CR-161772

ADVANCED TECHNOLOGY APPLICATIONS FOR SECOND AND THIRD GENERATION COAL GASIFICATION SYSTEMS

JULY 10, 1980

APPENDIX

SRS/SE TR80-11

SRS NAS 8-33846

spectra research systems

SOUTHEASTERN OPERATIONS
HUNTSVILLE, ALABAMA 35805

500 WYNN DRIVE, SUITE 319
(205) 830-0375

(NASA-CR-161772) ADVANCED TECHNOLOGY APPLICATIONS FOR SECOND AND THIRD GENERATION COAL GASIFICATION SYSTEMS. APPENDIX (Spectra Research Systems, Inc.) 116 p HC A06/MF A01 CSCL 21D G3/28

N81-25231

Unclas 23524

SRS

spectra research systems

SOUTHEASTERN OPERATIONS

600 WYNN DRIVE, SUITE 319, HUNTSVILLE, ALABAMA 35805

(205) 830-0375

ADVANCED TECHNOLOGY APPLICATIONS FOR SECOND AND THIRD GENERATION COAL GASIFICATION SYSTEMS

JULY 10, 1980

APPENDIX

SRS/SE TR80-11

Rodney Bradford
John D. Hyde
C. Wendell Mead

NASA CONTRACT: NAS8-33846
COR: Mr. Lott W. Brantley

XVI. APPENDIX

COAL CONVERSION PROCESS DESCRIPTIONS

CONTENTS

PROCESS DESCRIPTIONS/CONFIGURATIONS

	PAGE
CONOCO-British Gas Slagging Lurgi	1
METC Stirred Fixed Bed	11
COGAS	19
HRI Fast Fluidized Bed	28
U-GAS	32
Texaco	40
CO_2 Acceptor	49
HYGAS	55
Westinghouse	63
EXXON Catalytic	70
BI-GAS	74
Shell Koppers	83
Hydrogasification	86
Molten Salt	92
Winkler	98
Koppers-Totzek	104

BRITISH GAS/SLAGGING LURGI

SRS

DEVELOPMENT

1936 - Many variations of the Lurgi process have been developed and operated on the bench and pilot plant scale. Lurgi technology is being used in several gasifiers around the world at present.

1953-1954 - Pilot Plant at Holten, Germany

1955-1958 - Pilot Plant at Solihull, England (5.1 MMSCFD) gas production

1974 - Pilot Plant at Westfield, Scotland
British Gas Corporation - Conoco - DOE

- Planning and/or design for several U. S. plants are underway using the Lurgi process (most without DOE funding)

1977 - Contract for conceptual design was awarded by ERDA (DOE) to Conoco for a demonstration plant using the British Gas/Slagging Lurgi process. Management of the project is broken down into three phases:

Phase I - Conceptual design
Phase II - Demonstration plant design and construction
Phase III - Operation and process evaluation

1981 - Scheduled start of construction if British Gas/Slagging Lurgi project is selected for continuation

CURRENT STATUS/PROJECT GOALS (DOE FUNDING)

CONOCO and ICGG (COED/COGAS) have prepared conceptual designs of commercial-scale plants, established capacity and general concepts for the demonstration facility, performed considerable site-specific evaluations of the demonstration plants in the locations proposed, and completed the confirmatory technical support programs to validate basic data; and have developed certain business considerations for the government-contractor cost-shared plant. An evaluation of this information was undertaken in November 1978 as the basis for an evaluation between CONOCO and ICGG. A re-evaluation of the project is planned in March/April 1980 to select one of the two contractors to proceed to completion of the demonstration plant design. The project not selected may be continued at a slower pace since the funds for a second demonstration plant have been authorized.

The primary goal of this project is production of synthetic pipeline-quality gas (approximately 1,000 Btu/scf) to be used as a substitute for natural gas.

The main features of the technical approach are:

- Convert eastern coal to gas in a fixed-bed British Gas/Lurgi slagging gasifier
- British Gas Corporation (BGC)/Lurgi slagging gasifier is a major advance over dry-ash Lurgi
- Improved conversion of synthesis gas to high-Btu gas
- Product compatible with natural gas in pipeline
- Minimize environmental impact by waste products.

GASIFICATION PROCESS

The Conoco High-Btu Pipeline Gas project utilizes the slagging gasifier of the British Gas/Lurgi process. The slagging process is a modification on the existing commercial Lurgi process in that it will accept caking coals and operate at higher temperatures. The process reduces the carbon content of the molten ash stream and thereby increases the conversion of carbon in coal to gas. Carbon conversion to products is better than 99.9 percent. The process also produces less tar, phenol, and heavy hydrocarbons than the older-type commercial Lurgi coal gasification units. The tars recycled to the gasifier produce a higher yield of gas.

Sized coal is received into the gasifier through a top lock hopper. Steam and oxygen are mixed and fed into the gasifier bed through tuyers in the gasifier wall. As the coal decends the steam and oxygen pass upward through for gasifier zones (1) carbon combustion (2) gasification (3) devolitization (4) drying

Gases leaving the gasifier are scrubbed and cooled to remove some tar and oil by quenching with a gas liquor (recycled water) spray. A major portion of the crude gas then passes through a convertor to adjust the H_2 - CO ratio (a requirement for later methanation); the remainder by passes the converter.

The Lurgi Rectisol process removes the hydrogen sulfide and the carbon dioxide while the naptha and water (liquor)are removed by condensation in the purification step.

The gas then passes to the methanation step in which methane is produced from carbon monoxide and hydrogen over a fixed-bed nickel catalyst. A catalyst life study conducted in a PDU operation is expected to confirm an improved processing scheme.

The gas product is (after acid gas and CO_2 removal) compressed and dried to pipeline gas.

Ash is removed from the gasifier as the molten slag from the bottom slag tap hole. The slag is then quenched with water and is finally removed through a lock hopper.

By-products from the Rectisol process, scrubbing, condensing and acid gas removal are then processed in the water and oil clean up and sulfur plant.

In the gas liquor separator, coal fines, tar, and tar oil are removed from the water. The fines with tar and oil are recycled to extinction in the gasifiers. Naptha is also extracted in the gas separator.

The Lurgi Phenosolvan process extracts phenols from the water.

Ammonia is removed from the gas by the Phosam W process to produce aqueous ammonia.

An air separation plant will produce the oxygen used in the gasifier, a requirement for making pipeline-quality gas.

In addition to tar precipitation, oil separation, and phenol extraction processes, the Conoco Plant will include all the service sections required, such as steam production, water purification, air separation, incineration, waste treatment, as well as product loading, tankage, and buildings.

REACTANTS

Coal:

In the Conoco British Gas/Slagging Lurgi process coal is crushed, screened, and sized (1/8 in. to 1¼ in. range) and fed into a top mounted lock hopper at a rate of 3800 TPD.

Almost all coals may be processed; coals with moisture content higher than 20% and refractory ash content higher than 15% by weight require additional treatment. A dolimite flux may be added to accomodate the refractory ash.

Oxidant/Steam

Steam and oxygen are mixed in various ratios depending primarily on the type of coal being processed.

Steam: 0.25 to 0.5 lbs/lbs of moisture and ash-free (MAF) coal
Oxygen: 0.4 to 0.7 lbs/lbs of MAF coal

Sample operating results at Westfield, Scotland Plant were

Steam: 0.41 lbs/lbs of MAF coal (Pittsburgh No. 8)
Oxygen: 0.56 lbs/lbs of MAF coal

PRODUCTS

Gas:

Projected Conoco SNG Composition

Component	Mol %
Methane	85.99
Hydrogen	9.70
Carbon Monoxide	0.05
Carbon Dioxide	3.18
Nitrogen	1.07
Water	0.01

Higher Heating Value	902.6 Btu/SCF
Available at	1012 psig and 105°F

By-Products:

	(sample) per ton of coal
Tar Products	13.9 gal.
Naptha	2.6 gal.
Ammonia Solution	8.4 gal.
Crude Phenol	1.1

Projected output of demonstration plant:

	Baseline	Ohio No. 9
Coal Feed (t/d)	1270	1256
Prime Product Gas (Mscf/d)	19	19.0
Naphtha (bbl/d)	108	145.9
Fuel Oils (bbl/d)	38	197.9
Sulfur (t/d)	56	54.2
Ammonia (t/d)	4.5	8.2

Waste:

- Water
- Slag frit
- Acid gases

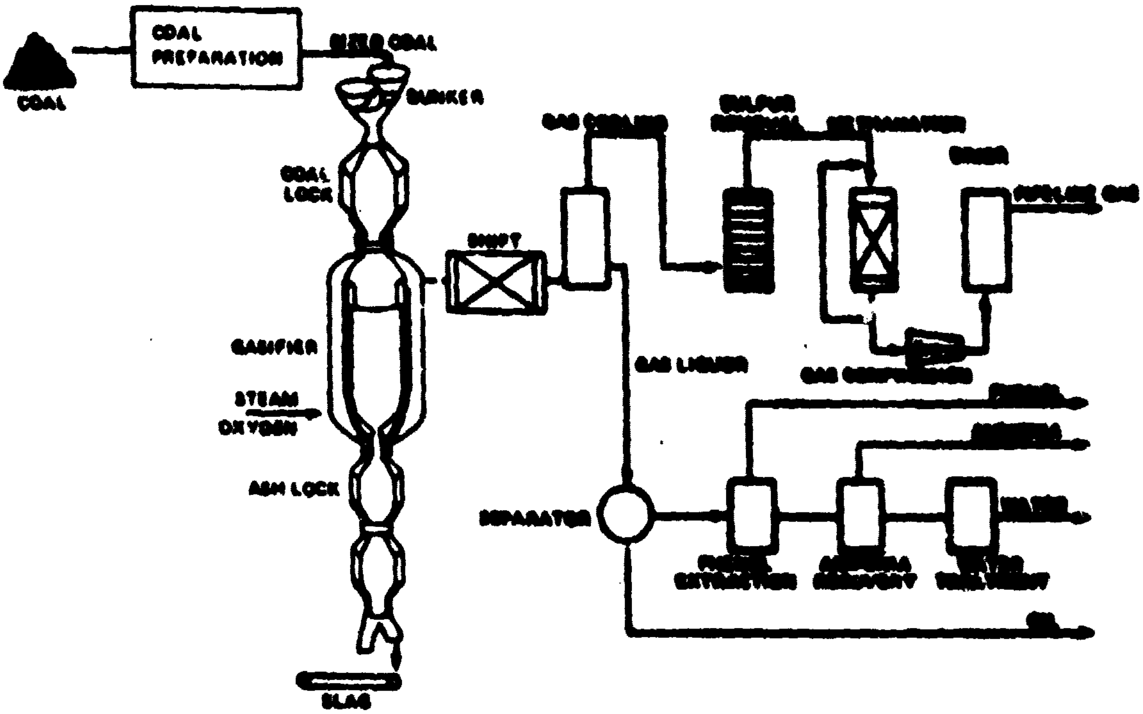
SAMPLE OF SLAGGING LURGI GASIFIER OPERATION

(BEFORE METHANATION)

Coal	Donisthorpe
Run number	Test 67
Dates of investigation	Prior 1964
Longest continuous period of operation, Hours	81
Coal processed, tons	281
Input Flows	
Coal, lb./hr.	6930
Oxygen, scfh	47,000
Steam, lb./hr.	2140
Product Output Per Ton of Dry Coal	
Tar, gal.	15.4
Gas scf	68,800
Liquor ton	0.25
Feed Coal Content	
Coal moisture as received, wt.%	12.7
Coal ash content (including flux) %	11.4

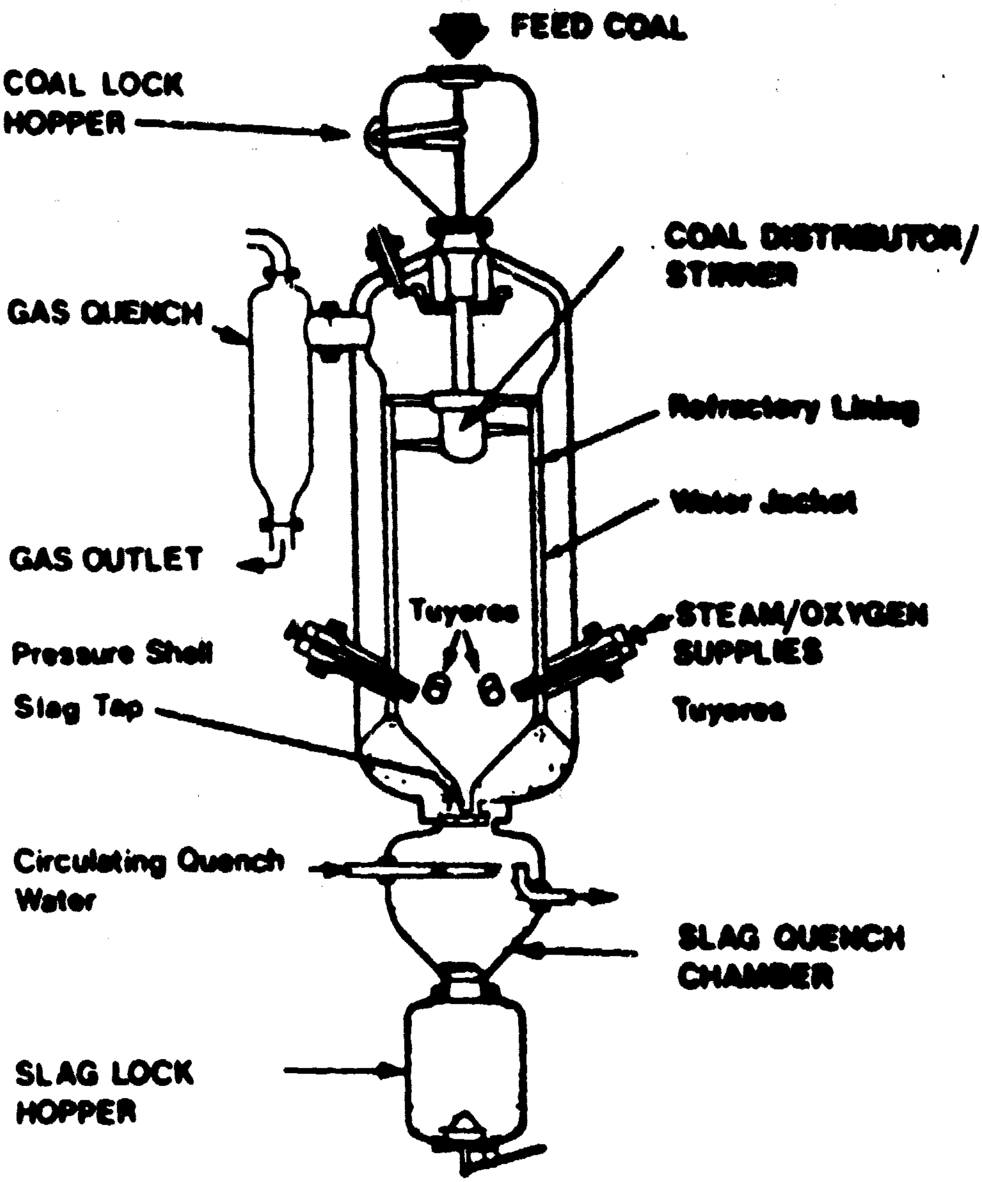
TYPICAL PROPERTIES OF FEED COAL

Elemental Analysis	Weight % Dry
Carbon	76.7
Hydrogen	5.7
Nitrogen	1.4
Sulfur	1.0
Oxygen	15.2
Trace Compounds	1.0
Coal Feed Analysis	
Moisture, Weight %	16.5
Ash Weight %	16.5
HHV Average Btu/lb.	8870
Ash Flow Point	2723 °F



British Gas/Slagging Lurgi Process

ORIGINAL PAGE IS
OF POOR QUALITY



BRITISH GAS/SLAGGING LURGI GASIFIER

METC

STIRRED FIXED BED

SRS

DEVELOPMENT

Prior 1965 - McDowell-Wellman Engr. Co. of Cleveland, Ohio developed the Wellman - Galusha process that has been used in commercial use for over 35 years.

1967 - METC installed an atmospheric stirred fixed bed gasifier in Morgantown W. V. that was built by McDowell-Wellman. Operation began in 1967. (20 TPD capacity)

1972 - METC gasifier upgraded to 300 psig operation

1972-Present - METC operation has been continually upgraded to process many types of coal

CURRENT STATUS/PROJECT GOALS

Improvements in the gasifier and its support systems have resulted in a versatile system for the study of fixed-bed gasification phenomena. A recently completed Holmes-Stretford gas cleanup system will provide increased capabilities to perform complex fixed-bed test programs on a pilot plant scale. The data from these studies can be used to design fixed-bed gasification systems capable of operating in caking coals containing large percentages of fine material. In addition, these data taken with sophisticated instrumentation systems will contribute greatly to the understanding of coal gasification phenomena.

During FY 1980, the new Holmes-Stretford system will be connected and made operational. Concurrent with this activity the operation of the gasifier will be continued to further explore the parameters that control the gasification process. The movable stirrer will be used to the maximum advantage in these studies.

During FY 1981, METC will continue data acquisition with the objective of obtaining the engineering and operability data that are required for equipment evaluation and scale-up of fixed-bed gasifiers. In addition, METC will install and test a tar combustor and a dirty water evaporator integrating both into the fixed-bed gasifier pilot plant.

PROCESS DESCRIPTION

The METC gas producer, has inside dimensions of 3.5 feet in diameter by 24 feet long. The lower portion of the steel shell is water jacketed, while the upper section is expanded and lined with refractory to the same inner diameter as the lower portion. The fuel bed, which is normally kept at a depth of about 6 to 8 feet is supported on a rotating grate. The grate is made up of three flat circular plates, spread eccentrically one above the other. The rotation of the grate pushed the ash horizontally between the plates so that it can drop through holes in the lower two plates. Ash is withdrawn by use of a lock hopper.

The gasifier is equipped with a vertical stirrer in the center. Cooling water inside the shaft and the 2 lower horizontal agitators of the stirrer. The third agitator arm is not cooled and is used to level the bed.

Coal is stored in two adjacent silos and carried by a belt conveyor and a bucket elevator to the two lock hoppers located near the top of the producer. Once fed, the coal progresses down through the bed until the residue is discharged through the grate and subsequently lock hoppered out of the system.

Air is mixed with superheated steam and introduced into the producer below the grate. The air rate, to a large degree, controls the temperature.

The product gas, after leaving through a side outlet in the dome , passes through the first of two fixed-diameter orifices that are used to control system back pressure. The gas then flows through a cyclone separator which removes most of the entrained dust, then through the second pressure letdown orifice. The main flow of gas proceeds through a series of mufflers to an atmospheric flare, while a small fraction is diverted, cooled, cleaned of dust, tar, and water, metered, and analyzed by gas chromatographs for carbon monoxide, carbon dioxide, hydrogen, methane, nitrogen sulfide, and oxygen.

REACTANTS

Coal:

Requirements vary from sized coal (50% less than ½ in.) to run of mine coal. Both caking and non-caking coals have been tested. Coal is not pre-dried and is fed from pressurized lock hoppers by a continuous screw feed system.

Oxidant:

Air (mixed with super heated steam) is fed into the gasifier below the grate at a rate of about 2.7 to 3.6 lbs/lb of coal

Steam:

Steam feed rate varies from about 0.3 to 0.8 lbs/lb of coal.

In a commercial plant steam would be generated in the gasifier water jacket.

PRODUCTS

Gas:

Range of gas composition (dry bases after gas scrubbing and cooling

Mole %	CO	13-24
	CO_2	6.5-14
	H_2	11-18
	CH_4	0.5-3
	H_2S	0.2-0.9
	N_2	51.5-59.3
HHV, Btu/scf, dry		100-170

Typical production of about 2 million scfh

By-Products:

About 70 lbs of tar per ton of coal in pilot plant

In a commercial plant the gas from the cyclone would be contained in the condensate. Various products would then be separated for commercial uses.

Waste:

Ash (low carbon) dosposed by landfill

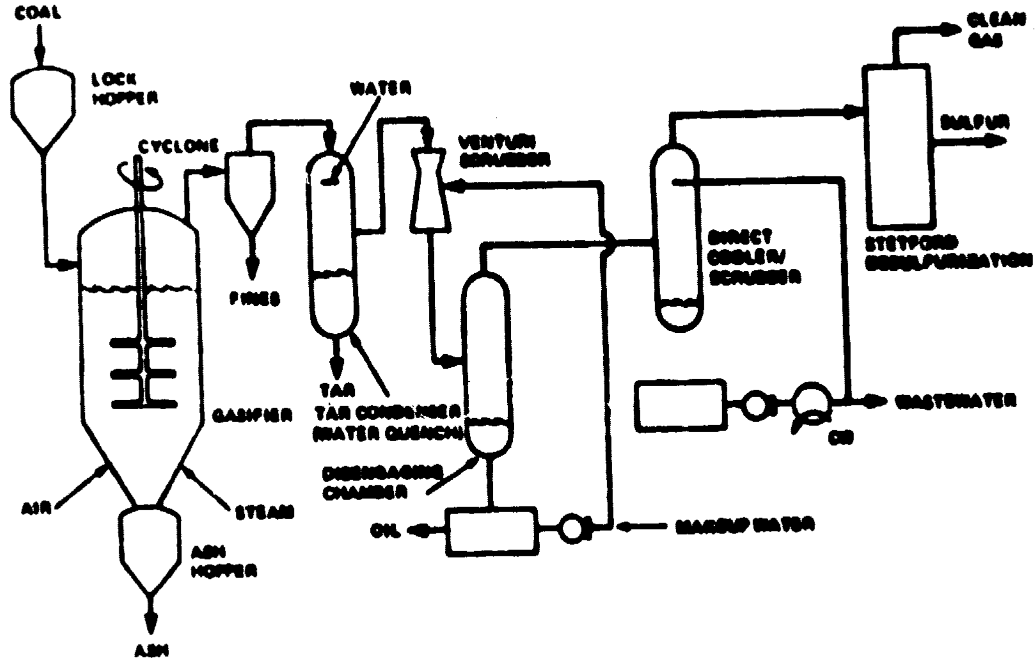
Waste Water
Some of the tars and oils are waste for pilot plant scale but would not be for commercial operation

TYPICAL ANALYSIS OF COAL TESTED

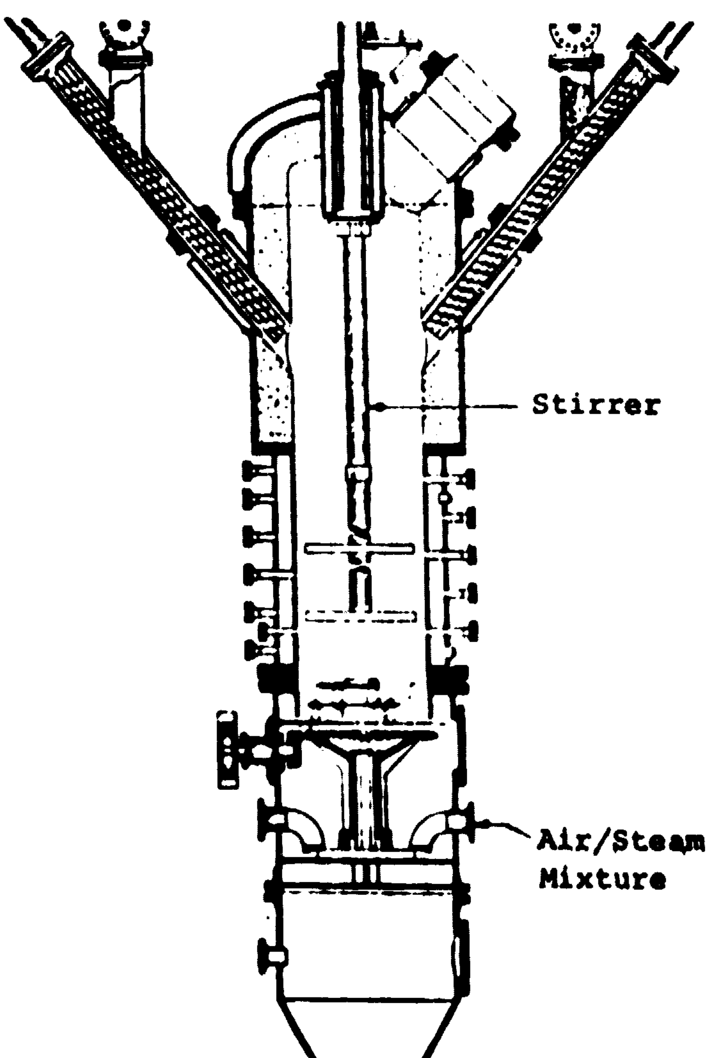
Coal Type	Ohio #8	Illinois #6
Run Numbers	31,32	39,82,83
Dates of Investigations	10-69	9-70, 6-76
Longest Continuous Period of Operation (hrs)	44	73
Total Operation (hrs)	124	148
Analysis, Percent		
Ultimate		
Carbon	70.3	65.7
Hydrogen	5.0	4.8
Nitrogen	1.1	1.7
Sulfur	4.3	3.7
Oxygen	11.2	12.9
Ash	8.1	11.2
Proximate		
Moisture	4.3	5.2
Volatile Matter	40.2	36.1
Fixed Carbon	47.4	47.5
Ash	8.1	11.2
HHV (Btu/16)	12,900	11,750
FSI (free swelling index)	5	4½
ASH FUSION TEMP. °F		
Initial Deformation	2,135	2,230
Softening Point	2,200	2,350
Fusion Point	2,260	2,440

TYPICAL OPERATING DATA

Coal	Ohio #8	Illinois #6	
Pressure, psig	80	0	144
Input, lb/hr			
Coal	1382	1030	1401
Air	4594	2550	3894
Steam	600	322	668
Input Ratios, lb/lb			
Steam: Coal	.4	.3	.5
Air: Coal	3.3	2.3	2.8
Output, lb/hr			
Ash	105	69	154
Cyclone Dust	9	28	23
Gas	7460	3322	4965
Tar		23	35
Water		242	
Gas Yield			
MSCFH	97.0	44.2	76.9
SCF/lb Coal, as rec. basis	70.2	47.0	54.8
Gas Analysis (Mole %)			
CO	20.4	21.8	18.2
CO_2	6.8	6.9	10.6
N_2	54.7	51.5	52.3
H_2	14.0	17.8	15.6
CH_4	2.0	2.0	2.4
C_2H_6		.2	.0
H_2S		.2	.7
O_2	1.1	.0	.0
Heating Value Btu/SCF	148	153	138
Cold Gas Efficiency	81	56	65
Throughput lb/hr/ft^2 grate	144	107	146



STIRRED FIXED BED GASIFICATION PROCESS



GASIFIER

COGAS

SRS

DEVELOPMENT:

1962-1966 - Office of Coal Research/FMC Corporation 2 TPD PDU Princeton, N. J. called "COED" (Char Oil Energy Development) process of four pyrolyzers

1970-1975 - 36 TPD Pilot Plant COED pyrolyzer process Princeton, N. J.

1974-1978 - 50 TPD char gasifier Pilot Plant by Cogas Development Co. at Leatherhead, England. Plant used COED pyrolyzer plus the Cogas two-stage steam/air blown gasifier

1977 - Contract for conceptual design was awarded by ERDA to ICGG for a demonstration plant using the COED/COGAS process. Management of the project is broken down into three phases:

Phase I - Conceptual design
Phase II - Demonstration plant design and construction
Phase III - Operation and process evaluation

1981 - Scheduled start of construction if ICGG-COGAS project is selected for continuation

1976-1978 - Grand Forks Energy Technology Center (GFETC) - DOE (ERDA) sponsored the operation of a slagging fixed-bed facility (approx. 0.5 Ton/$_{hr.}$) that was operated from 1958-1966 by the Bureau of Mines.

1978 - GFETC stopped operation to update and modify the facility. This was accomplished in 1979.

1980 - Shakedown to be accomplished in 1980

CURRENT STATUS/PROJECT GOALS

ICGG and CONOCO (British Gas/Slagging Lurgi) have prepared conceptual designs of commercial-scale plants, established capacity and general concepts for the demonstration facility, performed considerable site-specific evaluations of the demonstration plants in the locations proposed, and completed the confirmatory technical support programs to validate basic data; and have developed certain business considerations for the government-contractor cost-shared plant. An evaluation of this information was undertaken in November 1978 as the basis for an evaluation between CONOCO and ICGG. An re-evaluation of the project is planned in March/April 1980 to select one of the two contractors to proceed to completion of the demonstration plant design. The project not selected may be continued at a slower pace since the funds for a second demonstration plant have been authorized.

The primary goal of this project is production of synthetic pipeline-quality gas (approximately 1,000 Btu/scf) to be used as a substitute for natural gas.

The main features of the technical approach are:

- Convert coal to liquids (low-sulfur fuel No. 2 and No. 6 oil equivalents) and char; convert char to synthesis gas
- Apply COGAS gasifier (high-efficiency, low-pressure) development
- Convert synthesis gas efficiently to high-BTU gas
- Produce gas and liquid products compatible with market standards
- Minimize environmental impact of waste products.

PYROLYSIS/GASIFICATION PROCESS

Dried crushed coal is treated in three (and in some cases four) fluidized-bed stages at successively higher temperatures until the major fraction of the volatile matter of the coal is volatilized. Heat for this pyrolysis is obtained from the gasifier by burning a portion of the char with air. Air is rejected as a slag "frit" from the combustor section of the gasifier. Hot gases from the gasifier then flow counter-currently to the coal and constitute the fluidizing gas and heat supply for the third and second stages in order. Hot char from the last stage may be recycled to supplement the heat from the gases. The first-stage fluidizing medium is supplied as flue gas from the gasifier where a portion of the char is burned with air. The char product of pyrolysis is fed to the gasifier. The raw oil is upgraded by hydrogenation to a high-grade naptha and synthetic low-sulfur No. 2 and No. 6 fuel oils. The hydrogen for this oil hydro-treating is supplied by reforming a portion of the product gas. The synthesis gas from the oil recovery is compressed to inter-mediate pressure and cleaned to reduce particulates and sulfur compounds to a level acceptable for methanation. The resultant product gas is then methanated, dried, and compressed for utilization as a pipeline gas.

Raw synthesis and oil vapor from the first two pyrolysis stages are water scrubbed and quenched to condense out the raw oil. Liquor from the oil recovery is sent to waste treatment after passing thru ammonia recovery. The hot flue gas from the combustor rises through the lift tube and heats the entrained circulating char. The char stream is separated from the flue gas at the top of the lift tube. The char is then fed to the gasifier. The flue gas, after passing through cyclones, is cooled in a waste heat boiler to produce high pressure superheated steam which is expanded through power recovery turbines. The flue gas is then used in coal driers and preheat the feed coal.

The molten slag flows out of the bottom of the combustor into a slag quench tank, where circulating water quenches the slag to a solid form. It is then settled and sent to disposal.

REACTANTS

Coal:

In the ICGG/Cogas process coal is fed to the pyrolyzers at a rate of about 2200 TPD. The feed coal must be crushed to less than 1/8 in.. Since the gasifier is of fluid bed type, with a series of fluid bed pyrolyzers, it is expected that it will accept all types of coal. No limits are set on the moisture content of the coal, since the process includes a drier which prepares the coal for processing.

The low temperature of the fluidized beds will preclude ash fusion problems for most coals. Coals with ash fusion temperatures greater than 2600°F will require addition of a fluxing agent in the char combustor which is a slagging type.

Oxidant:

Air is fed to the combustor at a rate of 4.5 to 5.0 tons of air per ton of coal to the pyrolyzers.

Steam:

Steam is fed to the gasifier at a rate of 1.0 tons of steam per ton of coal to the pyrolyzers.

PRODUCTS

Gas:

Projected COGAS SNG Composition

Component	Mol %
Methane	91.5
Carbon Dioxide	0.1
Hydrogen	0.4
Inerts	5.0
C_2-C_4	3.0

Higher Heating Value 950.00 BTU/SCF

By-Products:

	(sample) per ton of coal
Sulfur	45 lbs
Light hydrocarbons (sulfur free)	35 lbs
Ammonia	8 lbs
Syncrude (low sulfur fuel oil)	1 bbl

Projected output of demonstration plant:

	Baseline	Illinois No. 6
Coal feed (t/d)	2210	2210
Prime product gas (Mscf/d)	23.2	23.2
Naphtha (bbl/d)	360	390
Fuel oils (bbl/d)	1543	1543
Sulfur (t/d)	69.5	56.3
Ammonia (t.d)	3.7	8.7

Waste:

- Slag
- Sour water
- Acid gases

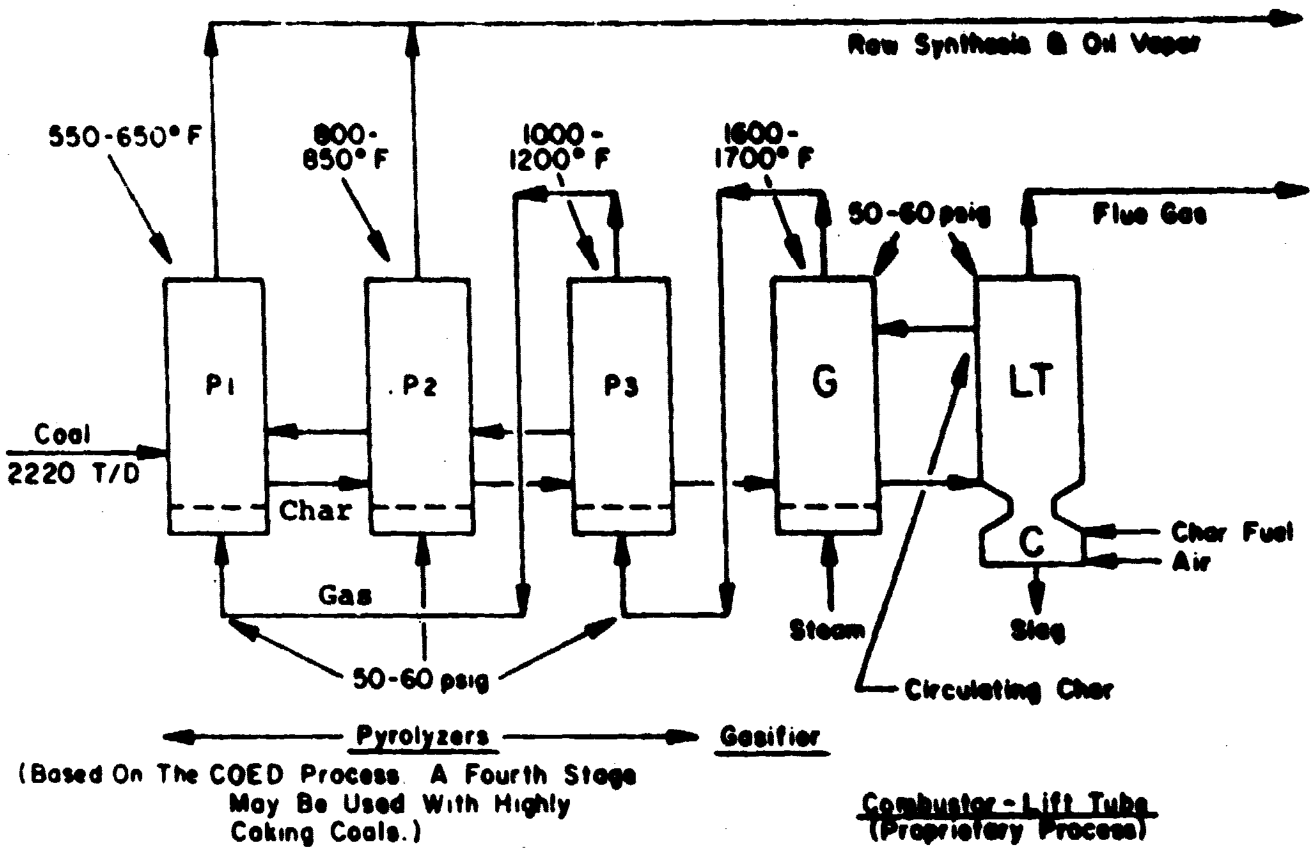
TYPICAL PROPERTIES OF COED PYROLYSIS OILS

Coal Source	Illinois No. 6-Seam
Properties of Derived Oil	
Elemental Analysis	
Weight % dry	
Carbon	79.6
Hydrogen	7.1
Nitrogen	1.1
Sulfur	2.8
Oxygen	8.5
Ash	0.9
API Gravity, 60 °F	-4
Moisture, Weight %	0.8
Pour Point, °F	100
Viscosity, SUS 210 °F	1333
Solids, wt. % dry basis	4.0
Gross Heating Value, Btu/lb.	15,050

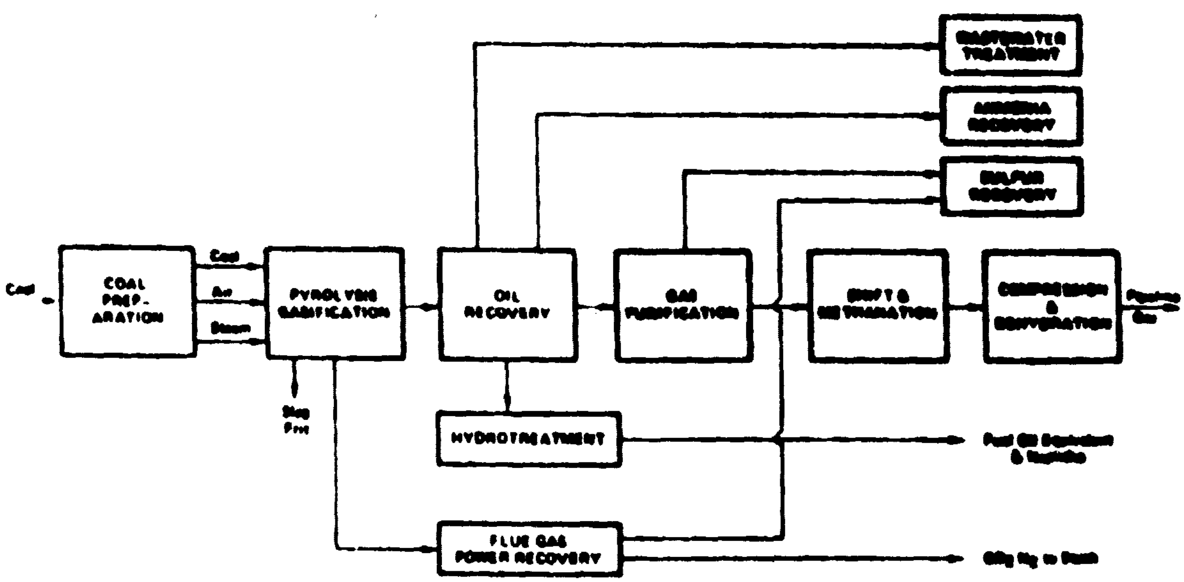
SAMPLE OF PYROLYSIS OPERATIONS

COED PROCESS

Coal	Illinois No. 6 - Seam High Volatile C-Bituminous
Run numbers	P-43B - P-46
Dates of investigation	12/28/73 - 2/4/74
Longest continuous period of operation, days	6
Coal processed, tons	514
Pyrolyzer Temperatures, °F	
Stage 1	350-420
Stage 2	800-830
Stage 3	990-1100
Stage 4	1445-1545
Input Flows	
Coal to stage 1, lb./hr. (wet)	1409-2570
Oxygen to stage 4, scfh	2815-3250
Steam to Stage 4, lb./hr.	450-525
Nitrogen to stage 4, scfh	0
Nitrogen to stage 4 off-gas, scfh	0
Product output per ton of dry coal	
Oil, bbl.	1.11-1.14
Char, lb.	1170-1280
Gas (N_2, CO_2, H_2S, H_2O-free) scf	4823-12580
Liquor gal.	18.3
Coal moisture as received, wt.%	11.4-12.0



PYROLYSIS/GASIFICATION PROCESS



COGAS Technical Process — ICGC

HRI FAST FLUIDIZED BED

SRS

DEVELOPMENTS

1960's	Hydrocarbon Research, Inc. (HRI) operated a 750 Mscfd gasifier
1977	DOE (ERDA) Funding began on HRI 600 lb/hr PDU at Trenton, N. J.

CURRENT STATUS/PROJECT GOALS

The fast fluidized bed process now being tested at HRI is a process that was developed by A. M. Squires, City College, New York.

Testing is being done on higher temperature operation using various coals at 600 lb/hr. rate in FY 1980. Operational funding may continue into FY 1981.

The overall program plan is to develop a low- or intermediate-Btu coal gasifier which uses the principles of fast fluid bed operation to achieve a much higher throughput and better turndown capability than conventional fluid bed gasifiers.

REACTANTS

Coal:

Coal (-20 mesh) is fed pneumatically into the lower section of the gasifier. Test have been run on Eastern (caking) coals.

Oxidant:

Air (quantity not available)

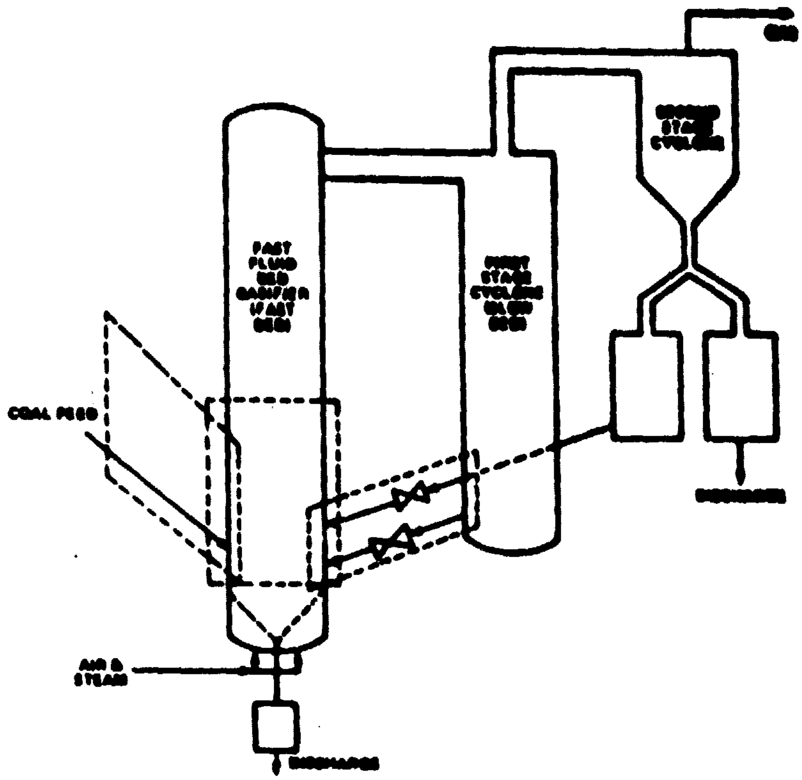
Steam:

(Quantity not available)

GASIFICATION PROCESS

In the fast fluid-bed process, -20 mesh coal is fed into the lower section of the fast fluid-bed gasifier. The incoming coal is mixed with char fed from a companion slow fluid-bed gasifier at a rate of ten parts char to one part feed coal. The coal reacts with air and steam fed into the bottom of the generator.

The gas/solids from the gasifier pass through a primary cyclone to remove practically all solids, which are then discharged into the nitrogen-gas charged fluidized-bed reactor directly below. The char from the slow bed reactor is then fed into the fast fluid-bed reactor via a transfer leg. Ash from the fast fluid-bed reactor drops to the bottom and is discharged. Gas and particulates from the primary cyclone are passed on to a secondary cyclone for further separation. Product gas is low-Btu gas.



HRI FAST FLUIDIZED BED PROCESS

ORIGINAL PAGE
OF POOR QUALITY

U-GAS

DEVELOPMENT

1945	Institute of Gas Technology (IGT) began studies that later led to U-Gas process.
1947	6 in. diameter fluidized bed reactor to investigate coal gasification. At about the same time a cyclone reactor was used to gasify coal.
1950-53	An 18 TPD plant was constructed in Chicago, Ill. for medium-BTU coal gasification. Studies were made at this plant until 1953. The process featured a flash pulverizer and a slagging gasifier.
1964-73	IGT continued research and development for both the U-Gas and the HYGAS (High-BTU) processes. PDU operations were utilized for these studies.
1974	Pilot plant (6 TPD) began operation in Chicago by IGT. The plant was operated until 1977 with Office of Coal Research and Dept. of Interior funds as part of the HYGAS project.
1978-present	Pilot plant has been operated under DOE and Memphis Light, Gas & Water Industrial Fuel Gas Demonstration Plant Program.
1978	Memphis Light, Gas & Water was awarded a contract by DOE for conceptual design of a 2800 TPD (175 MMCFD low/med. Btu gas) demonstration plant to be located near Memphis, Tn.

CURRENT STATUS/PROJECT GOALS

IGT is continuing operation of its 6 TPD pilot plant under DOE sponsorship.

The Memphis Phase I conceptual design effort was completed in December 1979. An evaluation and a GO/NO GO decision to proceed beyond Phase I was made during the second quarter of FY 1980. Development of the environmental impact statement continued through FY 1980 and is ready for final issue. Fifty million dollars in deferred prior year funds will carry the program through FY 1980 and one project into FY 1981. Additional funds will be required in FY 1981 to maintain schedule.

Operation of the plant is slated for 1984. Foster Wheeler is the A/E and construction manager and IGT is the process developer.

This project will lead to the operation of an industrial-user-dedicated plant to produce and deliver to Memphis industrial consumers, via a pipeline system, 175 MMscfd (equivalent to about 50 MMscfd of natural gas).

GASIFICATION PROCESS

The coal, steam and oxygen (or air) are injected into the fluidized bed gasifier. The bed operates at 50-350 psig and about 1900 °F (the temperature depends on the type of coal feed but is set to maintain non-slagging conditions).

The gases leaving the gasifier are passed through heat exchangers for heat recovery and fed to a venturi scrubber for the removal of ammonia, hydrogen sulfide, and coal dust. The fuel gas is then compressed to 195 psig and treated in a Seloxol acid-gas absorption process to remove essentially all of the hydrogen sulfide and organic sulfur compounds and part of the carbon dioxide. The purified gas from the Selexol unit is ready for distribution.

Simultaneous with coal gasification, the ash is agglomerated into larger and heavier particles by creating a hot zone within the fluidized bed. The temperature in the hot zone is close to the ash-softening point of the specified coal. Under these conditions, ash particles are agglomerated, and increase in size until they are heavy enough to fall through the rising gases and the agglomerates are then removed from the gasifier through a lock hopper system.

Coal fines - either from attrition or present in the coal feed - are carried with the product gas as it leaves the gasifier. The fines are removed from the hot gases by cyclones and are returned to the ash-agglomerating hot zone within the fluidized-bed. Here, they are gasified, agglomerated with the bed ash, and eventually discharged with ash agglomerates.

Acid gas from the Selexol unit contains hydrogen sulfide and is fed to a conventional Claus process. In the Claus unit the H_2S is partially oxidized to form elemental sulfur and water. The off-gas from the Claus unit, is processed to a SCOT tail-gas unit, to recover remaining H_2S and recycle it back to the Claus plant. The off-gas from the SCOT process is environmentally acceptable to vent.

REACTANTS

Coal:

The raw feed coal is first crushed to less than 1/4 inch and is pneumatically injected into the gasifier via lock-hoppers. Lignite, or non-caking subbituminous coals can then be fed directly to the gasifier. Caking coals require pretreatment by contact with air in a fluidized-bed reactor operating at gasifier pressure and approximately 700-800°F. This pretreatment step forms an oxidized layer on the surface of the coal particles, thus preventing agglomeration in the gasifier.

The moisture content of the coal can affect the crushed coal flow, but almost any moisture content coal can be processed.

The ash sofening and fusion points of the ash influence the temperature in the ash agglomerating zone of the gasifier.

Oxidant:

Air and steam are mixed with coal to feed the gasifier. Air is fed at a rate of 2.8 to 3.3 ton/ton coal. If oxygen feed is used the requirement is 0.55 ton/ton coal.

Steam:

0.2 to 0.6 ton/ton coal is required for mixing with coal and air at gasifier pressure.

PRODUCTS

Gas:

Typical product gas composition
(oxygen blown)

Feed Coal	Subbituminous
HHV of coal, Btu/lb (dry)	11,290
Gas composition, mole %	
CO	41.4
CO_2	16.1
H_2	35.8
CH_4	5.9
H_2S + COS	0.2
N_2 + Ar	0.6
	100.00
HHV, Btu/scf (dry gas)	320
Gas rate, Mscf per ton of coal	44

By-Products:

Steam for some processes (amount not available)

Sulfur (89 TPD in 2800 TPD coal feed plant)

Waste:

Ash (450 TPD in 2800 TPD coal feed)

Waste water

SAMPLE OF U-GAS OPERATION

Coal

Run number	130, 131, 132, 133
Dates of investigation	11/78 - 2/79
Longest continuous period of operation, Hours	153
Coal processed, tons (total all runs)	309

Input Flows

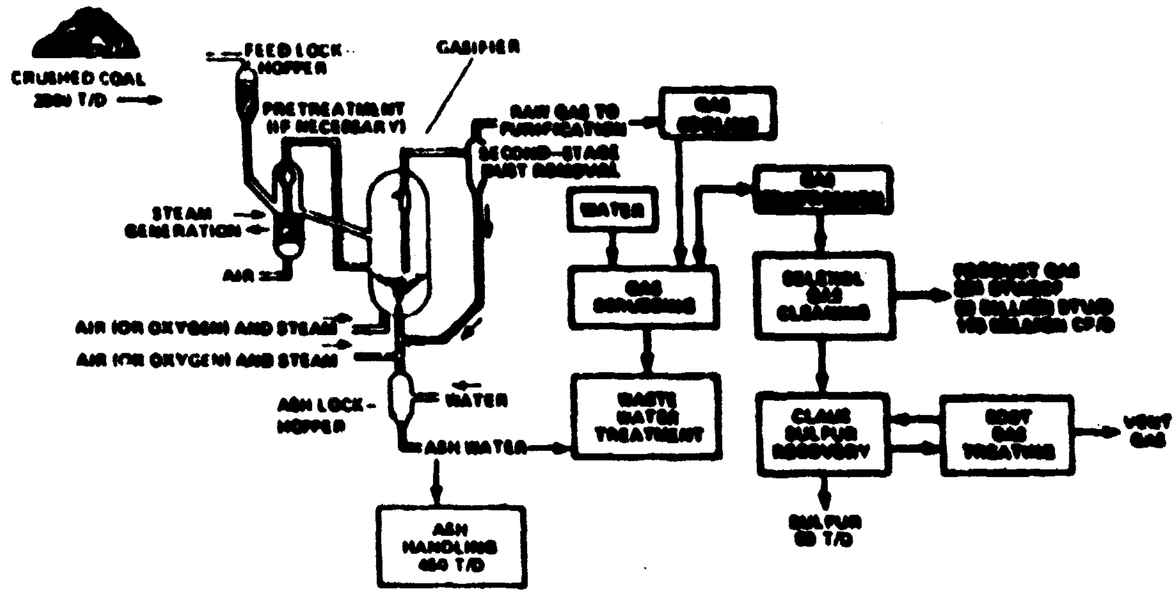
Coal, lb./hr.	1500
Air, lb./hr.	750
Water (BFW) gal/ton of coal	710

TYPICAL PROPERTIES OF FEED COAL

	Bituminous Coal	
	Rom	Washed
Fixed Carbon	46.0	50.6
Volatile Matter	34.8	37.3
Ash	19.2	12.1
Sulfur	4.6	3.1
FSI	5.6	4.7

Coal Feed Analysis

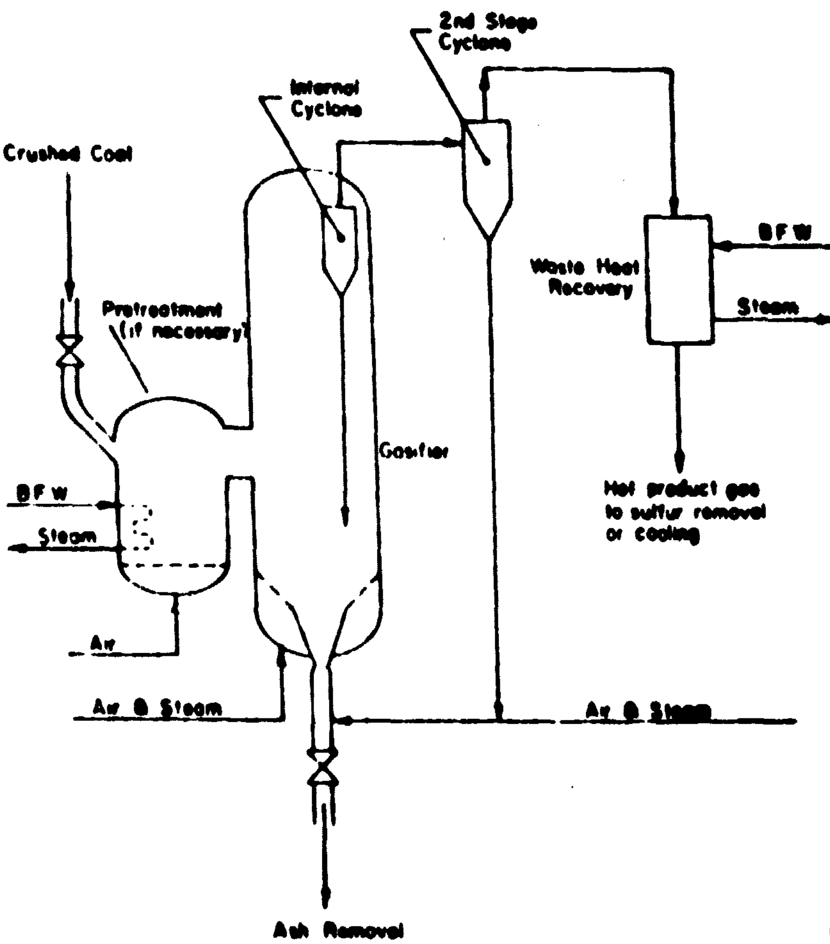
HHV Average Btu/lb.	8870
Ash Flow Point	2723°F



U-GAS PROCESS

LOW-BTU FUEL GAS DEMONSTRATION PLANT

(MEMPHIS)



U-GAS GASIFIER

TEXACO

DEVELOPMENT

1945	Texaco developed the TSGGP (Texaco synthesis gas generation process) at Montebello, CA. Over 75 plants involving some 160 gasifiers have been licensed since 1950.
1953	First commercial plant operation of the TSGGP
1948	Texaco began development TCGP (Texaco coal gasification process). This process evolved from the TSGGP
1956-58	A semi-commercial (demonstration) plant operated at the Olin Mathieson Chemical Plant in Morgantown, W. V. (100 TPD coal feed - 300 psig gasifier).
1977-80	Conceptual design by W. R. Grace & Company (DOE Funding) of a 1700 TPD (coal feed) demonstration plant using Texaco gasifiers for the production of 1200 TPD ammonia at Baskett, KY.
1978-80	Design and construction for TVA by Brown & Root of a 170 TPD (coal feed) plant to produce 135 TPD ammonia at Muscle Shoals, AL.
1979	TVA began siting and conceptual design studies for a 20,000 TPD medium BTU commercial scale demonstration plant for North Alabama (Texaco gasifier under consideration)
Current -	Texaco operates a 15 TPD (coal feed) high pressure pilot plant at Montebello, CA.
-	A 160 TPD pilot plant recently completed in Essen, West Germany is in operation.

CURRENT STATUS/PROJECT GOALS

W. R. Grace & Co. (Industrial Fuel Gas Demonstration Plant Project):

Conceptual design was completed in FY 1980. There was competition for the continuation of this project by Memphis light, gas & water on a similar design using the U-gas process. However, W. R. Grace retooled its project from medium-BTU gas to synthetic gasoline production. DOE has provided funding for continuation of both projects. The W. R. Grace project will employ the Texaco gasifier and the Mobil-M gasoline process to produce about 50,000 bbl/day of high-octane gasoline.

TVA Ammonia from Coal Project:

Plant construction should be started by mid 1980. Brown & Root is the contractor for the construction of the 8 TPH Texaco process gasifier and the Air Separation Plant is being installed by Air Products and Chemicals, Inc. The remainder of the work will be done by TVA.

The coal gasifier will provide 60% of the gas feed to the existing ammonia plant. A three year period of demonstration is planned for the project.

Texaco is operating its Montebello, CA. Pilot Plant and West Germany facilities without federal funding.

GASIFICATION PROCESS

The coal is gasified by reaction with steam and by partial oxidation in an entrained flow slagging gasifier. The gas formed in the gasifier flows downward and is quenched with water just beneath the partial oxidation combustion chamber of the gasifier. The quenched and steam saturated synthesis gas leaving the gasifier still contains small amounts of particulate matter which must be removed by a final water scrubbing.

An alternate method for cooling the product gas is also available. In this option, the gas leaves the gasifier unquenched at an elevated temperature and passes through a gas cooler where high pressure steam is genérated. Selection between the two methods for gas cooling often hinges upon the ultimate disposition of the product gas.

The gas cooler option is generally used when there is no need for steam in the synthesis gas, such as the production of clean fuels. The remainder of the Texaco process system is similar except for a different routing of some of the water streams since the synthesis gas leaving the gas cooler usually contains a higher level of particulates than the synthesis gas leaving the water quench and thus a more thorough final water scrubbing must be employed.

The direct quench mode is generally selected for such end uses as the production of high purity hydrogen and ammonia, where the steam is necessary for the reaction to convert carbon monoxide to additional hydrogen. After leaving the water scrubber the synthesis gas goes directly to the shift converter to produce the additional hydrogen.

The synthesis gas then goes to acid gas removal step where carbon dioxide and hydrogen sulfide are removed.

The molten slag (with hot gas) leaving the combustion chamber is quenched. The slag is quenched and the solidified slag is removed through a series of lock hoppers.

The water stream that results from the operations such as the quenching and scrubbing steps is treated and a portion of the sediments are recycled to the slurry feed to the gasifier.

REACTANTS

Coal:

Pulverized coal is passed through a screening step then slurried with water and pumped to the gasifier (the slurry is preheated before entering the gasifier). The coal slurry (about 60% coal by weight) enters the gasifier at the top through the steam-coal nozzle.

Bituminous coals and lignites have been tested and coal of virtually any moisture content can be processed. Up to 150 TPD coal feed has been processed in existing plants.

Oxidant:

Oxygen (preheated) is fed to the gasifier through a water cooled burner near the steam-coal nozzle at a rate of about 0.8 lb/lb of coal

Steam:

Provided by the water in the slurry. Excess steam is produced and a separated in a cyclone

PRODUCTS

Gas:

Typical gas composition
after quenching and scrubbing
(oxygen-blown gasifier)

Feed Coal	Illinois No. 6
HHV of coal, Btu/lb (dry)	13,150
Gas composition, mole %	
CO	37.6
CO_2	20.8
H_2	39.0
CH_4	0.5
H_2S	1.5
N_2 + Ar	0.6
	100.0
HHV of gas, Btu/scf (dry)	253
Gas volume, Mscf per ton of coal feed	53

By-Products:

Steam (amount not available)

Waste:

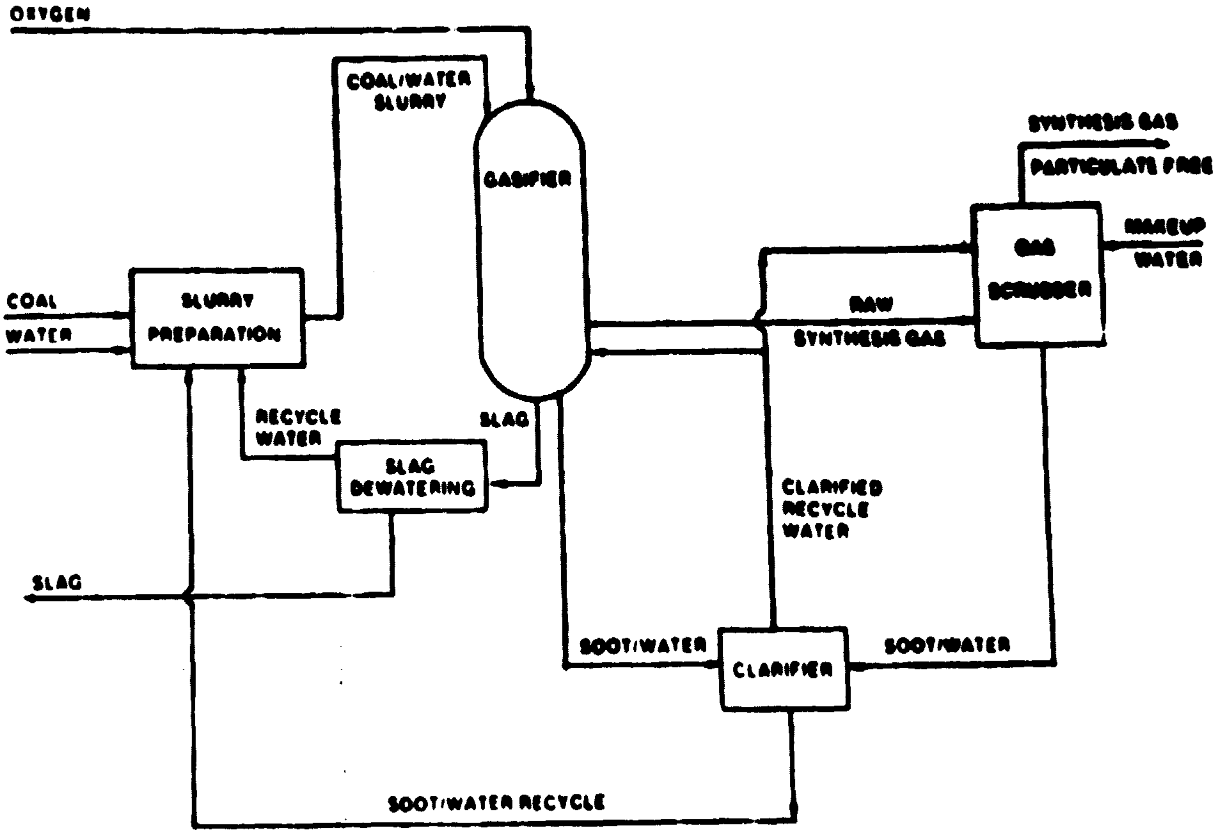
Waste water

SAMPLE TEXACO PROCESS PERFORMANCE

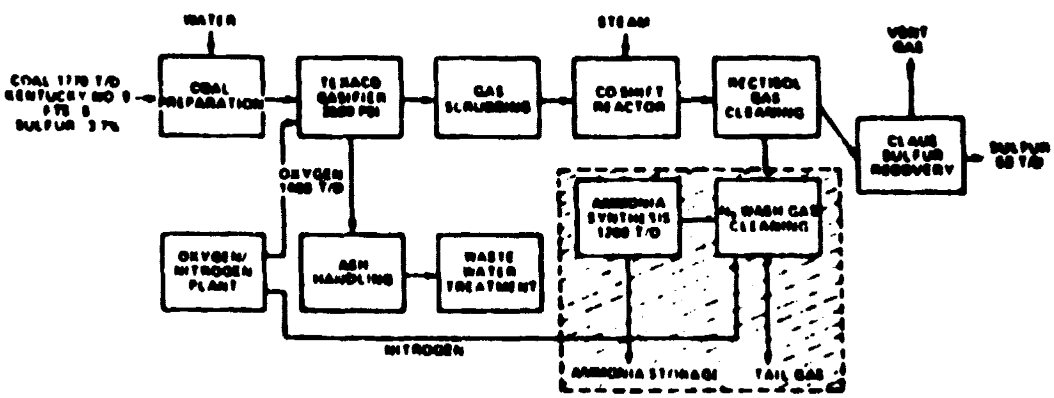
Feed Coal	Eastern Coal
Oxidant	Oxygen
Slurry Solids Loading, %	56.0
Fuel Flow, lbs/hr.	1059
Moderator Flow, lbs/hr.	831.95
Moderator	Water
Oxidant, scf.hr.	28,600
Dry Product Gas, scf/hr.	33,300
Product Gas Composition (Volume % dry basis)	
H_2	36.15
CO	41.55
CO_2	20.64
N_2	.38
CH_4	.40
H_2S	.80
COS	.05
High Heating Value, BTU/scf (H_2S and COS-free basis)	257
Cold Gas Efficiency, %	66.0

TYPICAL FEED COAL PROPERTIES

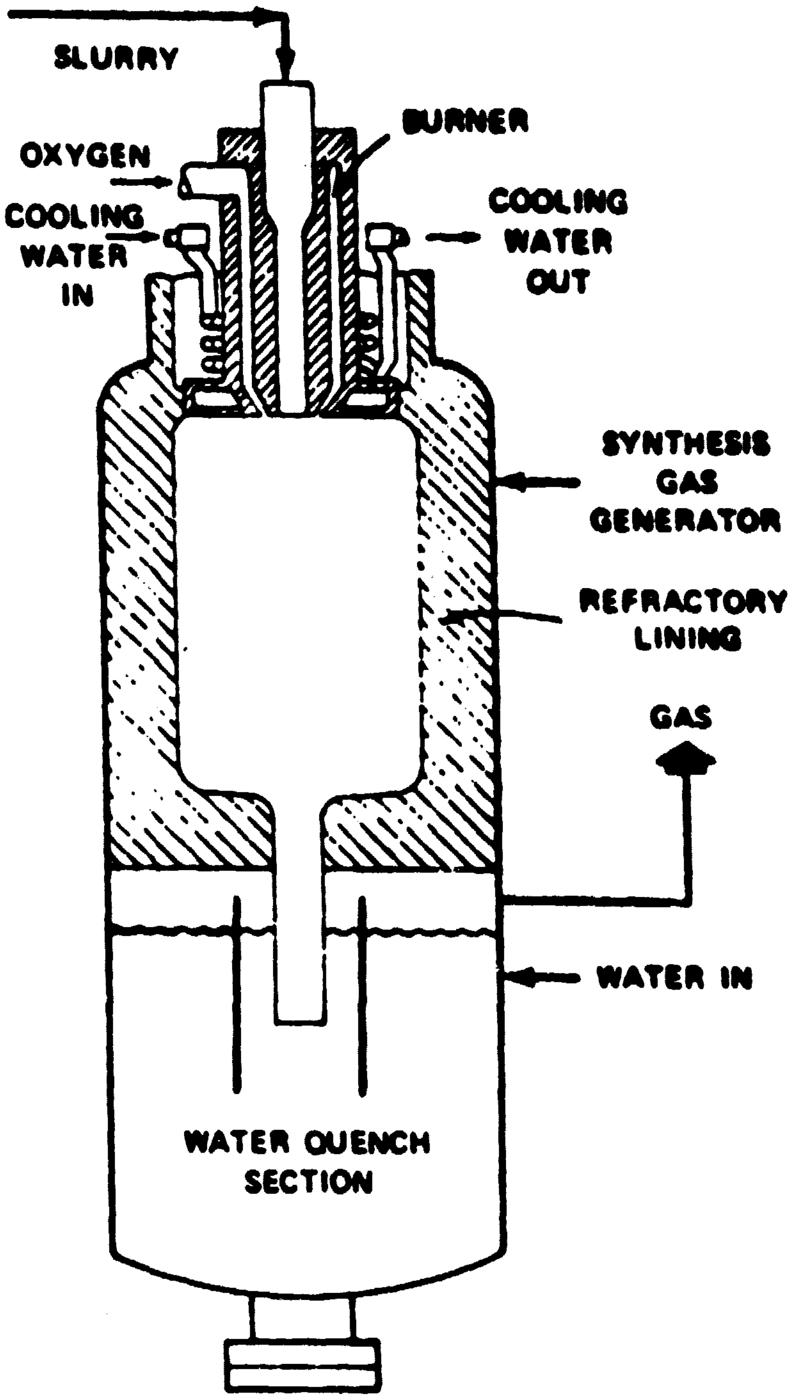
Coal Composition, Wt%	Eastern Coal
C	67.6
H	5.2
S	3.3
N	1.0
O	11.1
Ash	11.8



TEXACO COAL GASIFICATION PROCESS



TEXACO GASIFIER FOR AMMONIA PRODUCTION



TEXACO GASIFIER

(possible configurations: exact configuration of current gasifier is not available)

CO_2 ACCEPTOR

FLUIDIZED BED GASIFIER

DEVELOPMENT

Prior - 1964	Extensive bench scale studies were made by Consolidated Coal Co.
1964	ERDA (DOE) sponsorship began
1971	30 TPD pilot plant at Rapid City, South Dakota began operation.
1972-1977	Pilot plant operated for 79 runs (longest run was 290 hours)

CURRENT STATUS/PROJECT GOALS

The process development was carried to the 4- TPD pilot plant stage. The test program has been completed and the pilot plant has been shut down.

The principal objectives of this effort was to demonstrate the operability of all process features and thus establish that its comparative advantages were real and could be incorporated into the design of a commercial coal gasification facility. These advantages include the ability to produce synthesis gas without the need of an oxygen plant, production of a synthesis gas that has a high H_2/CO ratio and is therefore suitable for methanation without the need of a shift-conversion unit, high carbon utilization, and minimization of cleanup facilities because of the lack of oils and tars and the low concentrations of CO_2 and H_2S. The process is especially well suited for gasification of the enormous reserves of Western lignites and subbituminous coals.

GASIFICATION PROCESS

The acceptor, calcined limestone or dolomite, at 1850°F, is fed from the regenerator to the top of the gasifier's fluid bed while steam is injected at the bottom. Devolatilization and gasification of coal take place in the presence of steam, CO, H_2, and the acceptor.

Spent acceptor leaving the gasifier is calcined in a regenerator vessel. The heat required for calcination is obtained from the combustion of char product from the gasifier. The temperature of the regenerator is approximately 1850°F, a temperature at which the carbon dioxide acceptor reaction is reversed. The calcined acceptor is returned to the gasifier through a standleg. The flue gas from the regenerator is passed through a heat exchanger where steam is generated for use in the gasifier.

The product gas leaves the gasifier through an internal cyclone. It is then cooled and scrubbed in a water spray tower and this results in med-Btu gas. In a commercial plant the product gas from the gasifier could be passed through heat recovery to produce steam.

Methanation (about 55%) is required to obtain SNG. In a commercial scale plant H_2S would be treated, and for some coals the flue gas may require SO_2 scrubbing.

The coal ash is mainly carried out in the flue gas, separated in cyclones, and discharged via lock hoppers; the remainder is removed in a reject acceptor purge from the regenerator.

REACTANTS

Coal:

The process uses lignite or subbituminous coal crushed to +100-8 mesh.

The coal is dried to 5% by weight of moisture and is preheated to 500°F, then completely dried before being fed to the gasifier.

Acceptor:

Limestone or dolomite crushed and sized to +9-6 Tyler mesh and fed to the regenerator. 3.6 lb/lb recirculating acceptor required to gasifier. 0.25 lb/lb make up acceptor to regenerator.

Oxidant:

Air fed to the regenerator at a rate of about 2.3 lb/lb of coal fed to gasifier.

Steam:

1.1 lb/lb of coal fed to gasifier (steam to gasifier)

BFW:

260 gal/ton of coal (BFW to regenerator)

PRODUCTS

Gas:

Typical gas composition before methanation

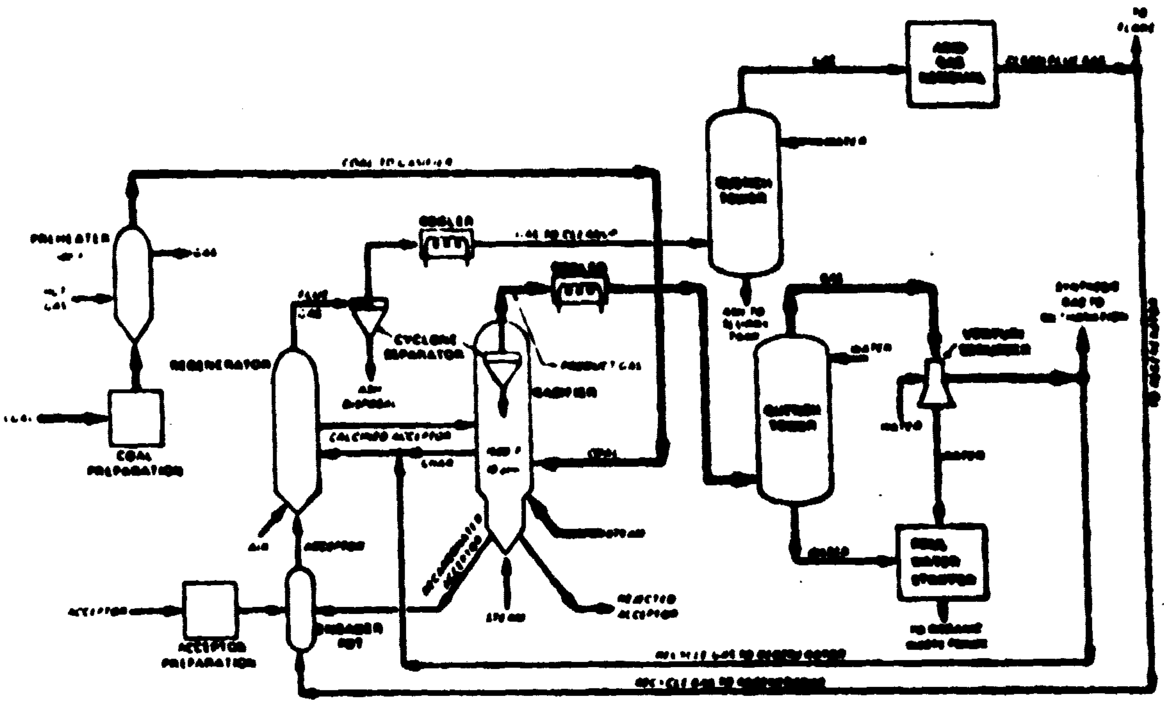
Feed Coal	Lignite
HHV of coal (BTU/lb	11,350
Element	**Mole %**
CO	15.5
CO_2	9.1
H_2	58.8
CH_4	13.7
H_2S + COS	0.0
N_2 + Ar	2.9
HHV, Btu/SCF, dry	380

By-Products:

1.1 ton/ton steam
15 lb/ton ammonia
Sulfur (in commercial plant)

Waste:

Waste water
Ash
Rejector acceptor



CO_2 ACCEPTOR PROCESS

ORIGINAL PAGE IS
OF POOR QUALITY

HYGAS

SRS

DEVELOPMENT

Prior - 1964	HYGAS process under investigation by the Institute of Gas Technology (IGT)
1964	Research work began at IGT in Chicago, Ill. to lead to the design and operation of a pilot scale plant
1971	80 TPD pilot plant in Chicago by IGT under OCR and Dept. of Interior and AGA
1971 - 1977	From 1971 to 1974 operations were carried out with a hydrogen source from the steam reforming of natural gas. During 1974 a larger steam-oxygen gasification unit was designed, constructed and integrated into the bottom of the HYGAS reactor.
1977	Major emphasis (by DOE) placed on providing design concepts for a commercial demonstration plant. DOE let a contract for this effort to Procon.
1979	Design of commercial plant completed

CURRENT STATUS/PROJECT GOALS

During the operational phase of the pilot plant to support the process design work, several periods of steady state operation were achieved. One of the most significant tests accomplished in the HYGAS plant was test run No. 79. A run-of-mine coal was processed during a 178-hour (7.5 days) steady-state period. Char conversion averaged 75 percent. Only one interruption of 40 minutes, caused by the faulty operation of a slurry feed pump, occured during the entire test.

The pilot plant has processed lignite, subbituminous, and Illinois No. 6 (medium- and highly caking) coals into a high-Btu gas.

IGT is operating the pilot plant to confirm design parameters and determine the inherent operability of the process technology for demonstration plant scaleup. This work has been continued through 1980. On completion of this work, information will be available to determine the merits of constructing a demonstration plant.

GASIFICATION PROCESS

As the coal-oil slurry is injected into the gasifier the oil is removed in the top section of the gasifier, where it is vaporized by gases rising from the lower stages; the oil is recovered for recycle. Dried coal falls to the bottom of the first hydrogasification stage where it is entrained upwards with high velocity gas rising from the second stage. The hydrogen in the gas reacts with coal to form methane. At the top of the first stage char disengages from the gas and falls into the second stage, which is a fluidized bed and is gasified by the actions of both hydrogen and steam. Up to this stage, about 45% of the coal has been gasified; the remainder is used for the partial oxidation stage at the bottom of the vessel, where the char is fluidized with a steam-oxygen mixture and gasified.

After leaving the hydrogasifier, the raw gas is quenched and scrubbed, shifted, treated for CO_2 and H_2S removal, and methanated to produce SNG.

Oil condensed in the scrubber is recovered and recycled.

Water blowdown from the scrubber is sent to waste treatment.

The high-ash spent char from lower bed of the reaction system vessel is discharged through a solids control valve and carried away by steam. A circulating pump mixes it with water and maintains a slurry of even consistency with up to 30 weight percent solids. The coal ash slurry is let down in pressure using a special tungsten-carbide coated valve. The slurry is filtered at low pressure, and the filtrate is recycled to the quench vessel.

REACTANTS

Coal:

The coal-feed preparation includes drying and pulverizing to -10 mesh size. Coals of any rank, moisture content, or sulfur content can be processed.

Pretreated coal is slurried with a light recycle oil which is produced as a by-product in the process. The slurry is then pumped to approximately 1,000 psi and injected into the top of the hydrogasifier.

Oxidant:

Oxygen at a rate of from 0.22 to 0.26 lb/lb of coal feed for bituminous and subbituminous coals.

Steam:

Approximately 1.0 to 1.2 lbs/lb of coal feed.

PRODUCTS

Gas:

Typical product gas composition

Feed Coal	Bituminous
HHV of coal, Btu/lb (dry)	13,200
Gas composition, mole %	
CO	23.8
CO_2	24.5
H_2	30.2
CH_4	18.6
H_2S + COS	1.2
N_2 + Ar	0.1
NH_3	0.5
HHV, Btu/scf (dry gas)	370
Gas rate, Mscf per ton of coal	45

By-Products:

Light oils (predominantly light aromatics)
54 to 97 lbs/ton of coal feed

Waste:

Ash
Waste water

SAMPLE OF HYGAS OPERATION

Coal

Run number	54
Dates of investigation	7/76
Length continuous period of operation, Hours	81
Coal processed, tons	193

Input Flows

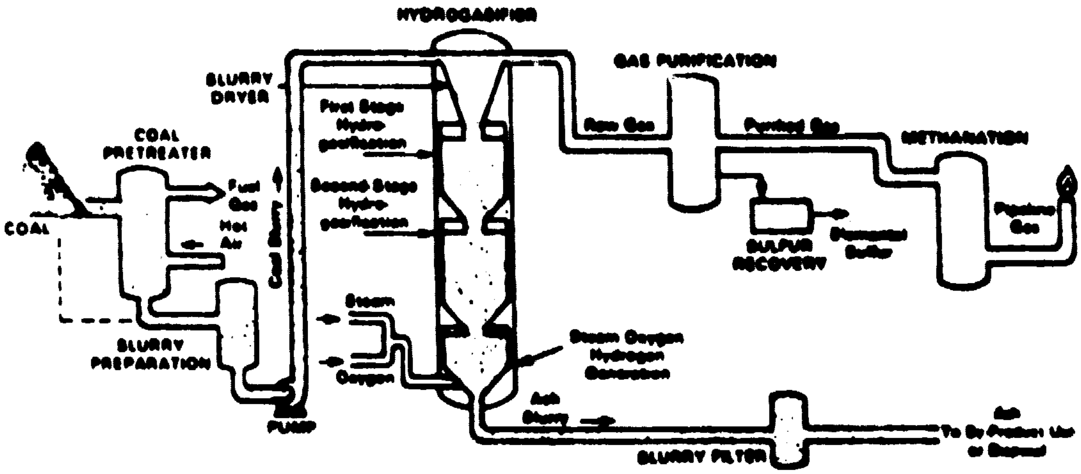
Coal, lb./hr.	4758
Oxygen, lb./hr.	764
Steam, lb./hr.	4141
Water, lb./hr.	4794

TYPICAL PROPERTIES OF FEED COAL

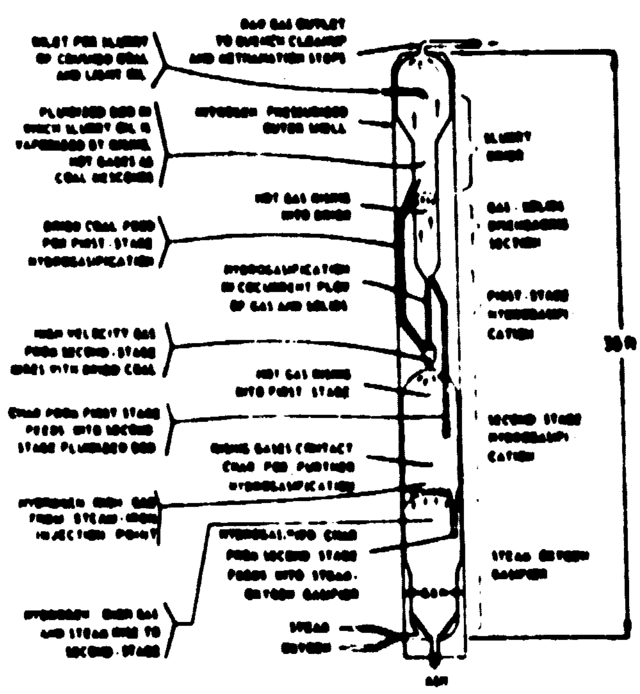
	Bituminous Coal	
	Washed	
Fixed Carbon	50.6	47.5
Volatile Matter	37.3	36.1
Ash	12.1	11.2
Sulfur	3.1	3.7
FSI	4.7	4.5

Coal Feed Analysis

HHV Average Btu/lb.	11750
Ash Flow Point	2440°F



HYGAS Pilot Plant Configuration



HYGAS Gasifier

WESTINGHOUSE

SRS

DEVELOPMENT

1972	Westinghouse began its Westinghouse gasification process development under the sponsorship of what it is now DOE and 5 industry partners.
1974	15 TPD PDU was completed at Waltz Mill, PA. by Westinghouse
1975-1977	Westinghouse evaluated the devolatilizer and the gasifier combustor as separate test at the 15 TPD PDU
1978-1979	Further testing on a single stage was accomplished and the complete coal gasification system was operated as an integrated process using several types of coal.

CURRENT STATUS/PROJECT GOALS

Since results to date indicate that single-stage gasification will be a simpler and more economical system, testing during CY 1980 is emphasizing that mode of operation. Tests are being run with both air and oxygen.

During FY 1981, the two-stage pressurized fluidized bed project will be continued to obtain performance data with which to assess process feasibility and economics. Design and scale-up data will be obtained on the gasifier system and components as well as data on load following characteristics, transient and failure mode behavior and control system characteristics.

This project focuses on development of a low-Btu gasification process capable of using caking coals without pretreatment. This gas product shall be suitable for operating utility gas turbines and combined cycle generating systems.

GASIFICATION PROCESS

Coal is introduced to the devolatilizer unit through a central draft tube. The coal and recirculating char are carried upward through the draft tube by hot gas entering the volatilizer from the gasifier-combustor. This gas provides most of the heat to the unit; it devolatilizes and partially hydrogasifies the coal. Desulfurized gases exit at the top of the devolatilizer and flow to the cyclone collector. Fines are removed in the cyclones and recycled to the gasifier/agglomerator. The gas then is cooled and scrubbed with water to produce clean low btu gas.

The dense, dry char from the devolatilizer and fines removed from the product gas are burned with air in the lower leg of the gasifier-combustor to provide gasification heat. Steam is injected into the same area for temperature control and to provide hydrogen for gasification. Gasification occurs in a fluidized bed in the upper portion of the gasifier-combustor. The hot low-btu gas from the gasifier-combustor improves in heating value as it passes through the devolatilizer.

Ash from fines combustion agglomerates on the char ash and segregates in the lower leg for removal.

The recycle solids (recirculating char and regenerated or make up dolomite), fluidized bed surrounding the draft tube, are needed to dilute the feed coal and to temper the hot inlet gases. A high ratio (up to 50:1) of recycle solids to coal feed is maintained to prevent or control agglomeration of the coal as it passes through its plastic phase.

REACTANTS

Coal:

Coal (crushed to less than ¼ in.) is fed to a dryer to remove surface moisture using recycled fuel, then to the devolatilizer. Caking, noncaking and high ash and sulfur content coals have been tested.

Dolomite:

Dolomite is fed to the devolatilizer and is regenerated and recycled to absorb H_2S.

Oxidant:

Air requirements are 2.2 to 2.8 lb/lb of coal feed

Steam:

Steam is required to feed the combustor and the dolomite regenerator. Consumption 0.2-0.4 lb/lb of coal feed.

PRODUCTS

Gas:

Typical product gas composition
(air blown)

Feed Coal	Subbituminous
HHV of coal, Btu/lb (dry)	11,290
Gas composition, mole %	
CO	19.2
CO_2	9.3
H_2	14.4
CH_4	2.7
H_2S + COS	0.1
N_2 + Ar	54.3
HHV, Btu/scf (dry gas)	135
Gas rate, Mscf per ton of coal	170

By-Products:

None

Waste:

Ash
Waste water
Spent sulfided dolomite

SAMPLE OF WESTINGHOUSE OPERATION

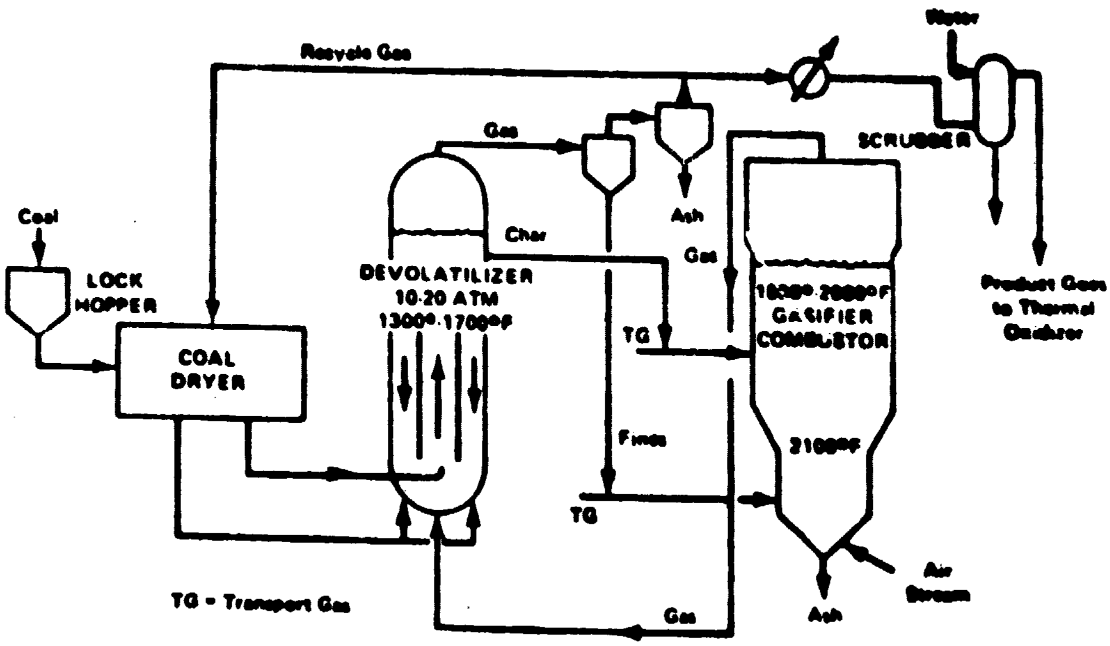
Coal	Indiana # 7 (caking)
Run number	TP-009-2
Longest continuous period of operation, hours	160
Coal processed, tons	46

Input Flows

Coal, lb./hr.	400-600
Air, lb./hr.	about 1200
Char withdrawal	

TYPICAL PROPERTIES OF FEED COAL

	Bituminous Coal
Moisture	16.2
Ash	8.4
Sulfur	0.52
FSI	1.5 to 2
HHV Average Btu/lb.	14250



WESTINGHOUSE

TWO STAGE PROCESS

EXXON CATALYTIC

SRS

DEVELOPMENT

Prior - 1978	Exxon has performed bench scale support work on catalytic gasification since 1968
1978	Exxon Research and Engineering Company was awarded a contract by DOE for a catalytic coal gasification process development program and construction began on a PDU at Baytown, Texas.
1979	PDU began operation

CURRENT STATUS/PROJECT GOALS

A study design was developed in 1978 for a conceptual large pilot plant along with an estimate of construction and operating cost for such a plant.

The PDU built and funded by Exxon is to operate on DOE funds at least through 1980.

Bench-scale R&D and engineering will be continuous through mid-FY 1981. An RFP for the transfer of technology from Exxon to a third-party process development company (possible licensor) is underway with competitive selection scheduled for late FY 1980.

Operation and research on the Exxon process should reveal the needs of the catalytic coal gasification process.

In FY 1981, a pilot plant will be designed for process development testing which will permit scale-up to a commercial with minimum risk. Efforts will include process design, detailed design, and iniation of some long lead procurement. PDU-scale testing will be continued to support the design effort.

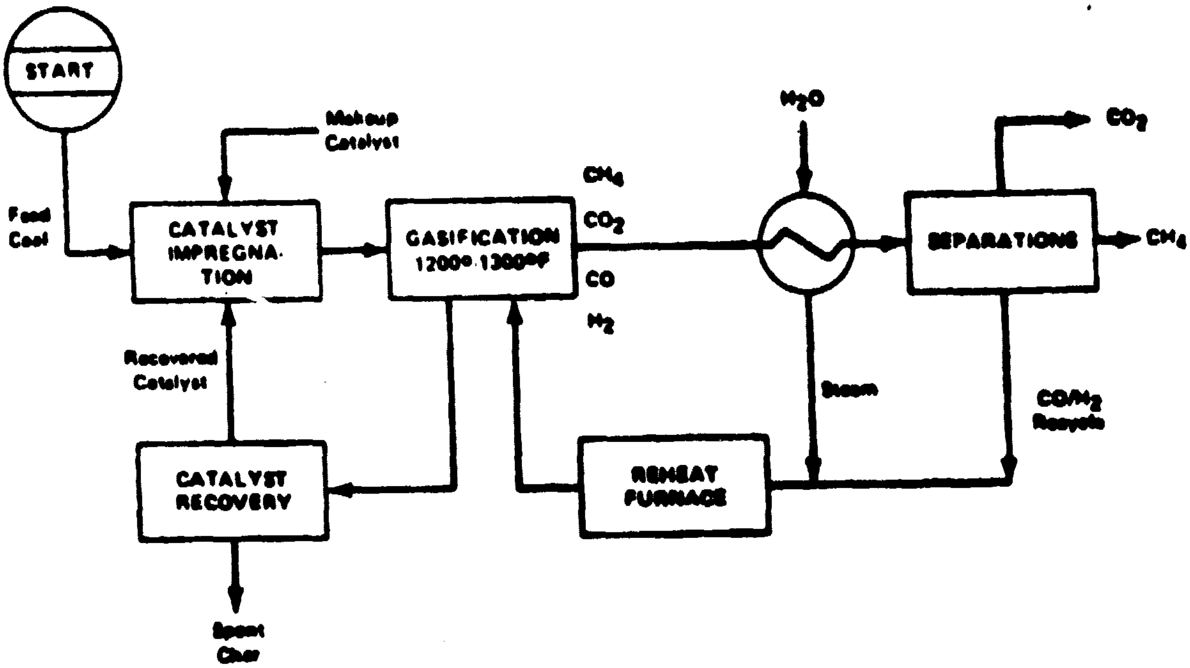
GASIFICATION PROCESS

Coal, (about 1TPD) is fed to the catalyst impregnation prior to entering the gasifier. The catalyst (potassium) for the impregnation is from make up catalyst and from recovered (from gasifier) catalyst.

Coal enters the gasifier where the coal is reacted with steam and recycled carbon monoxide and hydrogen at a temperature of about 1300°F. The product gas leaving the gasifier goes through heat recovery (which generates the steam required for the gasification process) and then to a separator. In this step (a series of steps) carbon monoxide and hydrogen for recycle, product methane, and carbon dioxide (vented) are produced.

The steam and CO/H_2 are preheated to about 150°F above the gasifier temperature and the recycled to the gasifier to keep the CO/H_2 content as high as possible thus forcing the net products of the gasification reactions to be CO_2 and CH_4. The recycle rate is set such that there is no net yield of CO and H_2 in the gasifier.

Char/ash residue containing catalyst is removed from the gasifier. The catalyst is recovered by water through a countercurrent leaching operation. It is estimated that up to 90 percent of the carbonate may be reclaimed in this manner. Some catalyst reacts with coal ash to form an insoluble potassium aluminosilicate, with about 5 percent weight of coal feed estimated lost in the insoluble form. The recovery of the remaining potassium by routes such as acid wash of char is currently being investigated.



EXXON CATALYTIC GASIFICATION PROCESS

PROCESS SUMMARY

This third generation catalyst gasification process represents one of the more promising approaches to coal gasification. The most significant feature of this process is that it uses coal impregnated with an alkali metal catalyst to convert coal directly to SNG within the gasifier in a single step. The catalytic SNG process has other significant technical advantages including a potentially higher thermal efficiency than that of thermal coal gasification processes because of the reduced need for high-level heat input and for heating and cooling of gas streams.

ORIGINAL PAGE IS OF POOR QUALITY

BI-GAS

SRS

DEVELOPMENT

1963	Bituminous Coal Research, Inc. began development of this process at its Monroeville, Pa. facilities.
1965	Process testing (that later led to the Bi-Gas process) began using rocking autoclaves.
1967	Tested continuous (externally heated) flow reactor at a 516/hr. rate.
1968-72	100 lb./hr. internally fired PDU testing and cold flow model testing.
1976	Operation of a 120 TPD pilot at Homer City, Pa. began. Stearns-Roger Corp. designed and built the plant. Babcox & Wilcox designed and fabricated the gasifier.

CURRENT STATUS/PROJECT GOALS

Although continuous plant operation has not been highly successful, continuous operation of the pilot plant for up to 39 hours has been achieved. The plant has attained successful operation of the coal slurry feed spray-drying system at 750 psig and the successful demonstration of slag tapping without the addition of flux. Other milestones include the attainment of stage-two carbon conversions in excess of 40 weight percent. (Forty weight percent was anticipated from PDU studies.)

The Bi-Gas pilot plant must be developed to the point where steady state operations can be attained for adequate periods to obtain scaleup data. In addition it is necessary that improved solids flow and temperature instrumentation techniques be developed to resolve problems such as coal and char flow rate monitoring and extremely short thermo couple life.

It is planned to operate the Bi-Gas pilot plant for at least 24 additional months in order to develop an effective data base for scaleup purposes.

During FY 1981, the gasifier will be operated to acquire the experience necessary to achieve integrated operation. This same experience will provide data needed for further refinement of the control instrumentation and preparation of the downstream gas processing systems for operations in conjunction with the gasifier.

GASIFICATION PROCESS

The gasifier consists of three separate zones: (1) a slag quench zone in the bottom, (2) stage 1, where the char burners are located, and (3) stage 2, where coal feed is injected.

The coal enters the gasifier through injector nozzles near the throat which separates the stages. Steam is injected through a separate annulus in the injector. The two streams combine at the injector tip and join the hot synthesis gas from the bottom stage (Stage 1). A mixing temperature of about 2,200°F is attained rapidly and the coal is converted to methane, synthesis gas, and char. The raw gas and char rise through Stage 2, leave the gasifier at about 1,700°F, and are quenched to 800°F by atomized water and sent to a cyclone separator.

Raw gas leaves the cyclone separator for further processing, while the char is recycled to the gasifier. The raw gas then enters the raw-gas scrubber and passes upward through a curtain of downward-flowing water. The water scrubs the char dust, cools the gas, and condenses the moisture. This char free gas is med.-Btu gas (oxygen feed). The gas then flows to the shift reactor where the hydrogen-to-carbon monoxide ratio is adjusted to the desired value. Hydrogen sulfide and part of the carbon dioxide are removed in the Selexol unit upstream of the methanator. Hydrogen sulfide gas goes to a Claus unit. The product gas from the methanator goes through final carbon dioxide removal in the Selexol unit.

The residual char in stage 2 is separated from the exiting gas stream and recycles to stage 1 of the gasifier. In stage 1, the char is completely gasified under slagging conditions with oxygen and steam, producing the heat required for the endothermic reactions in stage 2.

In stage 1 char burners are arranged to fire cyclonically, causing a swirling motion which promotes slag separation as well as gasification. Molten slag, separated in this manner, flows down the stage 1 walls into the quench zone.

The slag quench zone is located at the bottom of the gasifier and contains cooled recirculating water. As the molten slag from stage 1 falls into the water, it is shattered to a granular form. Granular slag settles to the bottom of the zone, where high-pressure water jets agitate and move it to the outlet nozzles. The slag is then sent to one of the two slag lock hoppers prior to disposal.

REACTANTS

Coal:

Raw coal is pulverized so that 70% passes the 200-mesh. It is then mixed with water and fed to a cyclone, where the solids are concentrated into a slurry. This slurry is further concentrated in a thickener and centrifuge, repulped, and mixed with flux to produce the desired consistency. Coal of virtually any moisture content can be processed.

A pump transports the blended slurry at high pressure to a steam preheater. Here it is contacted with hot recycle gas in a spray drier which nearly instantaneously vaporizes the surface moisture. The coal is then conveyed to a cyclone at the top of the gasifier vessel by a stream of water vapor and inert recycle gas, as well as additional recycled gas from the methanator. The coal is separated from the recycle gas in the cyclone and the coal flows by gravity into the gasifier.

The Bi-Gas reactor can handle all types of coal.

Oxidant:

Oxygen (along with steam) is reacted with char in stage one of the gasifier. Oxygen requirements are 0.5 lb/lb of coal feed

Steam:

0.4 lb/lb of coal is required

BFW:

140 gal/ton of coal

PRODUCTS

Gas:

Typical medium-Btu gas before methanation

Feed Coal	Pittsburg Seam	
HHV of coal, Btu/lb (dry)	14,090	

Mole %	Before Methanation	After Methanation
CO	29.3	0.1
CO_2	21.5	0.5
H_2	32.0	4.6
CH_4	15.7	92.7
H_2S + COS	0.8	0
N_2 + Ar	0.7	2.1
Heating value (HHV), Btu/scf (dry)	356	900+
Gas produced, Mscf per ton of coal	53	

By-Products:

Steam could be produced in some commercial processes.

Waste:

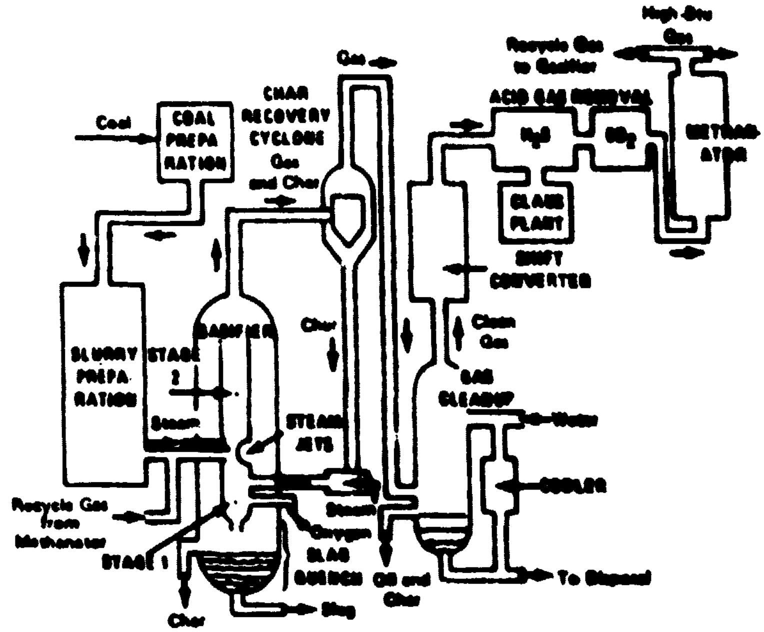
Waste water
Slag

SAMPLE BI-GAS OPERATION

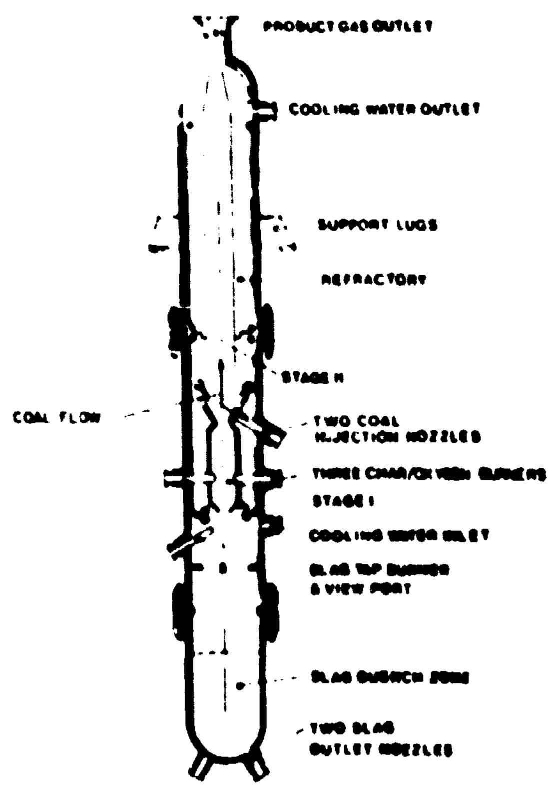
Coal Type	Pittsburgh Seam
Longest continuous period of operation, Hours	39
Coal Feed Rate	10,000 lb/hr
Oxygen to Burners	6,500 lb/hr
Steam to Zone I and II	12,000 lb/hr
Process Gas Out	27,800 lb/hr
Slag Out	700 lb/hr
Recycle Char	11,000 lb/hr

TYPICAL PROPERTIES OF COAL FEED

Elemental Analysis	Weight % Dry
Carbon	75.9
Hydrogen	5.7
Nitrogen	1.4
Sulfur	2.7
Oxygen	4.9
Ash	8.3



Bi-Gas Process



The BI-GAS Gasifier

SHELL-KOPPERS

SRS

DEVELOPMENT

1976	Shell International Petroleum Co. and Krupp-Koppers began operation of a 6 TPD PDU Shell's Amsterdam Netherlands laboratory
1978	Shell began operation of a 150 TPD pilot plant at the German Shell Hamburg/Harbury refinery.

CURRENT STATUS/PROJECT GOALS

A number of different coals have been successfully gasified at 450 psig pressure. The plant has now been operated for more than 3000 hours.

The 150 TPD plant has been in operation since Nov. 1978 and has completed a number of successful runs. Shell is providing funding for operation.

REACTANTS

Coal:

Pulverized coal or lignites up to 40% ash and 2% moisture (5 to 8% moisture for lignites)

Coal is fed by a high pressure slurry of coal and water through a lock-hopper system. Pneumatic feed systems are also being evaluated.

Oxygen or Air:

Quantities not available

Steam:

Quantity not available

PROCESS DESCRIPTION

The process uses a one step slagging entrained flow gasifier. The process draws heavily on the technologies of the Koppers-Totzek coal gasification process and Shell's oil gasification process. Changes and improvements of the old processes include pressurized gasification system, fly ash recycle and lock-hopper coal feed system.

The process operates at about 3600°F temperature in the combustion zone and 2700°F at gas exit from the gasifier. The pressure in the gasifier is 450 psig.

Ash is removed as molten slag.

Medium-Btu gas is produced (low Btu gas with air feed). Carbon monoxide/hydrogen ratio will be essentially that of the Koppers-Totzek atmospheric process, although CO_2 content of the raw gas may be lower.

HYDROGASIFICATION

SRS

DEVELOPMENT

Prior - 1968	PETC (Pittsburgh Energy Technology Center) worked on the development of the hydrogasification process beginning in the early 1960's.
1968	PETC initiated the hydrane process.
1968 - 1976	Hydrane process was tested (bench scale) at PETC
1976	Hydrane program was redirected to modify the hydrane reactor to a simple one stage reactor. Rockwell International was chosen (by ERDA) to develop a one stage gasifier.
1978	Testing was completed on a ¼ Ton/hr. operation by Rockwell using Illinois and Kentucky coals.
1979	Testing began at Rockwell on a 3/4 Ton/hr. gasifier.

CURRENT STATUS/PEOJECT GOALS

Currently, a 3/4 ton/hr experimental reactor development unit (PDU) is in place and operational. A 4 ton/hr hydrogasifier facility design was completed and "shelved." Work was accomplished on preparing a test site and ordering priority equipment. In addition, there was extensive progress on selection of an architect/engineer firm for a preliminary commercial-scale design.

During FY 1979, hydrogasification studies were performed at Rockwell International to expand the data base. Additionally, related hydrogasification studies were performed at the Pittsburgh (dilute-phase hydrogasification or modified hydrane process) and Morgantown Energy Technology Centers and at Carnegie-Mellon Institute of Research. This related support work is to continue at least thru 1980.

Major activities for FY 1981 will include comprehensive testing of the Rockwell 3/4 TPH PDU, preliminary design of a commercial process, and hydrogasification support efforts.

Rockwell has used the hydrogasifier in a liquefaction process called flash hydropyrolysis (high-mass-flux, short-residence-time)

PROCESS SUMMARY

The hydrogasification process is a promising third generation coal gasification technique in that almost all of the methane produced is generated in the gasifier by direct hydrogasification of the raw coal. This technique results in a high thermal efficiency and makes the hydrogasification approach a potentially attractive way to convert coal to a subsititute natural gas.

GASIFICATION PROCESS

In the reactor, liquid products are formed initially, but these are further hydrogenated to gases if the reactions are not quenched. An entirely gaseous product is obtained by tailoring the reactor conditions to completely hydrogenate the liquid products.

The Rockwell reactor is based on the application of rocket engine techniques to achieve rapid mixing and reaction for a controlled time interval. Employing these techniques, flash hydropyrolysis can be carried out in the reactor. The coal is reacted with gaseous hydrogen which is preheated to achieve the required reactor temperature.

The products leaving the gasifier are sent to a separator to remove char liquid. The gas then must go through final purification and clean up and some methanation may be required to achieve the desired final product gas.

REACTANTS

Coal:

Pulverized coal is fed through a pressurized feeder vessel then into the gasifier through a rocket-engine type injector. The coal is pretreated with hydrogen or nitrogen in the feeding process.

Both caking and non caking coals have been tested. Kentucky #9 (high volatile A bituminous), Illinois #6 (high volatile C bituminous), Montana Rosebud (sub-bituminous) and peat have been run in particle sizes ranging from 70% less than 200 mesh (power plant grind) to 90% less than 200 mesh.

Oxidant:

Air is required to feed oxygen production; (quanity not available)

Hydrogen/Nitrogen:

Less than 1 lb/100 lb coal

PRODUCTS

Gas:

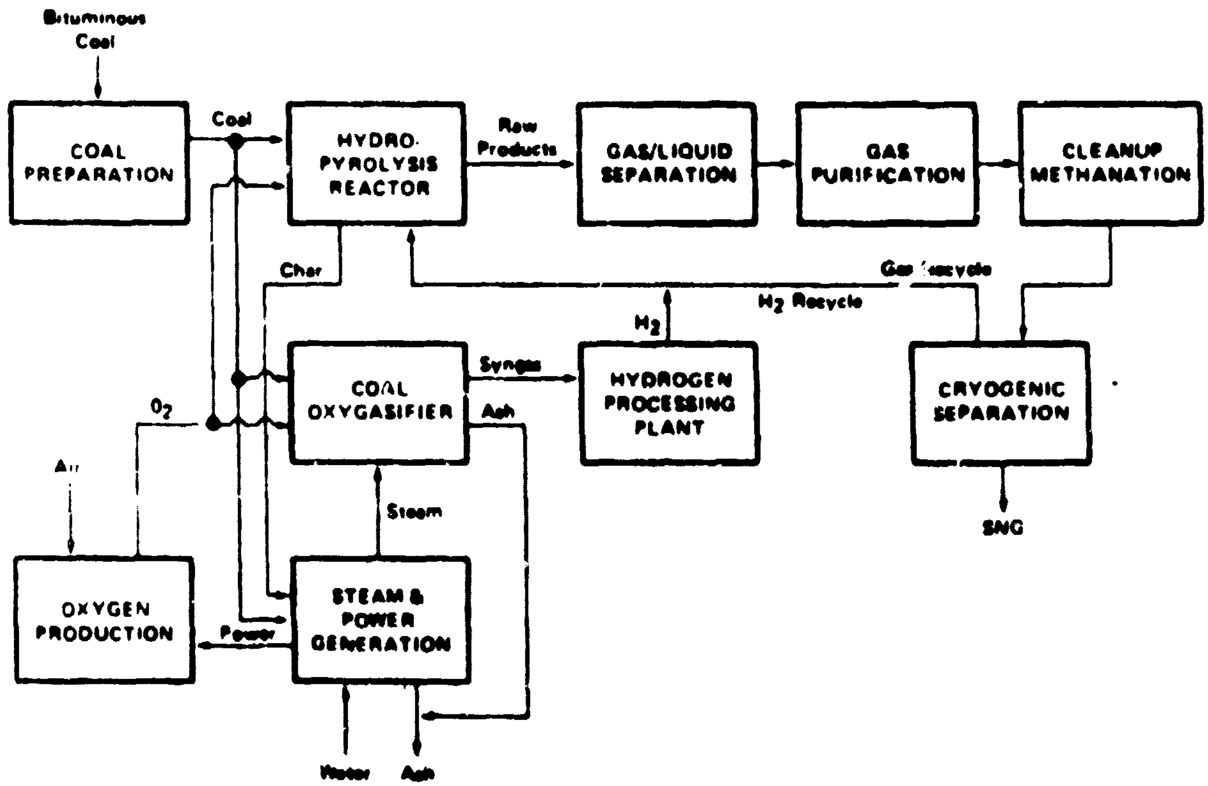
Approximate gas composition before methanation

CO	10-15%
CO_2	2%
CH_4	80-90%
C_2H_6	0-10%

By-Products: NA

Waste:

Water
Ash



HYDROGASIFICATION PROCESS

MOLTEN SALT

SRS

DEVELOPMENT

Prior - 1974	Atomics International Division of Rockwell International di[illegible] extensive experimental work to develop the molten salt gasification process. Bench scale operations.
1974 - 1976	Rockwell conducted a development test program which included operation of their 3'O.D. reactor. Preliminary engineering was conducted.
1976 - 1978	Engineering, construction and startup of a 1 Ton/hr. PDU at Santa Susana, CA by Rockwell
1968	Pullman-Kellogg has developed a molten salt process. Development started about 1968.

CURRENT STATUS/PROJECT GOALS

Since the facility has been started up a number of successful runs have been made. Atmospheric pressure gasification tests have been made with operating periods of 157 and 240 and 272 hours, respectively. The product gas averaged about 90 BTU/scf as predicted for low pressure, low throughput operation of the system. During a recent run, all plant systems were operated on an integrated basis including the regeneration and recycle of pure sodium carbonate.

It is anticipated that during FY 1980 the feasibility of this coal gasification concept will be demonstrated. In addition, a design will be prepared for modification to the unit that will permit its operation to produce a medium-Btu fuel/synthesis gas.

GASIFICATION PROCESS

The coal and carbonate are conveyed into the reactor by nitrogen and air.

In the molten salt reactor, coal is gasified in a molten pool of sodium carbonate, sulfide, and sulfate through which air is blown. Conducting gasification reactions in the molten salt medium permits very high oxidation rates (about five times higher than the corresponding gas-solid reaction rates) and results in retaining ash and sulfur in the melt.

The low or medium BTU gas leaving the gasifier passes through a scrubber for particulate removal. The gas can be used as product gas or is sent through purification, methanation and water removal to produce high-Btu product gas (SNG)

Since ash and sulfur are retained in the molten salt pool, the melt must be continuously withdrawn from the gasifier and fresh sodium carbonate added. This melt is regenerated by an aqueous process in which the melt is quenched and mixed with recycle liquor to dissolve the salt; insoluble ash components are removed by settling and/or filtration; and the dissolved sodium sulfide is converted to hydrogen sulfide and sodium carbonate (or bicarbonate)by reaction with carbon dioxide and steam. The hydrogen sulfide is oxidized to sulfur dioxide, which is then absorbed in an aqueous carbonate spray dryer, where a convenient solid is produced for disposal. The regenerated sodium carbonate is returned to the gasifier vessel.

REACTANTS

Coal:

Coal is fed to the gasifier in a crushed (less than ¼ in.) state with a pneumatic conveyor. Coal must be dried to less than 10% moisture for the solids feed system. Coal types from anthracite to lignite can be processed.

Sodium carbonate is mixed with coal and fed to the gasifier. Recycle $Na_2\ CO_3$ is required at a rate of about 0.3 lb/lb of coal feed; make up $Na_2\ CO_3$ is required at a rate of about 0.02 lb/lbs of coal feed.

Oxygen:

Air is required at a rate of 3.5 lb/lbs of coal for oxygen blown process about 0.7 lb/lb of coal feed is required.

Steam:

Steam at a rate of 0.1 to 0.4 lb/lb of coal feed is required for the oxygen-blown med.-BTU gas production.

PRODUCTS

Gas:

Typical product gas composition

(airblown, before methanation)

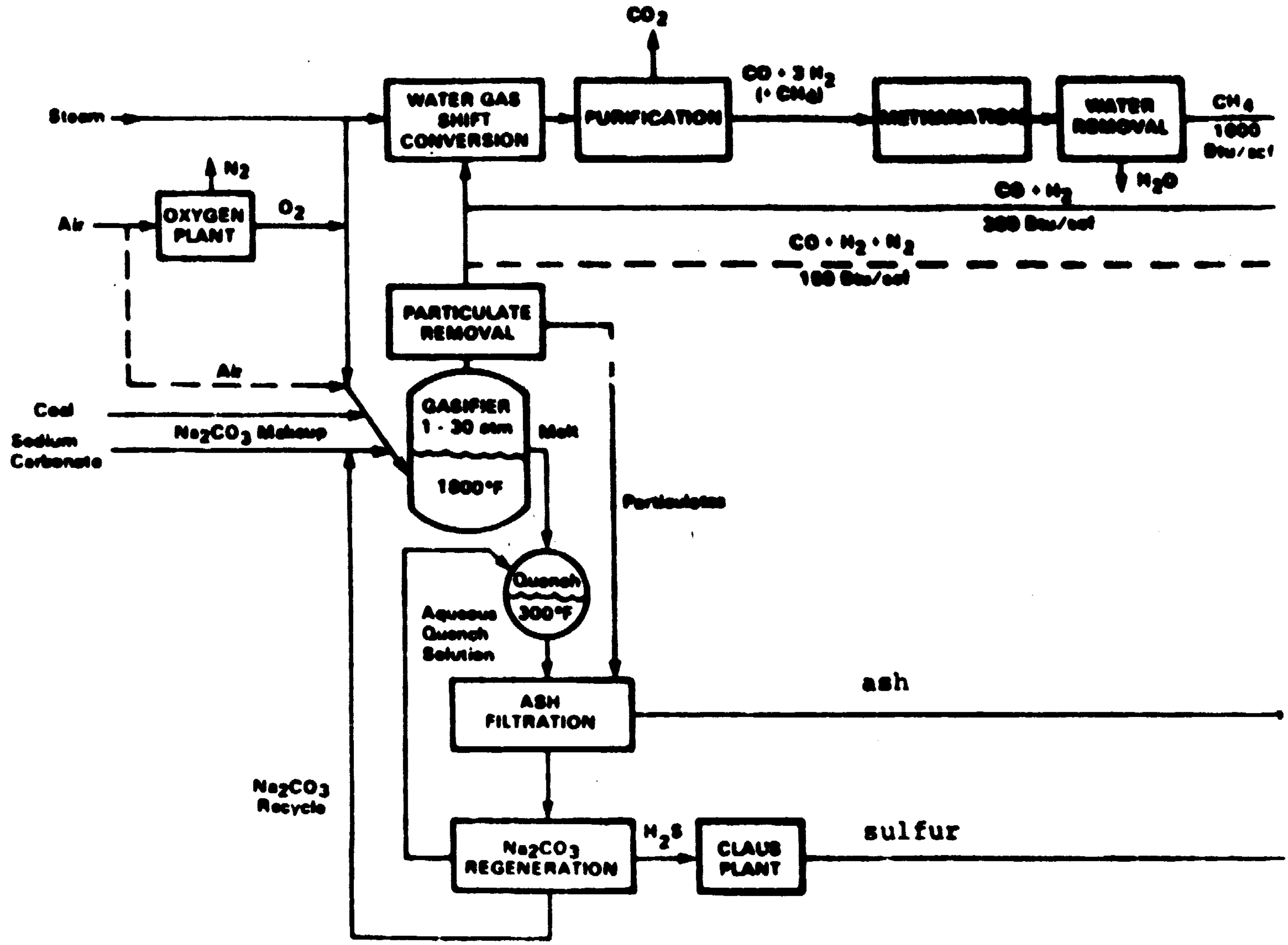
Feed Coal	Kentucky #9
HHV of coal, Btu/lb (dry)	12,000
Gas composition, mole %	
CO	29.7
CO_2	3.5
H_2	13.2
CH_4	1.5
Sulfur Compounds	5 ppm
NH_3	5 ppm
N_2	48.0
O_2	1.4
HHV, Btu/scf (dry gas)	158
Gas rate, Mscf per ton of coal	145

By-Products:

Sulfur (in a commercial plant)

Waste:

Ash (ash pond or landfill disposal)
Spent Salt
Waste Water (small amounts)



Molten Salt Gasification Process Development Systems

ORIGINAL PAGE IS
OF POOR QUALITY

WINKLER

DEVELOPMENT:

1922 - Dr. Fritz Winkler discovered the winkler process at Oppau, near Manneheim, Germany

1926 - First commercial producer at Leuna, Germany

WINKLER PLANTS

Plant No.	Location	Year	Type of Coal	Normal Capacity per Gasifier (MM SCFD)	No. of Gasifiers
1	Leuna-werk Leuna, Germany	1926- 1930	Lignite	54 27	5 5
2	Braunkohle-Benzin AG Bohlen, Germany	1936	Lignite Coke	26	3
3	Braunkohle-Benzin AG Magdeburg, Germany	1938	Lignite Coke	26	3
4	Yahagi, Japan	1937	----	8	1
5	Braunkohle-Benzin AG Zeitz, Germany	1938	Carbonized Brown Coal	20	3
6	Dai-Nihonyinzo-Hiryo Japan	1938	Semi-Coke	12	2
7	Nippon Tar, Japan	1938	Weak Caking Coal	12	2
8	Toyo-Koatsu, Japan	1939	Weak Caking Coal	13	2
9	Sudetenlandische Treibstoffwerke Brux, Czechoslovakia	1943	----	26	5
10*	Fabrika Azotnih Tendinjenja Gurazda, Yugoslavia	1953	Sub-Bituminous	5	1
11	Calvo Sotelo Puertollano, Spain	1954	Bituminous	8	1
12	Union Rheinische Braunkohlen Wesseling, Germany	1954	Lignite	11	1
13	Calvo Sotelo Puertollano, Spain	1957	Bituminous	8	1
14*	Azot Sanyyii TAS Kutahya, Turkey	1959	Lignite	11	2
15*	Neyveli Lignite Corporation Madras, India	1959	Lignite	37	3
16	Union Rheinsche Braunkholen Wesseling, Germany	1960	Lignite	11	1

*Currently in operation.

CURRENT STATUS

Davy Powergas, Inc. Licensor for the Winkler process has successfully operated a gasifier at 1.5 atma pressure. A 15 atma pressure is under development by Davy Powergas.

GASIFICATION PROCESS

The Winkler gasifier has a vertical cylindrical construction with a steel shell lined on the inside with refractory. The coal feed inlet is located in the lower portion of the gasifier. The steam and oxygen (or air) are charged through nozzles located at several levels in the fluid bed. The fluidized bed occupies only part of the gasifier volume, while the remainder serves as a disengaging zone. Secondary steam and oxygen injection is provided above the bed level to gasify unconverted carbon leaving the bed. Above this level, a radiant heat boiler is installed to recover heat from the gases before they leave the gasifier and resolidify any solid particles which may have melted.

Coal is crushed to 0 x 3/8" size and dryed if necessary.

GENERATOR

The coal feed from the preparation section or dryers, as the case may be, is stored in the feed bunker, which provides surge capacity, before entering the gasifier through the variable speed screws. These screws, in addition to providing control on the coal feed rate, serve to seal the generator preventing steam from wetting the coal feed and blocking the bunker and screws.

In the fluidized bed, the coal particles react with oxygen and steam resulting in a produced gas containing hydrogen, carbon monoxide, carbon dioxide, methane and unreacted steam. Gasification in the Winkler Generator is primarily a combination of combustion and water gas reaction, and due to the relatively high temperatures, all of the tars and heavy hydrocarbons are reacted.

REACTANTS

COAL:

Almost any coal can be processed

SAMPLE COAL FEED

COMPOSITION	DRIED LIGNITE TO GASIFIER WT %
H_2O	8.00
C	64.13
H	4.58
O	17.76
N	0.57
S	0.76
Ash	4.20
	100.00

HHV (BTU/LB) - 10,939

OXYGEN:

98% Purity Oxygen - 0.5 Ton/Ton of Coal Feed

STEAM:

0.2 to 0.3 Ton/Ton of Coal Feed

BFW:

198 Gal./Ton of Coal Feed

PRODUCTS

GAS:

TYPICAL PRODUCT GAS
LIGNITE FEED

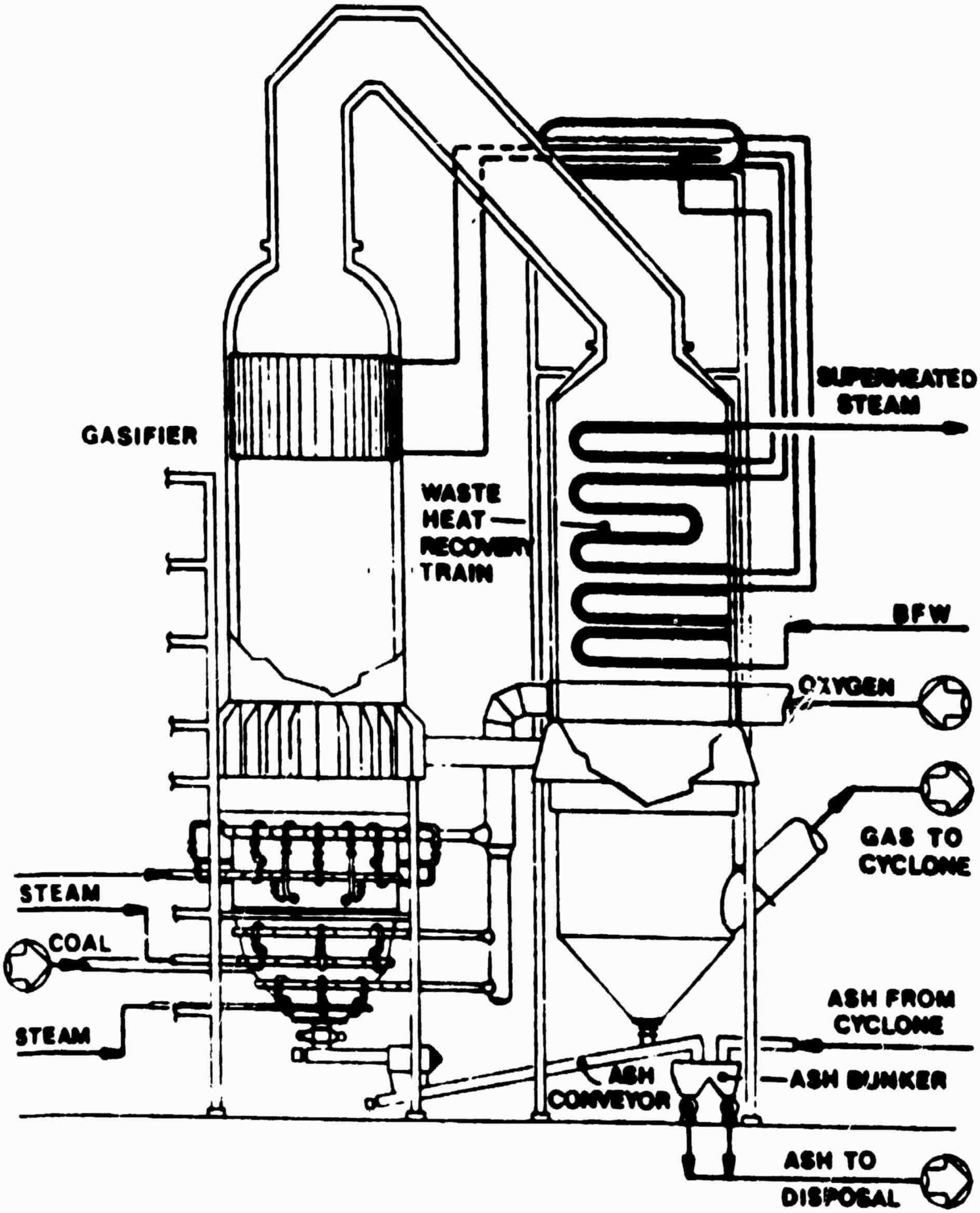
COMPOSITION	MOL %
CO_2	14.25
CO	45.54
H_2	36.37
CH_4	2.39
N_2	1.10

BY PRODUCTS:

Steam - High Pressure 0.8 Ton/Ton

WASTE:

Waste Water
Ash



WINKLER GASIFIER

KOPPERS TOTZEK

SRS

DEVELOPMENT:

1948 - Koppers Co., Inc. of Pittsburgh and H. Koppers GmbH of Essen, Germany designed, built, constructed, and operated a 36 TPD coal gasifier for the U.S. Bureau of Mines at Louisiana, Missouri. This plant ceased operation in early 50's due to inexpensive natural gas and oil supplies.

1952 - First commercial KT plant operated in Finland by H. Koppers

1959-1974 - More than 50 gasifiers were installed for operation in 13 plants around the world. The larger plants being Ammonia plants producing 900 TPD in India and a 1000 TPD in Modderfontein, South Africa.

CURRENT STATUS:

Krupp-Koppers GmbH the West German licensor of the KT process has signed (1979) a contract with Petrobras of Brazil for a 600 TPD Ammonia plant. A 90 million cubic feet per day plant to produce gas is being planned in Poland using KT gasifiers.

Tennessee Energy Institute has applied for funds from DOE to build a Syn-Gasoline plant in East Tennessee, use of the K-T process is being considered. Koppers Co. is the U. S. Licensor of the K-T gasifiers.

GASIFICATION PROCESS

The two-headed K-T gasifier is horizontal and ellipsoidal in shape, with two heads shaped as truncated cones mounted on the ends. A waste heat boiler is mounted on the top to recover heat from the hot effluent gases. The gasifier has a set of two adjacent burners installed in each of the heads. Coal, steam, and oxygen are injected through the four burners. The gasifier shell has a double-walled construction, and the inner shell is protected from the high temperatures of gasification by a castable refractory lining. Heat escaping through the refractory is recovered by water circulating through the annulus between the inner and outer shells. The annulus is connected to a steam drum. Four-headed gasifiers employ burner heads 90° apart and a total of 8 burners. These larger units resemble intersecting ellipsoids and also have a double-walled construction.

Depending upon rank, the coal is dried to between 2% and 8% moisture and pulverized to 70% through 200 mesh. The pulverized coal is conveyed with nitrogen from storage to the gasifier service bins. 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. The pulverized coal is continuously discharged from each screw into a mixing nozzle where it is entrained in oxygen and low pressure steam. The mixture is then delivered through a transfer pipe to the burner head of the gasifier. Moderate temperature and high burner velocity prevent the reaction of the coal and the oxygen until they enter the gasification zone.

Coal is oxidized in the gasifier, producing a temperature in the flame zone of approximately 3500°F. Heat losses and endothermic reactions reduce the temperature of the gas mixture to about 2700°F. Ash in the coal is liquefied because the gasifier temperature is maintained at a level higher than the ash fluid temperature. About 50% of the ash in coal flows down the gasifier walls as molten slag and drains into a slag quench tank. The slag is quenched by circulating water and it shatters to a granular form. The remainder of the ash leaves the gasifier as fine slag particles entrained in the exit gas.

The entrained gas is quenched and solidified at the gasifier exit by water sprays. Solidification prevents particulate matter from adhering to the waste heat boiler tubes. The sensible heat in the gas is recovered in the waste heat boiler and high pressure steam is generated.

Gas leaving the waste heat boiler is water scrubbed and cooled in a washer cooler and Theisen disintegrator system. The particulate matter is reduced here to a negligible amount. Water from the gas cooling and cleaning system is sent to a clarifier. The separated sludge is sent to disposal along with the slag from the gasifier; the water is sent to the cooling tower and then recirculated to the cooling and cleaning system.

The scrubbed and cooled gas is processed in a sulfur removal system, resulting in the medium-BTU product gas.

As a result of the fluidization, the ash particles are segregated according to size and specific gravity; i.e., the heavier particles fall down through the fluidized bed and pass into the ash discharge unit at the bottom of the gasifier while the lighter particles are carried up out of the bed by the product gas to be further gasified in the space above the bed. Experience has shown that approximately 30% of the ash leaves at the bottom while 70% is carried overhead. The quantity of gasifying medium injected into the zone above the bed must be accurately controlled proportional to the amount of unreacted carbon being carried over. If this quantity is too small, ungasified carbon will be carried out of the gasifier resulting in a lower gasification efficiency, and if it is too large, potential product gas is unnecessarily consumed by combustion. Since the maximum temperature in the gasifier occurs in the space above the bed due to this secondary, gasification, any ash particles which melt would be those that are carried up and out of the gasifier.

The ash particles and gas leaving the gasifier pass through a refractory lined duct to the waste heat train. Here the gas is first cooled in a waste heat boiler where high pressure superheated steam is generated. It then passes through an oxygen (or air) preheat section for further cooling and into a separator. A decrease in velocity of approximately 60% and a change in direction of flow causes 30-40% of the ash to separate at the bottom of the waste heat train. Cyclones following the waste heat train eliminate an additional 45-50% of the entrainment. The ash removed in the waste heat train and cyclones is then mixed with ash leaving the gasifier and transferred to a bunker. The conveying medium can be either nitrogen in a pneumatic system or water in a slurry system; both have been used in the past.

Residual ash in the gas leaving the cyclones is separated in a direct contact wet scrubber and an electrostatic precipitator. (The scrubber-precipitator combination may be replaced with a high efficiency venturi type scrubber.) The solids contained in the scrubber bottoms are separated in a settler. The overflow water is recycled through a cooler and returned to the scrubber. If a pneumatic dry ash handling system is used, the slurry from the settler is mixed with the dry ash from the dry ash bunker, and the mixture is sent to disposal. By mixing the two, the water in the slurry cools and wets the dry ash, and thus prevents dusting problems during ultimate disposal.

KOPPERS-TOTZEK

REACTANTS

COAL:

Dry Feed to Gasifier Analysis, Wt%		Eastern Coal
C		76.2
H		5.0
N		1.3
S		0.7
O		6.6
Ash		8.2
Moisture		2.0
	Total	100.0

Gross Heating Value of Dried Feed, Btu/Lb	13,705

OXIDANT:

Oxygen 98% Purity, 0.85 TONS/TON OF COAL FEED

STEAM:

Process Steam 0.443 Ton/Ton of Coal Feed

PRODUCTS

GAS:

Raw Gas Analysis, Vol%, Dry		Eastern Coal
CO		53.27
CO_2		10.00
H_2		35.43
N_2 + Argon		1.07
H_2S		0.22
COS		0.01
	Total	100.00

Dry Gas Make - SCF/Ton Dried Feed	72,448
Gas Gross Heating Value, Btu/SCF, Dry	286

STEAM:

Jacket Steam, Lb/Ton Dried Feed	627
High Pressure Steam Lb/Ton Dried Feed @ 1500 psig/596°F (Saturated)	4,171

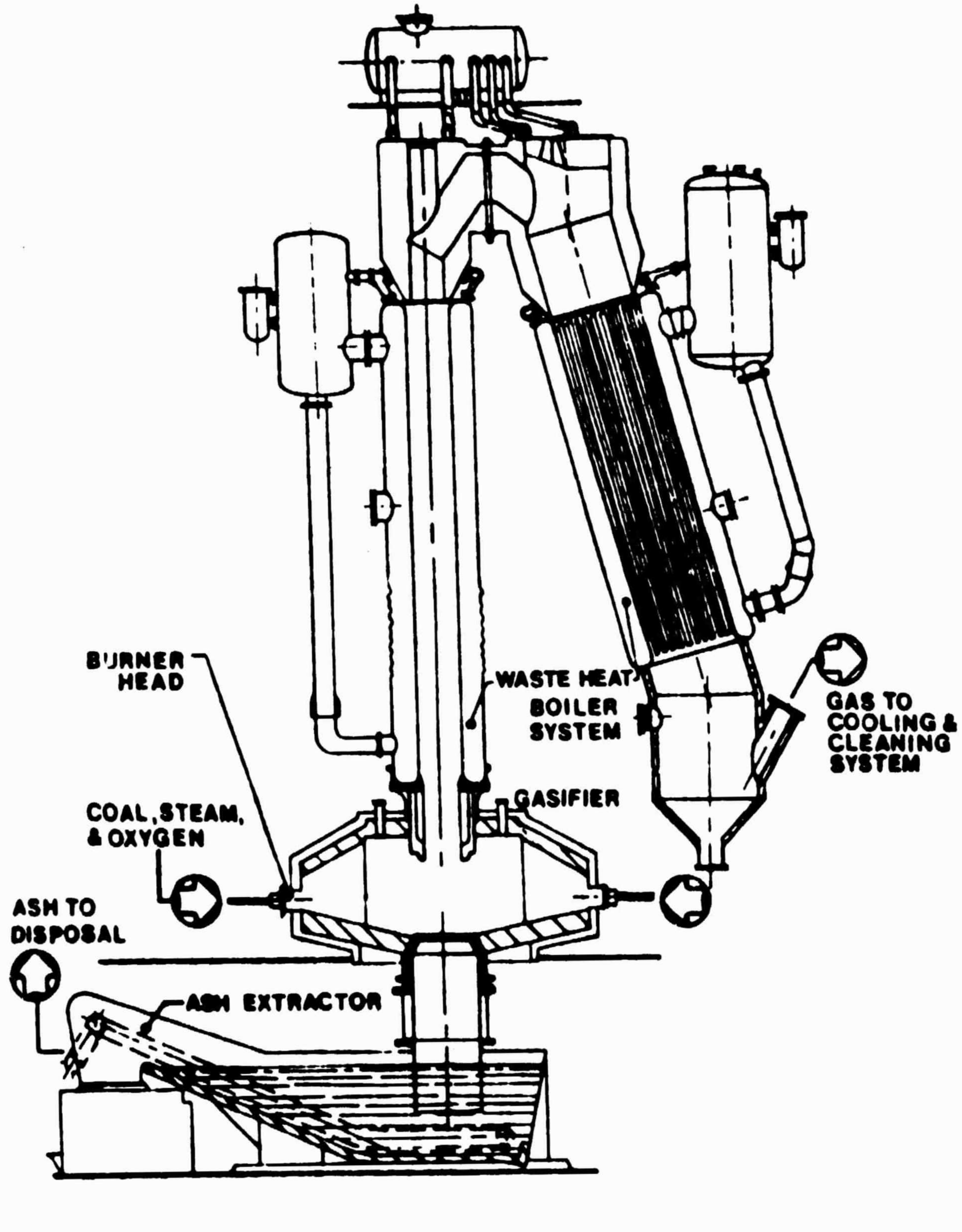
WASTE:

Slag

Waste Water

AMMONIA PRODUCTION PLANTS IN OPERATION USING K-T PROCESS AS OF JAN. 1, 1979

OPERATOR AND LOCATION OF PLANT		OUTPUT IN TONS/DAY
Nitrogenous Fertilizer Ptolemais, Greece	1959	270
	1960	
Chemical Fertilizer Mae Moh, Lampang, Thailand	1963	100
Azot Sanayii, Kutahya, Turkey	1966	340
Industrial Development Corp., Kaufe, Lusaka, Zambia	1966	100
Fertilizer Corp. of India (FCI): Ramagundam, India	1969	900
FCI, Werk Talcher, India	1970	900
Nitrogenous Fertilizer, Ptolemais, Greece	1970	135
AE&CI Ltd., Modderfontein, Republic of South Africa	1972	1,000
Industrial Development Corp., Kafue, Lusaka, Zambia	1974	200



K-T TWO HEADED GASIFIERS