaerated. Slurry from the slurry tank is then pumped to a centrifuge. The recovered solution in the centrifuge goes back to the oxidizer tank and the 50 percent concentrated sulfur cake passes to the reslurry tank. The concentrated sulfur slurry is mixed with water to a 30 percent slurry, which is pumped to the sulfur melter by a reslurry pump. The sulfur melter consists of a steam-heated exhanger where the temperature of the slurry is raised above the melting point of the sulfur at a pressure sufficiently high to prevent the solution from boiling. Separation of the molten sulfur and the hot solution occurs in the sulfur separator due to large difference in specific gravity. The molten sulfur passes to the sulfur storage pit with the hot solution being returned to the reaction vessel. A chemical mix tank is required for preparing fresh Stretford solution and adding makeup chemicals.

A purge stream from the recirculating Stretford solution stream is sent to the Nittetu incineration plant.

1.7.2 Nittetu Incineration

The stretford plant purge liquor (containing sodium salts) has high COD value and cannot be biodegraded. The Nittetu reductive incineration process is designed to decompose the purge liquor under high temperature and reducing atmosphere in which accumulated inert compounds such as Na_2SO_4, $Na_2S_2O_3$ and NaSCN in the solution are converted to the active components Na_2CO_3, $NaHCO_3$ and NaHS. Also, sodium vanadate is recovered with caustic alkali. Decomposed gas containing H_2S is recycled back to the Stretford plant.

The Nittetu process is shown in Figure 1-7, and Table 1-4 gives the material balance. The purge liquor from the Stretford process, containing about 70 percent water, is fed to an evaporator at the operating conditions of about 140°F and 100-200 mm Hg abs, where it is concentrated by use of decomposed gas as a heat source. Vaporized water from the evaporator is sent to a surface condenser, where it is condensed and recycled to the quench tank. The concentrated waste, with a total solid content of 40 to 45 wt percent, is fed to a furnace using spray nozzles. At the upper section of the furnace, a hot gas generator burns the product fuel-gas with substoichiometric air to produce hot reducing gas. In the furnace, water is vaporized from the waste liquor and the inactive salts are decomposed under the reducing atmosphere. These salts are in molten state. Some are carried over by hot decomposed gases and some flow along the refractory-lined wall to the quench tank located below the furnace. Here the gases are cooled quickly and the salts are collected and dissolved in the liquid. Hot decomposed gases are injected into the liquid through a downcomer tube and rise through an annular section between tube and weir where they are contacted intimately with water. The recovered solution is collected in the recovered solution tank and pumped back to the Stretford plant. The decomposed gas leaving the quench tank is first sent to the evaporator heat exchanger for heat recovery and finally to a gas cooler. The decomposed gas containing H_2S is sent back to the Stretford plant to be mixed with the raw gas from the GKT gasification plant.



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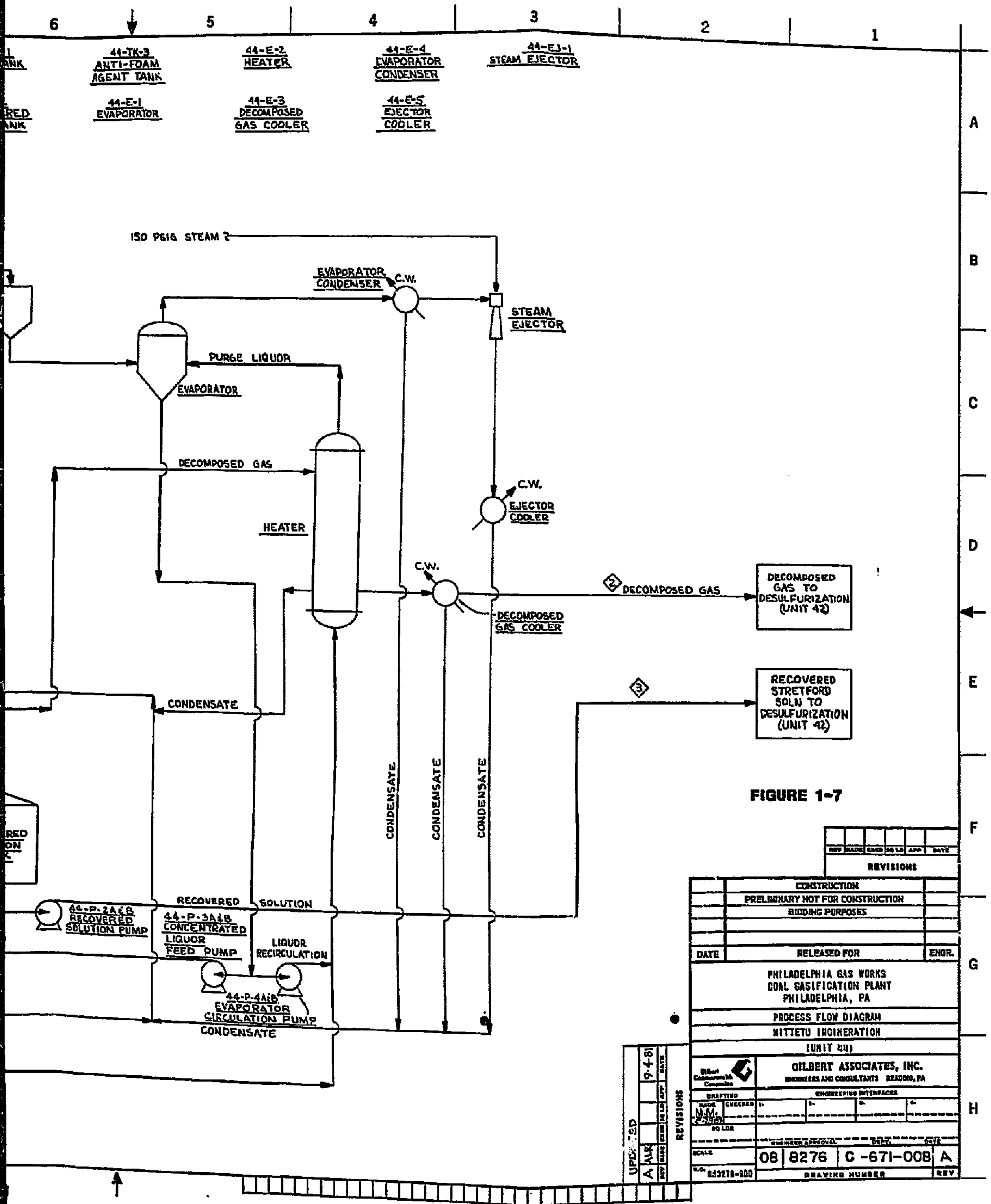
44-H-1 FURNACE
44-TK-1 QUENCH TANK
44-ME-1 HOT-GAS GENERATOR
44-TK-2 RECOVERED SOLN TANK
ANTI-FOAM AGENT
ANTI-FOAM AGENT TANK
PRODUCT FUEL GAS FROM GAS COMPRESSION (UNIT 62)
AIR
44-BL-1 AIR BLOWER
HOT GAS GENERATOR
FURNACE
QUENCH WATER
PLANT WATER TO QUENCH TANK (UNIT 84)
RECOVERED SOLUTION TANK
STRETFORD SOLN. PURGE LIQUOR FROM DESULFURIZATION (UNIT 42)
CONCENTRATED LIQUOR
PLANT WATER
PURGE LIQUOR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44-TK-3 ANTI-FOAM AGENT TANK
44-E-2 HEATER
44-E-4 EVAPORATOR CONDENSER
44-EJ-1 STEAM EJECTOR
44-E-1 EVAPORATOR
44-E-3 DECOMPOSED GAS COOLER
44-E-5 EJECTOR COOLER
150 PSIG STEAM
EVAPORATOR CONDENSER
C.W.
STEAM EJECTOR
PURGE LIQUOR
EVAPORATOR
DECOMPOSED GAS
HEATER
C.W.
EJECTOR COOLER
C.W.
DECOMPOSED GAS
DECOMPOSED GAS COOLER
DECOMPOSED GAS TO DESULFURIZATION (UNIT 42)
RECOVERED STRETFORD SOLN TO DESULFURIZATION (UNIT 42)
CONDENSATE
CONDENSATE
CONDENSATE
CONDENSATE
44-P-2A&B RECOVERED SOLUTION PUMP
RECOVERED SOLUTION
44-P-3A&B CONCENTRATED LIQUOR FEED PUMP
LIQUOR RECIRCULATION
44-P-4A&B EVAPORATOR CIRCULATION PUMP
CONDENSATE
REVISIONS
CONSTRUCTION
PRELIMINARY NOT FOR CONSTRUCTION
BIDDING PURPOSES
DATE
RELEASED FOR
ENGR.
PHILADELPHIA GAS WORKS
COAL GASIFICATION PLANT
PHILADELPHIA, PA
PROCESS FLOW DIAGRAM
NITTETU INCINERATION
(UNIT 44)
GILBERT ASSOCIATES, INC.
ENGINEERS AND CONSULTANTS READING, PA
ENGINEERING INTERFACES
DRAFTING
CHECKED
N.M.
ENGINEER APPROVAL
DEPT.
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AIR
UPDATED
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REVISIONS

FIGURE 1-7

TABLE 1-4

MATERIAL BALANCE FOR NITTETU INCINERATION PLANT

STREAM NUMBER	1	2	3	4
Temperature, °F	105	120	195	105.2
Pressure, psia	16.2	15.5	44.7	124.7
Total Flow, lbs/hr	1892	7424	3540	3500
Liquid, gpm	-	.0594	6.1	6.17
Flowing, lbs/gal	-	8.25	9.67	9.45
Vapor Flow, ACFS	13.6	27.70	-	-
Flowing, lbs/ft^3	0.0591	0.0743	-	-
Vapor Mol. Wt.	21.6	29.77	-	-
ADA Solution, lb/hr			3540	3500
CO_2	9.02	60.84	-	-
CO	76.33	23.99	-	-
H_2	35.53	11.13	-	-
COS	0.12	-	-	-
N_2	3.07	120.99	-	-
Ar	0.74	-	-	-
CH_4	0.01	-	-	-
H_2O	9.11	29.10	154.15	138.0
H_2S	-	4.02	-	-
NaHS	-	-	4.30	-
TOTAL	133.93	250.07	158.45	138.0

1.8 AIR SEPARATION

A 1200 TPD air separation plant is required to provide oxygen for the GKT Gasification Unit. The by-product nitrogen from the air separation plant is utilized for pneumatic conveying of pulverized coal from the coal preparation area to the gasification unit and for gasifier unit purging and blanketing.

The oxygen purity specified for the plant is 98 vol. percent with 2 percent inerts (mostly argon). The by-product nitrogen contains a maximum of 2 percent oxygen and is bone-dry. The required pressures for the oxygen and by-product nitrogen at the air separation plant battery limits are 1 psig and 40 psig, respectively. The oxygen product piped from the air separation plant is compressed to approximately 15 psig by a compressor within the GKT battery limits. The by-product nitrogen available at 40 psig from the air separation cold box will be adequate for the GKT gasification unit conveying and purging requirements.

The total normal nitrogen requirement for GKT gasification plant conveying and purging is shown below. The conveying nitrogen estimate is based on 7.0 lbs. of coal conveyed per lb of nitrogen. In addition to the normal nitrogen requirements, the nitrogen requirement for gasifier system emergency shutdown purging is also shown.

Conveying	186,140 Scf/hr (35 psig)
Purging & Blanketing	148,900 Scf/hr (25 psig)
Total Normal	335,040 Scf/hr
Emergency Shutdown Purging	893,470 Scf/hr (15 psig)

The air separation plant (Unit 50) is a turnkey facility. Engineering and design will be furnished by a contractor experienced in this field.

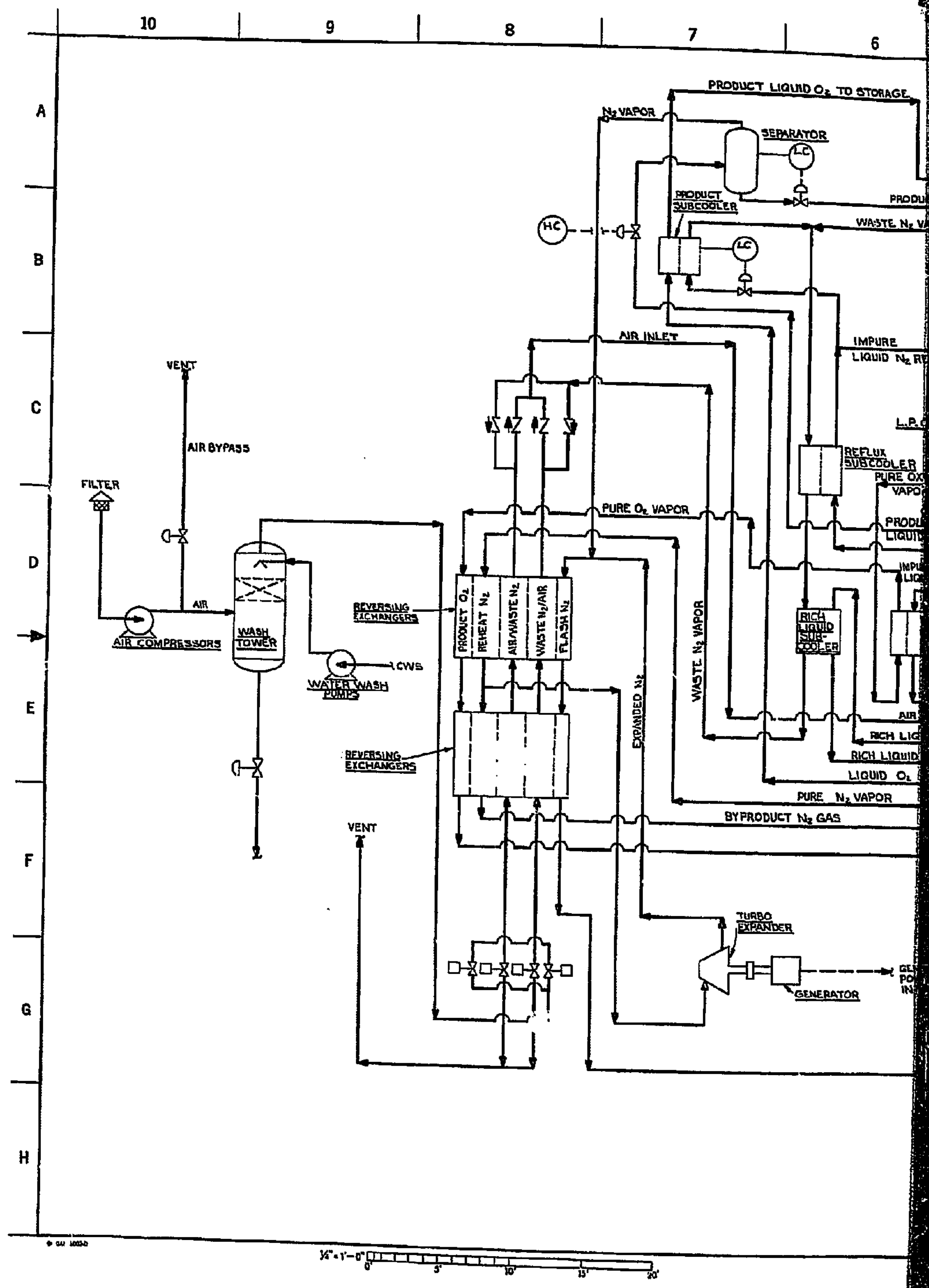
The basic process for separating oxygen from air is a distillation operation that takes place at low temperatures under moderate pressure in which air is reduced to the liquid state and the components are separated by fractionation. The cryogenic temperatures are achieved by special heat exchange equipment and expansion turbines that efficiently transfer heat and energy between feed and products to make the operation economically practical.

In a simplified form, the main process steps to produce oxygen and by-product nitrogen in an air separation plant include: air compression, water and carbon dioxide removal, cooling to liquid air temperature, gas expansion to produce refrigeration, separation of air by distillation, product heating by heat exchange with the incoming air, and compression of oxygen to the required pressure. Figure 1-8 depicts a typical low pressure cycle oxygen plant with liquid oxygen and nitrogen storage.

In the air separation plant the refrigeration process used to reach liquid air temperatures is regenerative. Warm process air entering the plant is cooled by the separated products as they leave in a reversing heat exchanger. The heat recovery is incomplete, however, so refrigeration must continuously be added.

Air also contains variable quantities of dust, water, carbon dioxide and hydrocarbons. These impurities must be removed from the system to insure a safe, efficient operation. In the process, dust is removed by a filter on the inlet of the main air compressors. The dust that goes by, along with other contaminants, is removed in a water wash tower.

For reliability and flexibility in turndown, two 50 percent air separation trains (600 tpd each) will be provided. In addition, there will be two main air compressors - one driven by an electric motor, the other by a steam turbine. Approximately 93,000 lb/hr of saturated steam at 925 psig is available for use by the air



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PRODUCT LIQUID O₂ TO STORAGE
N₂ VAPOR
SEPARATOR
LC
PRODUCT SUBCOOLER
HC
WASTE N₂ V
AIR INLET
IMPURE LIQUID N₂ R
VENT
AIR BYPASS
REFLUX SUBCOOLER
PURE OX VAPO
FILTER
PURE O₂ VAPOR
PRODU LIQUI
AIR
WASH TOWER
AIR COMPRESSORS
REVERSING EXCHANGERS
PRODUCT O₂
REHEAT N₂
AIR/WASTE N₂
WASTE N₂/AIR
FLASH N₂
WASTE N₂ VAPOR
RICH LIQUID SUB-COOLER
CWS
WATER WASH PUMPS
EXPANDED N₂
AIR
RICH LIQ
RICH LIQUID
LIQUID O₂
PURE N₂ VAPOR
BYPRODUCT N₂ GAS
VENT
TURBO EXPANDER
GENERATOR
¼" = 1'-0"
0'
5'
10'
15'
20'

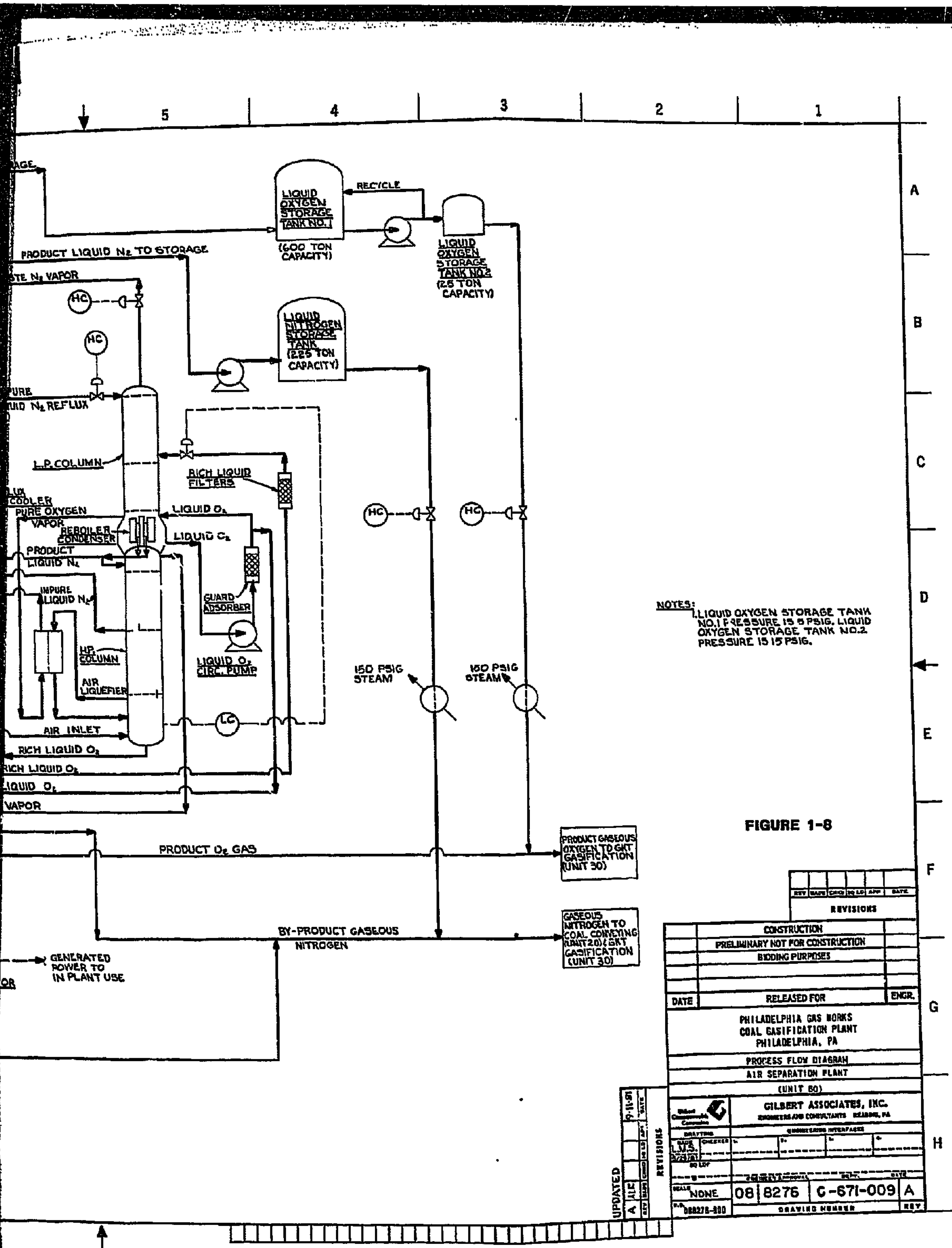
LIQUID OXYGEN STORAGE TANK NO.1
(600 TON CAPACITY)
RECYCLE
LIQUID OXYGEN STORAGE TANK NO.2
(25 TON CAPACITY)
PRODUCT LIQUID N₂ TO STORAGE
N₂ VAPOR
LIQUID NITROGEN STORAGE TANK
(225 TON CAPACITY)
HC
LIQUID N₂ REFLUX
L.P. COLUMN
RICH LIQUID FILTERS
COOLER
PURE OXYGEN VAPOR
REBOILER CONDENSER
LIQUID O₂
PRODUCT LIQUID N₂
IMPURE LIQUID N₂
GUARD ADSORBER
HP COLUMN
AIR LIQUEFIER
LIQUID O₂ CIRC. PUMP
150 PSIG STEAM
LC
AIR INLET
RICH LIQUID O₂
LIQUID O₂
VAPOR
PRODUCT O₂ GAS
PRODUCT GASEOUS OXYGEN TO GKT GASIFICATION (UNIT 30)
BY-PRODUCT GASEOUS NITROGEN
GASEOUS NITROGEN TO COAL CONVEYING (UNIT 20) & GKT GASIFICATION (UNIT 30)
GENERATED POWER TO IN PLANT USE
NOTES:
1. LIQUID OXYGEN STORAGE TANK NO.1 PRESSURE IS 5 PSIG. LIQUID OXYGEN STORAGE TANK NO.2 PRESSURE IS 15 PSIG.
REVISIONS
CONSTRUCTION
PRELIMINARY NOT FOR CONSTRUCTION
BIDDING PURPOSES
DATE
RELEASED FOR
ENGR.
PHILADELPHIA GAS WORKS
COAL GASIFICATION PLANT
PHILADELPHIA, PA
PROCESS FLOW DIAGRAM
AIR SEPARATION PLANT
(UNIT 60)
GILBERT ASSOCIATES, INC.
UPDATED
NONE
08 8276 C-671-009 A
DRAWING NUMBER

FIGURE 1-8

compressor steam turbine. This is approximately 65 percent of the total compressor power requirement. The electric driven compressor is sized to provide 50 percent of the air compressor requirement.

Compressed air from the main air compressors enters the base of water wash tower and is cooled by a countercurrent direct contact with water sprayed into the top of the tower. The warmer water is returned to the cooling water system by process air pressure. Air leaves at the top of the tower at near ambient temperature and flows to the reversing heat exchangers.

Compressed process air is cooled to liquid air temperatures in reversing heat exchangers by the outgoing streams. During this process, contained water and carbon dioxide are frozen and deposited as solids inside the exchanger.

At regular intervals, the air and the waste nitrogen stream, which is the largest effluent stream, are interchanged. Both continue to flow in the same direction, across the same temperature gradient, but the passages through which they flow are switched. As a result, the water and carbon dioxide deposited by the air before reversal is evaporated completely and removed from the plant by waste nitrogen. Switching is accomplished by an automatic system of timers, warm-end reversing valves, and cold-end check valves.

Slightly superheated air leaves the reversing exchanger, enter the high pressure column and is separated into an oxygen rich liquid at the bottom, pure liquid nitrogen at the top, and impure liquid nitrogen part way up the column.

Pure nitrogen gas from the top of the high pressure column is condensed in the reboiler by boiling pure liquid oxygen in the low pressure column. The returning liquid nitrogen serves as reflux for the high pressure column.

Further down the high pressure column, impure liquid nitrogen is withdrawn and subcooled, part of it providing reflux for the low pressure column and part of it acting as a subcooling medium for liquid oxygen product in the product subcooler, if required. Waste nitrogen vapor is withdrawn from the top of the low pressure column.

Rich liquid oxygen is taken from the base of the high pressure column, subcooled via the waste nitrogen stream, purified in the rich liquid filter, and passed to the feed entry tray of the low pressure column.

Provisions for nitrogen drawn off the top of the high pressure column will be made in two places. First is the pure liquid nitrogen stream sent to a nitrogen flash separator where resulting liquid is sent to nitrogen storage. The flash from the separator is combined with the effluent gas of the turbo expander and sent through the reversing exchangers for recovery of its refrigeration, then on to product usage, otherwise it goes out as waste nitrogen through the silencer. The operator will control just how much liquid nitrogen is withdrawn, from the high pressure column.

The other stream, cold pure nitrogen gas, is sent to the reversing exchanger. Part of this gas is drawn off at the midpoint and sent to the expander. Expander exhaust along with the possible flash from the separator is sent back to the reversing exchanger as described above.

Final separation of oxygen takes place in the low pressure column. Provisions for liquid oxygen to be taken from the base of low pressure column, passed through liquid oxygen guard absorber, subcooled in product subcooler, and then sent to storage will be made. The subcooling medium would be impure nitrogen from the high pressure column.

Product oxygen gas is taken off just above the bottom of the low pressure column and sent through air liquefier exchanger, where it may be superheated by a slipstream of condensing air, and then to the reversing exchangers for the recovery of the rest of its refrigeration, and finally to delivery to the GKT Gasification Unit battery limits.

Liquid oxygen and nitrogen storage facilities are required to provide 24 hours of back-up product oxygen and nitrogen during an emergency shutdown. Since the oxygen plant is dual train and has the capability of operating one train on either steam or electricity, it is expected that a shutdown would only reduce oxygen production by 50 percent. For this reason, the liquid storage requirement is 50 percent of design capacity for 24 hours, i.e., 600 tons.

The liquid oxygen storage consists of a main 600 ton liquid oxygen storage tank at 5 psig and a 25 ton liquid oxygen tank at 15 psig. Two 100 percent liquid oxygen pumps are provided to pump liquid oxygen from the 600 ton tank to the 25 ton tank. A vaporizer at the discharge of the 25 ton tank vaporizes the liquid oxygen for delivery to the GKT battery limits. The minimum delivery pressure of gaseous oxygen to the GKT battery limits is 1 psig. This system will insure that fluctuation of the oxygen pressure does not occur in the event that response time of the air separation unit is slow relative to the oxygen demand rate of the gasifiers.

The liquid nitrogen storage system consists of a 275 ton storage tank at 40 psig and a vaporizer which provides the normal nitrogen required for conveying and purging in the event of an air separation plant shutdown. The storage system will be capable of supplying nitrogen gas at 40 psig at a design withdrawal rate of 6000 SCFM. For gasification system emergency shutdown purging, a high pressure nitrogen tube trailer (rental) is provided. The high pressure tube trailer will provide an instantaneous supply of nitrogen for gasifier system purging. The tube trailer will be designed for a maximum withdrawal rate of 15,000 SCFM for 15 minutes, i.e. 225,000 SCF storage capacity.

1.9 PRODUCT GAS HANDLING

1.9.1 Gas Compression

The clean fuel gas from the Stretford plant is compressed to 40 psig and cooled to 100°F prior to dehydration and distribution. The product gas leaves the Stretford absorber at 105°F and 1.5 psig saturated with water vapor. The gas is compressed in a set of parallel compressors. The compressors are centrifugal machines with aftercoolers.

The compressors will be driven by condensing steam turbines using excess low pressure steam from the gasifier jackets. The steam is superheated prior to entering the turbines at 25 psig and 322°F (55°F superheat). There is sufficient steam to provide 100 percent of the compression duty. Because of the high specific volume of the steam, two turbines will be needed to handle the steam available. A third compressor driven by electric motor will provide 50 percent of the plant output and will be used for startup and standby duty.

The outlet gas from the compressor will be cooled in a shell and tube heat exchanger to 100°F with cooling water in order to condense as much water as possible. It is intended to minimize the load on the dehydration unit. The condensate from the compressor aftercoolers will be used as make-up to the plant main cooling tower.

1.9.2 Gas Dehydration

In the gas dehydration unit (Unit 64), excess water from the desulfurized and compressed gas (40 psig) is removed to meet the