3. COAL LIQUEFACTION PLANTS

Preliminary designs have been made for the COED process, the SRC process and the H-Coal process. A summary is given of the results of these design studies, including unit descriptions, effluents to the air, solid and liquid effluents and process alternatives. General comparisons of the processes are almost meaningless since the coal feeds are different and the products are completely different.

3.1 General Description of Coal Liquefaction Plants

In descriptions of the pollution aspects of coal gasification plants in previous sections of this report, it was possible to take advantage of the similarities in the total processing schemes to subdivide all processes into groups of major sections. Such a grouping is not as easy for coal liquefaction processes. This is a result of the significant differences in the nature of the liquefaction and in the different natures of the products formed.

Plants producing liquids from coals that are being used or investigated can be classified into three types. These are the Fischer-Tropsch process which produces liquids from synthesis gas that has been produced by coal gasification, coal pyrolysis as in the COED process being developed by the FMC Corporation, and coal hydrogenation. The latter type can be further subdivided into non-catalytic hydrogenation as in the Solvent Refined Coal process (SRC) of the Pittsburg and Midway Coal Mining Company and catalytic hydrogenation as in the H-Coal process being developed by Hydrocarbon Research, Inc. The Fischer-Tropsch process was not studied in the present work, but process reports have been issued on the other processes (41, 42, 43).

The plant outputs from the COED, SRC and H-Coal processes are quite different. COED produces, besides the liquid and gaseous products, a relatively large quantity of char, the SRC process produces mainly a heavy liquid product that solidifies above ambient temperatures, and the H-Coal process produces mainly a synthetic crude oil with some by-product gas.

A rough generalization of the areas required to produce these products can be made and a generalized scheme is shown in figure 3. In the main liquefaction train there are four areas common to all three processes. These are coal storage and preparation (grinding, drying, etc.), coal liquefaction, product separation and hydrotreating. Hydrotreating, in the H-Coal case, is carried out simultaneously with liquefaction. Hydrogen production is another major segment of the complex and the main train for this operation is similar to the gasification processes discussed in Section 2. Finally there are the auxiliary facilities, such as the oxygen plant, acid gas plant, utilities, etc. which are necessary for operation of the other segments of the processes. These facilities have been described in Section 2 for gasification.

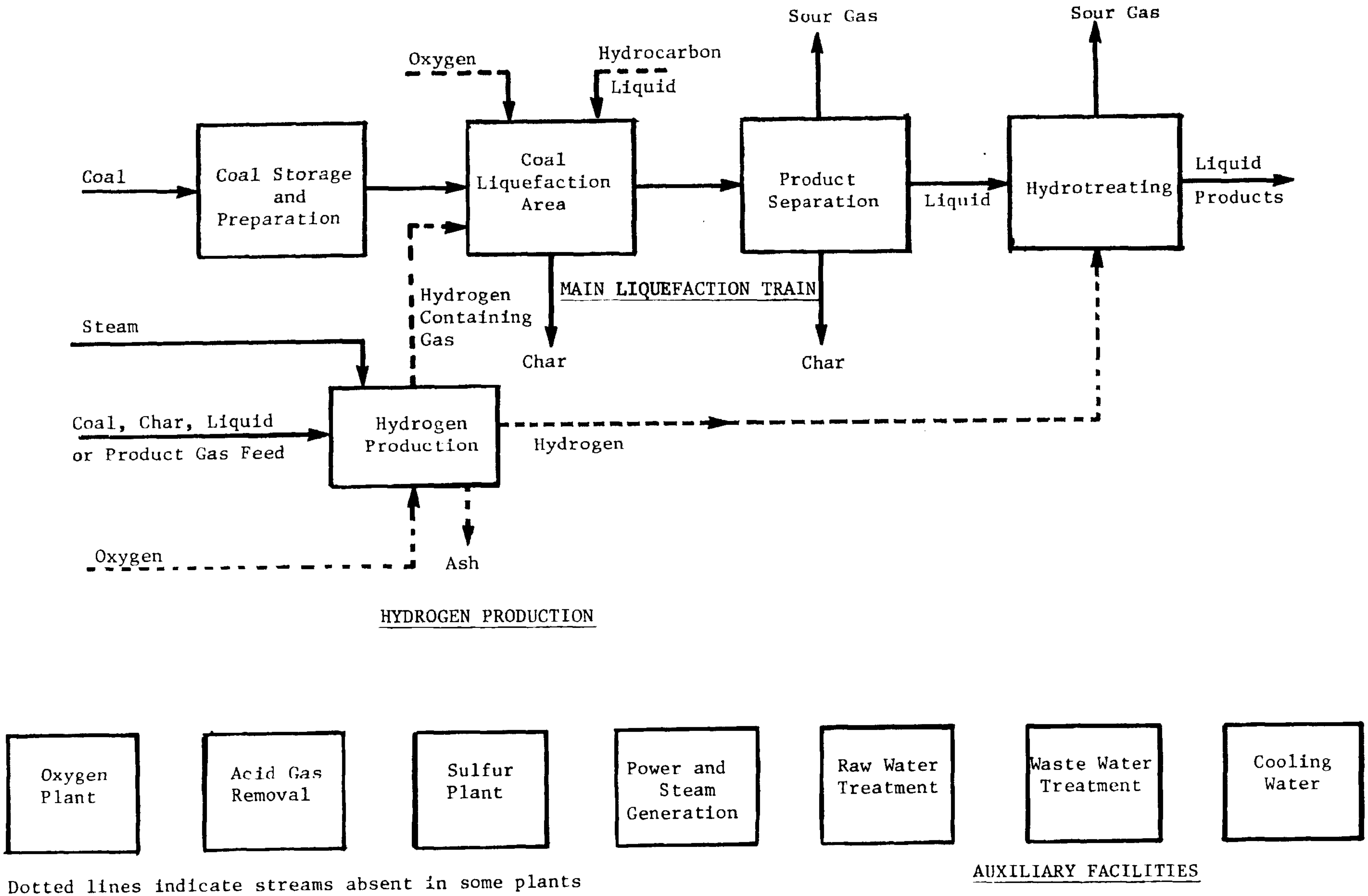

Figure 3

Generalized Coal Liquefaction Scheme

A more detailed description of the processes studied is given in Appendix B. For further details, the reader is referred to the process reports (41, 42, 43).

3.2 Main Liquefaction Train

3.2.1. Coal Storage and Preparation

In general, the description, effluents and alternatives in the area of coal storage and preparation are the same as those described in section 2.2 for gasification.

Table 26 summarizes the coal storage and preparation operations and Table 27 gives the analysis of the coals used in the processes. It should be noted that the SRC process only has three days storage and that, furthermore, gross coal cleaning takes place within the liquefaction complex with the removal of about 200,000 lb/hr of solids. This must be disposed of, possibly in the mine.

Table 28 summarizes operations of the coal dryers. In the COED process, partial drying is effected during milling operations using clean fuel gas. Drying operations are included with liquefaction. The SRC process uses coal with enough clean fuel gas to reduce sulfur emissions to that required by new coal-fired power sources. The H-Coal process makes use of clean fuel gas to fire the dryer.

3.2.2 Coal Liquefaction

Table 29 summarizes the liquefaction types and conditions. As indicated earlier, the COED process produces liquids by coal pyrolysis, the SRC process hydrogenates coal in a slurry and the H-Coal process uses an ebullating bed of slurry to hydrogenate coal with a catalyst. Table 30 shows the inputs to the reactors and Table 31 shows the outputs. The H-Coal process burns 65,800 lb/hr of clean fuel gas in a pre-heat furnace.

The only major effluent from this area is in the COED gas purge stream and in the flue gas streams. The flue gas should be relatively clean since clean fuels are used. The purge stream from the COED process is indicated to contain a relatively large quantity of combustibles and should, perhaps, be incinerated. It contains the equivalent of 250MM Btu/hr and is indicated to be sulfur free.

Leaks on high pressure equipment in the SRC and H-Coal processes may present problems from an atmospheric pollution viewpoint as well as liquids pollution. Water run-off from the process areas must of course be collected and treated.

Table 26

Coal Storage And Preparation Operations - Liquefaction

Process	Coal Type	Quantity Stored, tons	Size of Coal Feed	Fuel for Coal Drying	Other Operations
COED	Illinois No. 6	891,000	<16 mesh (minimum fines)	Fuel gas	--
SRC	Illinois No. 6	37,500	<1/8"	Fuel gas/coal	Extensive physical cleaning
H-Coal	Illinois No. 6	1,000,000	<40 mesh	Fuel gas	--

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 27

Coal Analysis - Liquefaction

Process	Coal Type	Proximate Analysis, %				Ultimate Analysis (MAF), %					
		Fixed Carbon	Volatiles	Ash	Moisture	C	H	N	S	O	Higher Heating Value, Btu/lb
COED	Illinois No. 6	44.0	32.0	10.0	14.0	75.5	5.5	1.2	4.6	13.2	12,420 (1)
SRC	Illinois No. 6	35.58	47.82	6.59	10	78.46	5.20	1.19	3.75	11.40	12,821 (2)
H-Coal	Illinois No. 6	37.8	43.3	8.9	10	78.5	6.0	1.1	5.5	8.9	12,983 (3)

(1) 5.9% Moisture

(2) 2.7% Moisture

(3) Dry

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 28

Coal Drying

Process	Fuel	Quantity, lb/hr	Heating Value, MM Btu/hr	Dried Coal Moisture Content, Wt. %	Dryer Vent Gas, lb/hr
COED[(1)]	--	--	--	--	--
SRC	Plant fuel gas/ Coal	6,853 2,700	150	2.7	244,300
H-Coal	Plant fuel gas	11,667	542	0	457,200

(1) Drying included with liquefaction

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 29

Liquefaction Descriptions and Operating Conditions

Process	Type	Temperature, °F	Pressure, psig	Major Reactor Products
COED	Fluid bed pyrolysis	Stage 1, 550-600 Stage 2, 850 Stage 3, 1,050 Stage 4, 1,550	8	Char, gas, liquid
SRC	Non-catalytic hydrogenation	840	1,000	Gas, char slurried in high melting liquid
H-Coal	Catalytic hydrogenation-ebulating bed	850	2,000	Gas, ash in liquid

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 30

Inputs to Liquefaction Reactors

(lb/hr, except as noted)

Process	Coal	Btu/lb Coal	Steam (Water)	Recycle Slurry	Gas	Combustion Air	Oxygen,	Transport Gas
COED	2,126,000 (1)	12,420	507,200	--	48,600 (4)	732,000	313,000	94,100
SRC	833,300 (2)	12,821	110,500	1,666,700	740,300 (5)	811,900	--	--
H-Coal	2,083,300 (3)	12,983	--	4,166,700	92,000 (6)	--	--	--

----

(1) 5.9% moisture

(2) 2.7% moisture

(3) Dry

(4) Natural gas. Does not include approximately 288,500 lb/hr gas recycled through char cooler.

(5) Syngas. Does not include 1,039.5 MM Btu/hr of fuel gas to preheat slurry

(6) Consists of make-up hydrogen. Does not include 65,800 lb/hr of fuel gas (1,580 MM Btu/hr) to preheat slurry or an unspecified quantity of recycled, hydrogen-containing gas.

(7) Oil only

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 31

Outputs From Liquefaction Reactors
(lb/hr)

Process	Raw Product	Char	Gas	Water
COED	2,174,500	1,042,600	732,000(2)	187,000
SRC	3,689,700(1)	--	873,200(3)	--
H-Coal	N.S.(1)	--	N.S.	N.S.

N.S. = Not specified

(1) Total product; includes char

(2) Purge gas must be treated due to high CO concentration

(3) Relatively clean flue gas

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

3.2.3 Products Separation

The raw product stream from liquefaction contains solids, liquids and gases and these must be separated. Table 32 shows the raw product composition. Most of the char in the COED process is removed during liquefaction, but a small portion exits the liquefaction section in the liquid-gas stream.

Heat is recovered from the raw products and the phases are separated. Product gas is passed to acid gas removal. Solids and liquids are separated by filtration in the COED and SRC processes and by vacuum distillation in the H-Coal process. The small quantity of oily solids from the COED process is recycled to coal feed. In the H-Coal process, 4,166,700 lb/hr of product oil is recycled to the slurry tank and the vacuum bottoms are used to produce hydrogen.

3.2.4 Hydrotreating

The H-Coal process does not have a hydrotreating section. In the COED and SRC processes, the liquid products from filtration are treated with hydrogen to reduce sulfur, nitrogen and oxygen compounds, and to hydrogenate unsaturated materials. Hydrogenation takes place at elevated temperatures and pressures.

The major effluents from hydrotreating are flue gases to the air and sour water. Since clean product fuel gas is used for fuel, the flue gases should be relatively clean. The sour water from the COED process is returned to the high temperature liquefaction reactor while it is sent to water treatment in the SRC case. Table 33 summarizes the inputs to the hydrotreating sections and Table 34 summarizes the output streams.

The liquid products from the hydrotreating area are sent to storage tanks.

3.3 Hydrogen Production

The production of hydrogen is similar in many respects to gasification which was discussed in Section 2. No attempt is made here to repeat that discussion, but a summary description of the hydrogen production facilities will be given. The reader is referred to Appendix B for more details or to the individual process reports (41, 42, 43).

In the COED process, by-product gas from the liquefaction process is mixed with cleaned bleed gas from the hydrogenation unit and fed to steam reforming reactors. Here it is reacted with steam to produce hydrogen and CO_2. The CO_2 is removed by acid gas absorption and residual carbon monoxide is removed by methanation. The product hydrogen stream is available for hydrogenation.

In the SRC operation, synthesis gas is available from the gasification section (see Section 3.6). This is shifted with steam to produce hydrogen, followed by CO_2 removal and methanation.

Table 32

Raw Product To Product Separation

(lb/hr)

Process	Liquid	Solid	Gas
COED	846,000	27,400 (1)	1,025,400 (2)
SRC	452,000	441,400	958,083
H-Coal	N.S.	N.S.	N.S.

N.S. = Not specified

(1) Oily solids; most char exits separately from reactors.

(2) Not including transport gas

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 33

Input Streams To Hydrotreating

(lb/hr)

Process	Product Oil	Hydrogen Make-up	Stripping Gas	Fuel Gas	Combustion Air	Water or Steam
COED	371,800	56,800	205,600	(1)	(1)	--
SRC	405,400	8,200	--	9,500	125,700	29,600
H-Coal	--	--	--	--	--	--

(1) 167 MM Btu/hr fuel gas and required combustion air.

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 34

Output Streams From Hydrotreating

(lb/hr)

Process	Liquid Products	Sour Gas	Stripping Gas	Sour Water	Flue Gas
COED	328,800	58,200	214,000	33,200	N.S.
SRC	385,750 (1)	15,900	--	41,400	135,156
H-Coal	--	--	--	--	--

N.S. = Not specified

(1) Not including 10,100 lb/hr to plant fuel

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

In the H-Coal process, bottoms from vacuum distillation are gasified in a Texaco type partial oxidation process, along with supplementary coal, with steam and oxygen. Solids are removed from the gas which then is passed through an acid gas removal step and to a shift reactor. Carbon dioxide is removed from the hydrogen which is then passed to the liquefaction section.

The major effluents from hydrogen manufacture are flue gases, CO_2 from acid gas removal and any purge from the acid gas removal units. The flue gases should be relatively clean since clean fuel is used. The CO_2 effluent should be clean but this should be checked in the case of the SRC process to be sure that COS is not admitted to the shift section. The waste water stream may contain carbonates and additives from the hot carbonate acid gas removal units. Its exact nature is unknown and should be ascertained.

Inputs to hydrogen production are shown in Table 35 and outputs are summarized in Table 36.

3.4 Auxiliary Facilities

As in gasification, auxiliary facilities have been included to make the liquefaction plants self sufficient. These facilities have been discussed in detail under gasification and will only be summarized here.

3.4.1 Oxygen Plants

Oxygen is required in the liquefaction complexes studied in this work and plants to produce the oxygen have been included. Oxygen plant descriptions and effluents have been discussed in the gasification section. Table 37 summarizes the oxygen requirements.

3.4.2 Acid Gas Removal

Although in liquefaction, as opposed to gasification, acid gas removal is not a part of the main train, such facilities are required to clean up various ancillary gas streams. A description of the processes has been given, along with effluents, in the gasification section.

All the plants require what may be called "primary" units for removal of a mixture of CO_2 and sulfur compounds. One primary unit is indicated for the COED process but two might be required; one would be used for streams from hydrotreating that contain ammonia. The ammonia could, however, be removed in a separate operation. Three primary units are required for the SRC process, one on recycle syngas, one on bleed gas from hydrotreating and one on syngas production. The latter is separate from the recycle gas unit because a part of the syngas produced is used for hydrogen production. The H-Coal process has two such plants, one on the recycle gas stream to liquefaction and one on the syngas prior to shifting in hydrogen production.

Table 35

Input Streams to Hydrogen Production

(lb/hr)

Process	Raw Material	Gasifier Steam	Oxygen	Other Steam and Water	Fuel Gas	Air
COED	108,000 (1)	(2)	--	(2)	46,000	N.S.
SRC	255,100 (3)	77,500	163,700	563,600	7,100	93,800
H-Coal	653,300 (4)	177,800	414,000	1,528,300	--	--

N.S. = Not specified

(1) Mixture of clean product gas and hydrotreater off-gas

(2) 86,000 lb/hr net water consumption

(3) Mixture of char, ash and heavy liquid

(4) Mixture of heavy bottoms and coal

. Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 36

Output Streams from Hydrogen Production

(lb/hr)

Process	Hydrogen	Synthesis Gas	Ash	Steam	Flue Gas/CO_2	Water	Acid Gas
COED	56,800	--	--	N.S.	N.S.[(1)]	N.S.	--
SRC	8,200	303,200	108,300[(2)]	331,500	168,300	129,700	111,600
H-Coal	92,000	--	222,300	508,000	1,104,800[(3)]	554,800	291,500

N.S. = Not specified

(1) 120,000 lb/hr CO_2 removed from raw hydrogen stream

(2) Water slurry containing 59,400 lb/hr slag

(3) CO_2 vent; contains 19,800 lb/hr water vapor

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 37

Oxygen Requirements - Liquefaction Processes

Process	Oxygen Required, lb/hr	Oxygen Required, lb per MM Btu in Liquefaction Feed Coal
COED	313,000	11.9
SRC	163,700	15.3
H-Coal	414,000	14.2[1]

(1) Includes coal to gasifier

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Besides the primary acid gas removal facilities, each plant requires a final CO_2 removal that may be referred to as "secondary" acid gas removal. These take out essentially pure CO_2 which can be vented.

Details of the acid gas removal facilities are summarized in Table 38.

3.4.3 Sulfur Recovery

Sulfur plants, including effluents and alternatives have been described previously. Table 39 summarizes available information on the sulfur plants used in the liquefaction complexes.

3.4.4 Ash and Solids Disposal

The disposal of ash and solids was discussed in Section 2. The type and quantity of ash from the COED process is uncertain since the type fuel is not completely specified. There is a large fraction of the coal input that is high Btu char; this will require disposition with recovery of heat equivalent. In the SRC process, the filter cake is gasified in a BIGAS type system. This was described in Section 2 above. The principal effluent consists of 108,300 lb/hr of a water slurry containing 59,400 lb/hr of ash. The H-Coal process has 222,300 lb/hr of ash from the hydrogen production section. Its fate is not specified.

There will, of course, be other solids from water treatment, etc. to be disposed of. These will be handled by methods similar to those used for gasification complexes.

3.4.5 Wastewater Treatment

Process wastewater in the COED process is injected into the last pyrolysis stage of the liquefaction section. Most of the sour water in the SRC process is injected into the coal slurry prior to liquefaction. Table 40 summarizes wastewater treatment information for liquefaction.

A discussion of wastewater treatment was given in Section 1. A general discussion of wastewater treatment has also been given in prior process reports (41, 42).

3.4.6 Electricity and Steam Generation

Table 41 summarizes the steam and electricity produced in the liquefaction plants. The H-Coal process uses high sulfur coal with stack gas scrubbing. The COED and SRC processes use fuel gas supplemented in the former case with char and in the latter case with clean product. The COED flue gas would require scrubbing.

Table 38

Liquefaction Acid Gas Removal Facilities

Process	Type of Removal		Type of Sulfur Guard	Quantity of Gas Treated, lb/hr		Quantity of Acid Gas Removed, lb/hr		H_2S Concentration in Primary Acid Gas, Volume %
	Primary ($H_2S + CO_2$)	Secondary (CO_2 Only)		Primary	Secondary	Primary	Secondary	
COED	Hot carbonate(1)	N.S.	ZnO	1,297,400	N.S.	658,500	120,000	7.2(1)
SRC	Monoethanol-(2) amine/caustic	Hot carbonate	---	1,438,400	149,000	469,900	67,400	7.6
H-Coal	Alkanolamine	Hot carbonate	---	N.S.	1,751,600	386,700	1,104,750	35.6

N.S. = not specified

(1) Separate unit may be necessary for ammonia containing streams.

(2) Three units required, one on recycle syngas, one on bleed gas from hydrotreating, and one on syngas production.

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 39

Sulfur Recovery In Liquefaction Systems

Process	Type of Sulfur Recovery	Quantity of Primary Acid Gas	H_2S Concentration, Volume %	Sulfur Produced, lb/hr	Sulfur in Tail Gas, vppm	Tail Gas Disposal
COED	Claus	658,500	7.2	42,500	N.S.	Beavon
SRC	Claus	469,900	7.6	26,400	N.S.	Beavon
H-Coal	Claus	386,700	35.6	107,900	N.S.	N.S.

N.S. = Not specified

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 40

Wastewater Treatment For Liquefaction Plants

Process	Total Wastewater Treated, lb/hr (1) (2)	Sour Water, lb/hr	Secondary and Tertiary Treatment
COED	1,494,900	0 (3)	--
SRC	532,200 (4)	178,700 (5)	biox pond
H-Coal	1,177,100	752,100	biox pond

---

(1) Does not include rain runoff

(2) Does not include miscellaneous streams

(3) Sour water incinerated in final reactor

(4) Does not include coal wash water

(5) Does not include 110,500 lb/hr injected to coal slurry

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 41

Generation Of Steam And Electricity In Liquefaction Plants

Process	Steam Plant, lb/hr	Boiler Fuel: Type	Boiler Fuel: Quantity, MM Btu/hr	Total Steam Generated, lb/hr: High P[1]	Total Steam Generated, lb/hr: Low P[1][2]	Flue Gas Scrubbing	Electrical Generation, kW
COED	782,800[2]	Fuel gas/ char	2,032[3]	1,151,000[4]	485,800[4]	Yes	95,370
SRC	715,300	Fuel gas/ liquid product	1,484	1,228,700[4]	298,520[4]	No	64,090
H-Coal	2,178,000	Coal	3,267	3,236,000	0	Yes	50,000

----

(1) Does not include extraction steam.

(2) 150 psig or less.

(3) Includes fuel for electrical generation.

(4) Does not include steam for electrical generation.

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Effluents from steam and electricity production are similar to those in gasification and are summarized in Table 42.

3.4.7 Cooling Water System

Table 43 summarizes the cooling water requirements and effluents. The large volume of air from the cooling towers offers a significant potential for atmospheric pollution. The cooling tower blow-down contains chemicals and may require special treatment. These effluents have been discussed in more detail in the section on gasification.

3.4.8 Raw Water Treatment

Raw water treatment and effluents were described in the gasification section. Table 44 summarizes the information on raw water treatment in liquefaction.

3.5 Products from Liquefaction Plants

As indicated above, the COED process produces a synthetic crude oil and a high Btu char, the SRC process produces a low melting solid fuel product and the H-Coal process produces a synthetic crude oil and has excess by-product gas.

Table 45 lists the properties of the synthetic crude from the COED process, Table 46 lists those for the products from the SRC process and Table 47 lists the properties of the H-Coal liquids product. Table 48 lists the properties of the char product from COED process. Table 49 lists the other products from the three liquefaction processes.

3.6 Miscellaneous Facilities

The SRC process produces synthesis gas used in liquefaction and for hydrogen production. The oily filter cake from product separation, together with oil, is gasified with steam and oxygen to produce the synthesis gas. The gasification system is a modification of the BI-GAS process described in Section 2 and Appendix A.5. Table 50 lists the inputs to and outputs from the syngas plant.

Table 42

Effluents From Steam And Electricity Production In Liquefaction

Process	Boiler Fuel	Ash, lb/hr	Flue Gas, lb/hr	Spent Limestone, lb/hr	SO_x, lb/hr	NO_x, lb/hr
COED	Fuel gas/char	12,800	N.S.	N.S.	Low	N.S.
SRC	Fuel gas/ liquid product	--	1,246,600[(1)]	--	Less than 1.2 lb/MM Btu	N.S.
H-Coal	Coal	24,900	3,121,000	39,400	Low	N.S.

N.S. = Not specified

(1) Includes flue gas from firing turbine

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 43

Cooling Water Requirements And Effluents From Liquefaction

Process	Cooling Tower Water, lb/hr				Air to Cooling Tower, MM scfd
	Cooling Water Circulated	Blowdown	Drift Loss	Make-up	
COED	100,000,000	1,200,000	300,000	4,500,000	N.S.
SRC	60,600,000	302,000	100,000	1,333,000	31,000
H-Coal	100,000,000	425,000	100,000	2,642,000	69,500

N.S. = Not specified

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 44

Raw Water Treatment In Liquefaction

Process	Raw Water Treated, lb/hr	Chemicals Added, lb/hr	Sludge From Water Treating, lb/hr	Water Treatment Sludge Disposal	Contaminated Water From Water Treatment, lb/hr	Contaminated Water Disposal
COED	3,795,000	N.S.	N.S.	N.S.	N.S.	N.S.
SRC	1,813,000	N.S.	N.S.	Concentrate; dispose of with slag	N.S.	N.S.
H-Coal	3,140,000	N.S.	N.S.	Concentrate; dispose of with ash	N.S.	N.S.

N.S. = Not specified

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 45

COED Syncrude Properties*

Product Quantity, lb/hr	328,800
API, ^{o}@60^{o}F	22
Pour Point, ^{o}F	0
Flash Point, PMCC, ^{o}F	60
Viscosity, cs. @ 100^{o}F	5
Ultimate Analysis, wt. %	
C	87.1
H	10.9
N	0.3
O	1.6
S	0.1
Ash	<0.01
Moisture	0.1
ASTM Distillation	
IBP	190
10%	273
30%	390
50%	518
70%	600
90%	684
EP (95%)	746
Metals, ppm	<10
% Carbon Residue, 10% Bottoms	4.6
Hydrocarbon Type Analysis, Liquid Vol. %	
Paraffins	10.4
Olefins	0
Naphthenes	41.4
Aromatics	48.2

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* Properties depend on severity of operation of hydrotreating unit.

Table 46

SRC Process - Major Streams From Plant

NET PRODUCTS

1. 242,900 lb/hr of heavy liquid, with a sulfur content of 0.5%.

Higher heating value	16,660 Btu/lb
Gravity	-9.7° API

2. 120,200 lb/hr of hydrotreated liquid, with a sulfur content of 0.2%.

Boiling range	400 to 870°F
Higher heating value	18,330 Btu/lb
Gravity	13.9° API

3. 22,700 lb/hr of hydrogenated light oils with the following approximate characteristics.

Boiling range	C_4 - 400°F
Gravity	52° API
Nitrogen	5 ppm
Sulfur	1 ppm

Table 47

Liquid Product from H-Coal Process

Synthetic Crude (91,240 b/d)	1,201,300 lb/hr

Synthetic Crude Inspections

Gravity, ^{o}API	25.2
Hydrogen, wt. %	9.48
Sulfur, wt. %	0.19
Nitrogen, wt. %	0.68

Table 48

Product Char Analysis From The COED Process

	PRODUCT CHAR
Quantity, lb/hr	1,042,600
Proximate Analysis, wt. %	
Volatile Matter	2.5
Fixed Carbon	75.5
Ash	21.1
Moisture	1.0
Ultimate Analysis, wt. % dry	
Carbon	73.8
Hydrogen	0.8
Nitrogen	1.0
Sulfur	3.2
Oxygen	0.0
Ash	21.2
High Heating Value, Btu/lb	11,700

Table 49

Other Products From Liquefaction

Process	Products, lb/hr			
	By-Product Fuel Gas	Sulfur	High Btu Char	Ammonia
COED	0	42,500	1,042,600 (1)	0
SRC	0	26,400	0	0
H-Coal	100,800 (2)	107,900	0	17,100

(1) See Table 48 for description

(2) HHV = 24,000 Btu/lb (900 Btu/scf); H_2 content = 56 Vol. %

Values shown in this table depend on the original bases chosen; plant sizes as well as other factors differ and direct comparison of the values is difficult. The process reports in references 3-10 should be consulted to determine each design basis, information sources, and qualifications (see Section 1.5) if individual numbers are to be utilized.

Table 50

Inputs And Outputs Of SRC Syngas Plant

Material	In, lb/hr	Out, lb/hr
Char Slurry	255,100	-
Oxygen	163,700	-
Steam	77,500	331,500
Water	437,100	29,100
Fuel Gas	2,440	-
Air	33,000	-
Slag Slurry	-	108,300
Flue Gas	-	35,400
Acid Gas	-	111,583
Clean Syngas	-	352,800