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In the last few years, the Texaco Coal Gasification Process has won wide acceptance as one of the few processes which is today ready for full commercialization. The Texaco technology has been developed over a period of more than thirty years. The process development work was initiated at Texaco's Montebello Research Laboratory near Los Angeles shortly after World War II and, in a pilot unit constructed at the Laboratory, coal was first gasified in 1948. In the early development years the Texaco Synthesis Gas Generation Process in which syngas is manufactured from heavy residual oil and the companion Texaco Coal Gasification Process were developed side by side. Work on residual oil gasification led to the installation and start-up of the first commercial residual oil feed Texaco Synthesis Gas Generation unit in 1956, and work on coal gasification resulted in construction of a prototype unit in Morgantown, West Virginia. The coal gasification plant at Morgantown was operated during 1956 and 1957, at the end of which time, it was determined the process could not compete economically with low cost natural gas. In the meantime, residual oil gasification projects became quite attractive and the technology was licensed throughout the world, resulting in construction of more than 80 commercial plants.

During the period following the demonstration work at Morgantown, development efforts at the Montebello Research Laboratory were directed mainly toward oil gasification and it was not until the oil embargo in 1973 that the emphasis was redirected and substantial effort was devoted to coal gasification.

In 1973 the Laboratory converted one of the oil gasification pilot plants to a coal gasification unit and process development work on coal was re-established. Facilities at the Montebello Research Laboratory now include two 15 to 20 ton per day coal gasifiers operating at pressures ranging from 350 to 1200 psi. In addition, a second 1200 psi. gasifier is presently under construction and will be ready for start-up by the end of this year. A picture of the operational pilot unit is shown in Figure 1.

Process Description

The Texaco Coal Gasification Process consists of feeding a concentrated slurry of coal and water into a refractory-lined pressure vessel through a special burner or injector where it is mixed with an oxidant, pure oxygen or, alternatively, air. The coal to oxygen ratio is adjusted so that the temperature within the gasifier is maintained at a level slightly higher than the fluid temperature of the coal ash. Under these conditions the gasification reactions occur rapidly and 90 to 99 percent of the carbon contained in the coal is gasified in a few seconds. Hot gases exit from the gasifier along with molten slag and are cooled in one of two alternate modes, the water quench mode or the waste heat recovery mode.

The water quench mode is shown in Figure 2. In this mode, the hot gases containing slag are directed beneath the surface of water in a quench chamber which is maintained at full gasifier pressure. In the quench chamber, the molten slag is rapidly solidified and the hot gases leaving this quench chamber are saturated with water vapor. As shown in Figure 2, these hot gases are scrubbed with additional hot water for removal of the last traces of particulate matter and passed to a shift converter where the carbon monoxide contained in the gas is converted to additional hydrogen. This mode is particularly attractive for those applications where hydrogen is required to manufacture, for example, ammonia, or where hydrogen may be used for refining and treating of coal liquefaction products or even low quality petroleum streams resulting from the refining of high sulfur heavy crude oil.

The slag from the coal remains in the water where it settles rapidly and is withdrawn periodically through a water-sealed lockhopper system. Unconverted carbon and some fine particles are present in the circulating water and are removed from the water by passing the water stream through a settler. Material recovered in the settler may be discarded or, optionally, recycled back to prepare additional slurry feed for the gasifier. The material removed through the lockhopper system is typically passed over a screen where the coarse material which is normally 99 percent or more ash is removed from the system and discarded. Extensive tests[1] have been made on this "coarse slag stream" and have shown that disposal by landfill poses minimal environmental impact. The underflow from the screen or "fine slag" usually contains some unconverted carbon and, optionally, can be fed back to the slurry preparation system or disposed of in a suitable manner. Extensive tests on this stream have also been reported.[1]

Water recovered from all of the streams is recycled to the process or to slurry preparation and the only water discharge from the process is that required to maintain an acceptable level of total dissolved solids in the circulating water. The build-up of solids in this water stream is dependent upon the composition of the nonhydrocarbon material in the coal feed. Depending upon the content of water soluble material in the feed coal, a water purge or blowdown stream ranging from 0.25 to 1.0 pounds per pound of coal fed is typical.

The alternate or waste heat recovery mode is shown in Figure 3. In this mode, the hot heterogeneous stream leaving the gasifier is directed downward through a radiant, water-jacketed cooler where high pressure steam is generated as the gases are cooled. This cooler or waste heat boiler is designed to cool the gases and slag in the gas stream to a temperature well below the softening point of the coal ash. The majority of particulate matter in this stream is collected in the water-filled chamber at the bottom of the radiation section. Hot gases containing a small fraction of the particulate matter are then passed through a convection section where additional heat is recovered. At the exit of the convection section, the gases are scrubbed with hot water for final particulate removal and the resulting synthesis gas is ready for further treatment, normally sulfur removal. This alternate mode would typically be selected for process sequences in which methanol, fuel gas or other petrochemicals are the desired end products.

Test runs in the pilot units have been made on a wide variety of coals and on residual products from several of the coal liquefaction processes, as well as coke from refining conventional petroleum residue. A partial list of coals that have been tested in the pilot plant is shown in Figure 4. Typical data obtained from gasification of a number of these materials have been published.[2,3]

Process Advantages

One of the principal reasons leading to the wide acceptance of the Texaco Coal Gasification Process is that of environmental acceptability. All material leaving an entrained flow slagging gasifier has been exposed to relatively high temperatures on the order of 2300°F to 2800°F. At this temperature level, partially gasified or partially oxidized carbonaceous material is extremely unstable. Therefore, the undesirable components, such as phenols, cresols and other partially oxidized or carcinogenic hydrocarbons are not found. In addition, the ability to recycle the small fraction of unconverted carbon back to the slurry feed greatly reduces the problem of by-product disposal.

The second reason for the widespread process acceptance is related to the simplicity of the feed system. The coal slurry, after preparation and proper control of the size distribution of the particles in the slurry, is relatively stable and can be pumped reliably with high pressure reciprocating pumps available in commerce today. No high pressure lockhopper feed systems are required and pretreatment of the coal is seldom necessary.

Thirdly, the high temperature and high pressure within the gasifier lead to rapid gasification reactions and therefore the gasifier itself is capable of relatively high throughputs per unit volume.

Commercialization Activities

The accelerated process development following the oil embargo in 1973 led to a large demonstration project designed for installation in Germany at the Ruhrchemie Petrochemical Complex near Oberhausen. This plant, jointly designed by Texaco, Ruhrchemie and Ruhrkohle, is rated at 165 tons per day of coal and went onstream in January of 1978.

Since the start-up of this plant, 40,000 tons of various bituminous coals have been gasified during run periods lasting up to 30 onstream days. Some of this operating data has been reported.[4,5] Figure 5 contains a summary of the various coals that have been gasified in the Ruhrchemie demonstration plant. Typical gasifier performance data for a Utah bituminous coal are shown in Figure 6.

Two additional demonstration plants are now in operation. Information relative to each of these three demonstration plants is shown in Figure 7.

Data obtained from the Montebello pilot units and from these demonstration plants are being used to design and construct a number of larger plants incorporating the Texaco Coal Gasification Process. The two most important projects underway at the present time are the Cool Water Coal Gasification Program, planned for construction in the Southern California high desert with start-up in late 1983 and the Tennessee Eastman Project under construction at Kingsport, Tennessee at Eastman's chemical plant, scheduled for start-up in the latter half of 1983.

The Cool Water Coal Gasification Program is presently sponsored by Texaco, the Southern California Edison Company, the Electric Power Research Institute, General Electric Company and Bechtel Power Corporation. Negotiations are underway with additional groups interested in participating in the program and Letters of Intent have been received from two other participants. The program is organized to design, construct, start up and test a modular commercial coal gasification combined cycle plant for a period of 7 years. The project, estimated to cost $300 million is designed to demonstrate the gasification of 1,000 tons per day of a western bituminous coal to fuel an integrated combined-cycle generation facility to produce 100 net megawatts of power for distribution in southern California. Details concerning the design and operation of this plant have been reported.[6]

The Tennessee Eastman Project, is also in the final engineering design stage. This plant will be the first full commercial operation using the Texaco Coal Gasification Process to go on-stream. Syngas from the plant will be used for a wide variety of chemical products most of which are related to the line of photographic materials Eastman manufactures.[7]

In addition to the projects mentioned above, there are numerous studies and proposed projects in various stages of development. Projects in which Texaco has publicly announced they will be involved with an equity position are shown in Figure 8. These projects include, in addition to the Cool Water Program, the Houston Natural Gas (HNG) project proposed to be located in Convent, Louisiana and produce methanol equivalent to 11,400 barrels per day of oil. Also, a co-generation plant to be located in the San Ardo oil field in the Salinas Valley of California which will use coal and, through gasification, produce electric power and steam for stimulation of the oil production.

Figure 9 is a summary of the commercial coal gasification projects that plan to use the Texaco Coal Gasification Process. In addition to the Tennessee Eastman project, these projects include: a hydrogen production plant for Gulf's SRC II program; WyCoalGas coal gasification (to gasify Lurgi by-products from western lignite); and the Canadian Alsands project (to produce hydrogen from fluid coke for use in manufacturing synthetic crude from Canadian tar sand oil). The SRC II and W.R. Grace projects both involve funding or loan guarantees from the U. S. Government in order that the projects proceed through the construction stage.

Of the sixty-three proposals submitted by industry in March, 1981 to the U.S. Synthetic Fuels Corporation, eighteen involve requests for funding for coal gasification projects of which over half specified incorporation of Texaco coal gasification technology. These SFC submittals included the Cool Water Program, WyCoalGas, W. R. Grace, Houston Natural Gas and San Ardo projects.

It is apparent from the information presented in the previous pages that the Texaco Coal Gasification Process has many attributes that make the process most desirable in today's environment. Not only has the technology been demonstrated on a semi-commercial scale, but it has also been shown (1) that the process inherently is environmentally acceptable.

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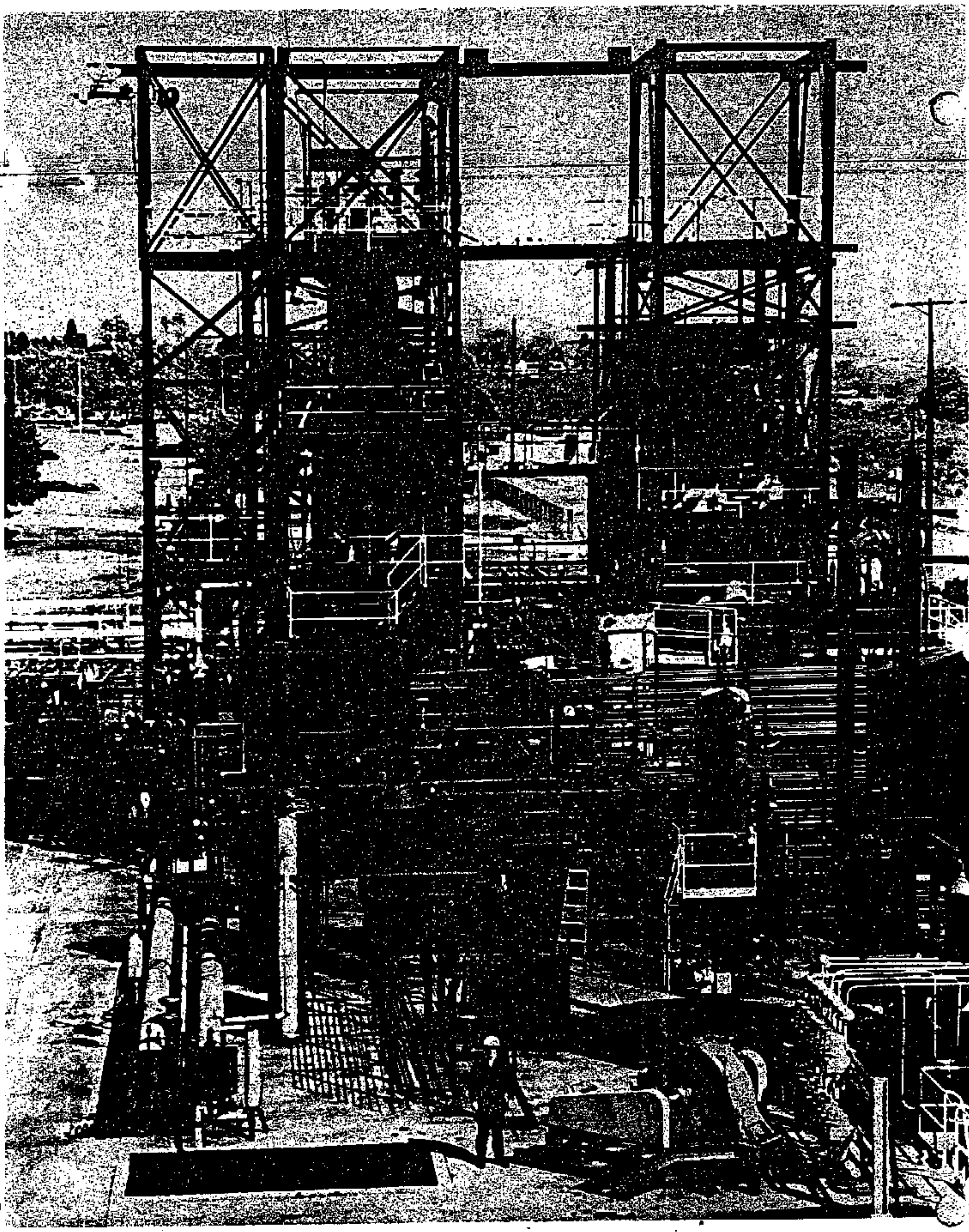

FIGURE 1

Figure 2

TEXACO COAL GASIFICATION PROCESS
Direct Quench Mode

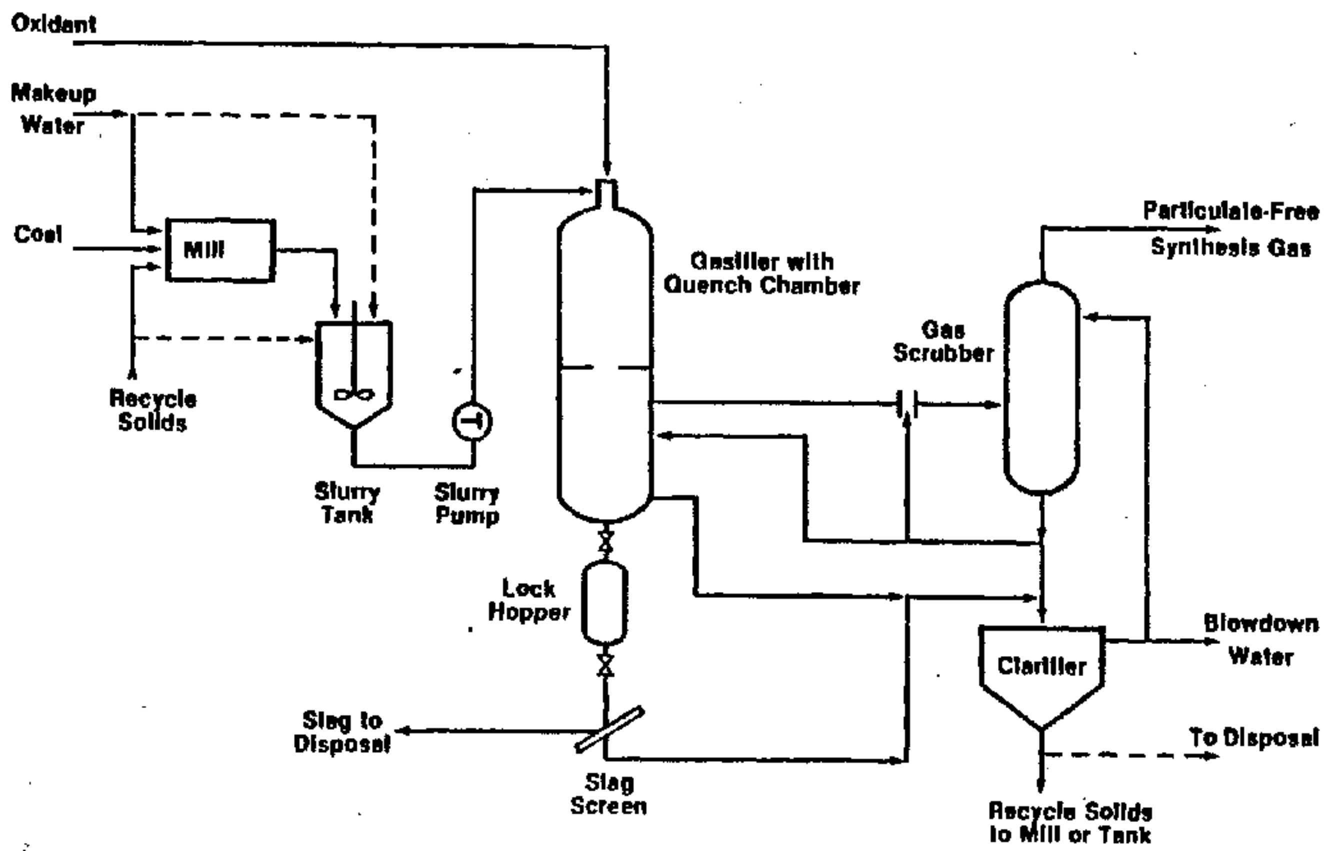

Figure 3

TEXACO COAL GASIFICATION PROCESS
Gas Cooler Mode

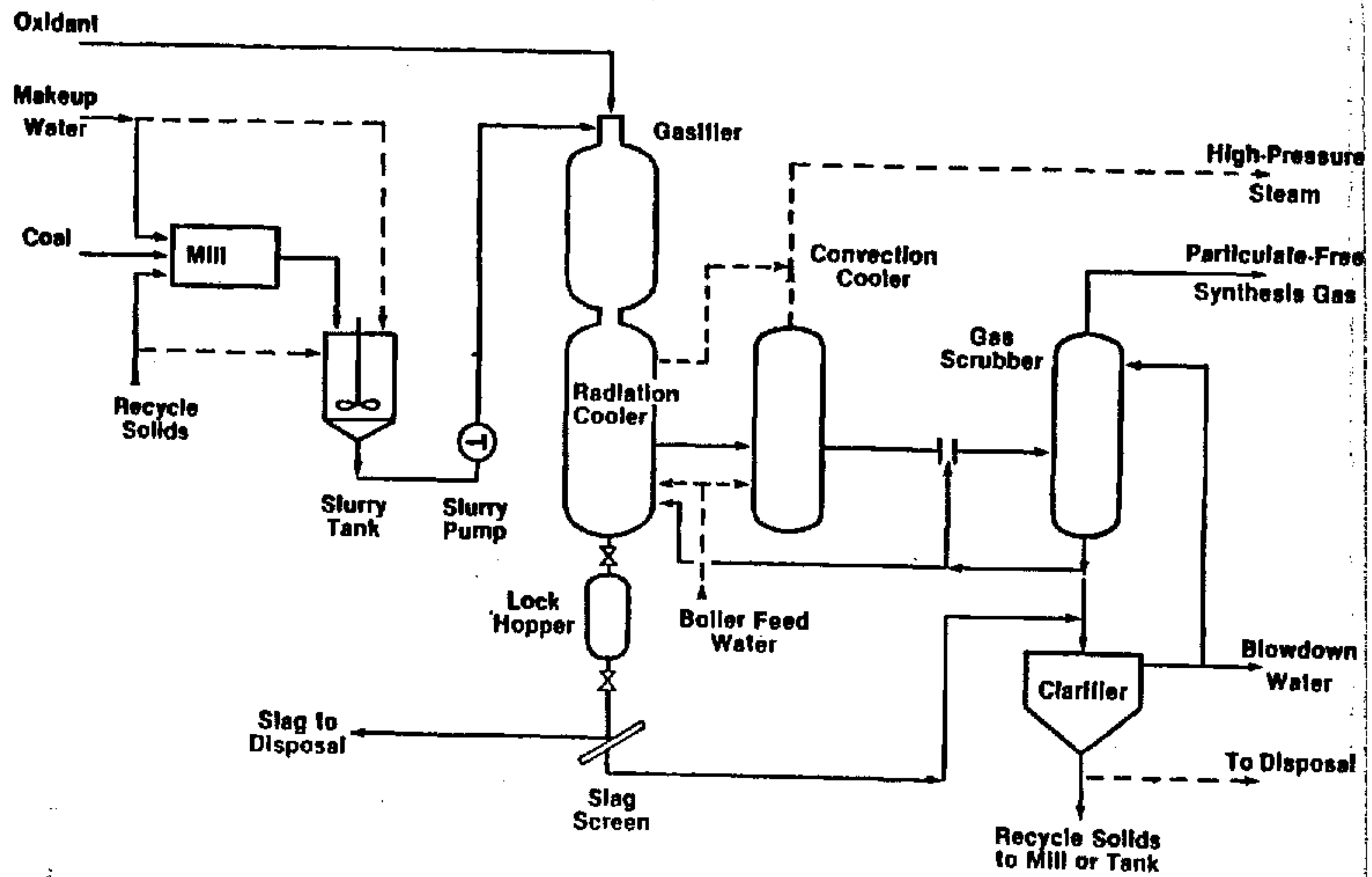

Figure 4

TEXACO PILOT PLANT EXPERIENCE ON FEEDSTOCKS

- **BITUMINOUS COALS**

  Kentucky No. 9
  Illinois No. 6
  Sewickly Seam
  Waynesburg Bituminous

  Utah Bituminous
  Black Mesa
  Kaiparowits

  Itsudan No. 1 (Japan)
  Ruhrcoal (Germany)
  South African Coals

- **SUB-BITUMINOUS COALS AND LIGNITES**

  Lake DeSmet
  Belle Ayr
  North Dakota Lignite
  Texas Lignite
  Ptolemais Lignite (Greece)

- **COAL LIQUEFACTION RESIDUES**

  SRC - I
  SRC - II
  H - Coal
  Exxon EDS

- **PETROLEUM COKES**

  Fluid Coke
  Delayed Coke
  Calcined Coke
  Fluid Coke from Tar Sands Bitumen

Figure 5

COALS GASIFIED AT RUHRCHEMIE DEMONSTRATION PLANT

Coal Type	Forge Coal	Fat Coal	Gas Coal	Gas Coal	Coal[1)] Sludge	High Volatility Bituminous coals		Med. Volatility Bituminous coal
No.	1	2	3	4	5	6	7	8
Origin		-Ruhr Area, West Germany-					-imported coals-	
Composition (% wt)								
C	85.4	81.9	80.8	79.4	60.0	70.9	68.6	65.8
H	4.0	4.7	5.0	4.9	3.8	5.0	4.6	3.5
N	1.6	1.5	1.5	1.6	1.1	1.2	1.2	1.5
S	0.8	1.1	1.1	1.0	1.4	3.6	0.6	0.8
O	2.6	4.0	5.1	4.6	5.8	7.1	12.4	8.6
Ash	5.6	6.8	6.5	8.5	27.9	12.2	12.6	19.8
Volatiles	16.0	21.7	32.1	29.0	24.2	38.5	37.6	23.8
Water Content[2)] (%)	<1	1	2	2	40-55[3)]	8	4	3
Ash Fusion Temperature[4)] (°C)	1360	-	1500	1450	-	1280	1370	1410
Hardgrove Index	99	100	-	68	-	55	47	66

1) from coal Washing
2) inherent moisture
3) as delivered
4) reducing Atmosphere

FIGURE 6

TYPICAL OPERATING DATA FROM RUHRCHEMIE DEMONSTRATION PLANT

Utah Coal

Coal Feed, tons/hr.	6.2
Oxygen Feed, tons/hr.	5.4
Gas Composition, mol % dry	
H_2	36.1
CO	43.8
CO_2	19.3
N_2	0.5
$H_2S + COS$	0.2
CH_4	0.1
Carbon Conversion, % of feed C	95.4
Cold Gas Efficiency, %	71.5

FIGURE 7

DEMONSTRATION PLANTS IN OPERATION

	RUHRCHEMIE/ RUHRKOHLE	CHEMICAL COMPANY	TENNESSEE VALLEY AUTHORITY
Plant Location	West Germany	U.S.A.	Alabama
Startup Date	1978	1979	1980
Feed Coal Rate, st/d	165	–	190
Oxidant	Oxygen	Air	Oxygen
Mode of Operation	Gas Cooler	–	Quench
Pressure, psig	540	–	600
H_2+CO Production, MMSCFD	9	–	10
Ultimate Product	Medium BTU Gas, Oxo-Chemicals	Electric Power	Ammonia

FIGURE 8

OTHER COMMERCIAL PROJECTS USING THE TEXACO COAL GASIFICATION PROCESS

PROJECT	SRC II	GRACE	WYCOALGAS	ALSANDS	TENNESSEE EASTMAN
LOCATION	W. Virginia	Kentucky	Wyoming	Alberta	Tennessee
PRODUCT	Hydrogen	Methanol	SNG	Hydrogen	Chemicals
STATUS	Detailed Eng. Design	–	–	Detailed Eng. Design	Under Construction
FUEL	Coal Liquefaction Residue	Coal	Lurgi By-products	Coke	Coal
TONS/DAY	2500	–	–	–	–
OXIDANT	Oxygen	Oxygen	Oxygen	Oxygen	Oxygen
GAS COOLING	Quench	Gas Cooler	Quench	Quench	–
PRESSURE, PSIG	815	–	–	–	–
H_2+CO (MMSCFD)	140	–	–	–	–
START-UP	–	–	–	–	1983

FIGURE 9

COMMERCIAL COAL GASIFICATION PROJECTS IN WHICH TEXACO HAS AN EQUITY POSITION

PROJECT	COOL WATER	HNG	SAN ARDO
LOCATION	California	Louisiana	California
PRODUCT	Power	Methanol	Power & Steam
STATUS	Procurement	Feasibility	Feasibility
FUEL	Coal	Coal	Coal
TONS/DAY	1000	6000	3600
OXIDANT	Oxygen	Oxygen	Oxygen
GAS COOLING	Gas Cooler	Gas Cooler	Gas Cooler
PRESSURE, PSIG	600	700	600
H_2+CO, MMSCFD	56	327	202
START-UP	1983	1989	1987