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TECHNOLOGY ASSESSMENT GUIDE
NO. 12
OCCIDENTAL RESEARCH PYROLYSIS

CHAPTER ONE: EXECUTIVE SUMMARY

1.1 OVERALL PROSPECTS FOR THE TECHNOLOGY

The Occidental Research Corporation Flash Pyrolysis process is an innovative approach to producing solid, liquid, and gaseous fuel products from coal. Through the use of process derived char as a heat transfer medium, the process avoids the requirement of an air separation plant (to provide oxygen) in producing a medium-Btu gas, among other products.

The process produces large amount of char, which is virtually free of sulfur and has a heating value similar to that of bituminous coal. Because of this, one process alternative being considered requires that the pyrolysis plant be situated near a large electric power plant, so that all of the char produced by pyrolysis will be consumed to generate electricity. Another possibility involves the recycle of all or most of the char to the pyrolysis plant where it would be used to generate more oil. Oil and gas would then be the only net products of the plant, with oil being much the larger in terms of Btu output.

Occidental claims a very high thermal efficiency for the process, in excess of 95 percent. This efficiency is based upon coal and electricity as inputs to the plant and a product spectrum consisting of gas, oils, char, and several by-products. The energy lost in this conversion process (less than 5% loss) is a full order of magnitude less than the loss during conversion of several other synthetic fuels plants, although one must also consider quality in making such comparisons. Its nearest competitors in the energy efficiency area operate in the 70-80 percent range at best. Occidental claims the reason for this high efficiency is due to the low endothermicity of the pyrolysis chemistry employed in the process, and they further state that these estimates have been verified in an independent engineering evaluation of the process. Although the process has considerable development ahead before commercial scale is reached, the availability of such an efficient system could be of great significance to the synthetic fuels industry.

1.2 ENGINEERING ASPECTS

The ORC concept has been under active development since 1969. R&D efforts have resulted in successful testing of the reactor concept beginning at the bench scale level (2-1/2"-4" reactor diameter) through a 10" diameter device. The system incorporates several unique concepts which will constitute an important advantage if the process can be proven at a commercial scale. These advantages include the use of air rather than oxygen, eliminating the need for an air separation plant, and the use of pyroysis (rather than gasification) chemistry which results in a higher overall thermal efficiency. The use of a solid heat transfer medium (hot char) allows convenient separation of flue gases from the combustible gas which is generated in the reactor and allows the use of air rather than oxygen. The process is also able to handle caking coals, provided that temperature limitations are observed. Perhaps its greatest single advantage is the thermal efficiency of 95.4 percent, claimed by ORC when operating on subbituminous coal.

Conceptually, the process is quite simple and employs standard technology with the exception of the reactor/char recycle system and the "Polystop" quench system. High solids circulation rates are employed in the reactor recycle loop. Previous tests of this system have faced expected problems of erosion, plugging and agglomeration problems when using caking coals at elevated temperatures.

The Polystop quench system has been shown to produce lighter, more stable oil products than would otherwise be produced from cooling by indirect heat transfer or quenching with a nonhydrogen-donor solvent. Use of the Polystop solvent allows protons to be transferred to free radicals within the hot oil, "capping off" the molecule and preventing polymerization and other reactions which would greatly increase the molecular weight of the oil. Thus, a lighter (higher value) product is produced which has better stability and storage characteristics. The Polystop quench process can therefore be thought of as an extension of the reaction system in which hydrogenation of the product stream is achieved. Light ends produced by these hydrogenation reactions are recovered from the quench operation and recycled to the pyrolysis reactor where they serve to increase the oil yield.

1.3 CURRENT COSTS

The total capital requirement for this 148 x 10^{12} Btu/year plant is $1.49 billion, which is dominated by a capital investment of $879 million. Interest during construction, working capital and start-up costs make up most of the remaining \$612 million. Annual operating and maintenance (at a 90 percent plant capacity factor) costs, exclusive of coal costs total \$68.5 million, and are largely comprised of taxes and insurance, labor and maintenance materials. By-product credits are given for sulfur, ammonia and phenols, and reduce operating and maintenance costs to a net annual \$62.8 million.

Taken together with a 20 percent capital charge, these O&M costs result in a nonfuel product of \$2.75/10^6 Btu, Assuming a coal cost of \$1.50/10^6 Btu, an average product cost of \$4.32/10^6 Btu is obtained.

1.4 RESEARCH AND DEVELOPMENT DIRECTIONS

The prime uncertainty at this time lies in the demonstration of process performance in larger scale operations. Product yields are a prime determinant of process efficiency, and the testing in larger scale pilot plants will be of great significance in the continuing evaluation of the technical and economic prospects for the process. Of equal importance will be proof of smooth and continuous operation in these larger plants, which may be difficult when handling certain caking coals. Most of R&D effort will probably be oriented at the reaction system, char recycle loop and quench operation.

CHAPTER TWO: ENGINEERING SPECIFICATIONS

2.1 GENERAL DESCRIPTION OF THE TECHNOLOGY

The Occidental Research Corporation (ORC) Flash Pyrolysis Coal Liquefaction process produces coal liquids for utilization as fuel oil and residual char for use as fuel in central power plants.

One unique aspect of the process is the use of hot recycle char as a solid heat transfer medium in the pyrolysis reactor. Because the char is heated in a vessel other than the reactor and then pneumatically transferred, air can be used for partial combustion of the char to provide the necessary heat. This feature precludes the need for oxygen in the system to provide heat of reaction. Moreover, the flue gases can be vented separately from the combustible gas generated in the reactor, avoiding dilution of this product.

The process is also noted for its ability to handle caking coals at temperatures below 1300°F. This feature eliminates the preparatory steps such as oxidative pre-treatment which are required for some other processes when using caking coals.

2.2 PROCESS FLOW, ENERGY, AND MATERIAL BALANCES

The flow scheme for the ORC flash pyrolysis system is shown in Figure 2-1. The conceptual commercial plant complex appears in Figure 2-2. Plant area numbers corresponding to major process areas are shown in this figure and are listed in Table 2-1.

Figure 2-1

Oxy Flash Pyrolysis Process Flow Scheme

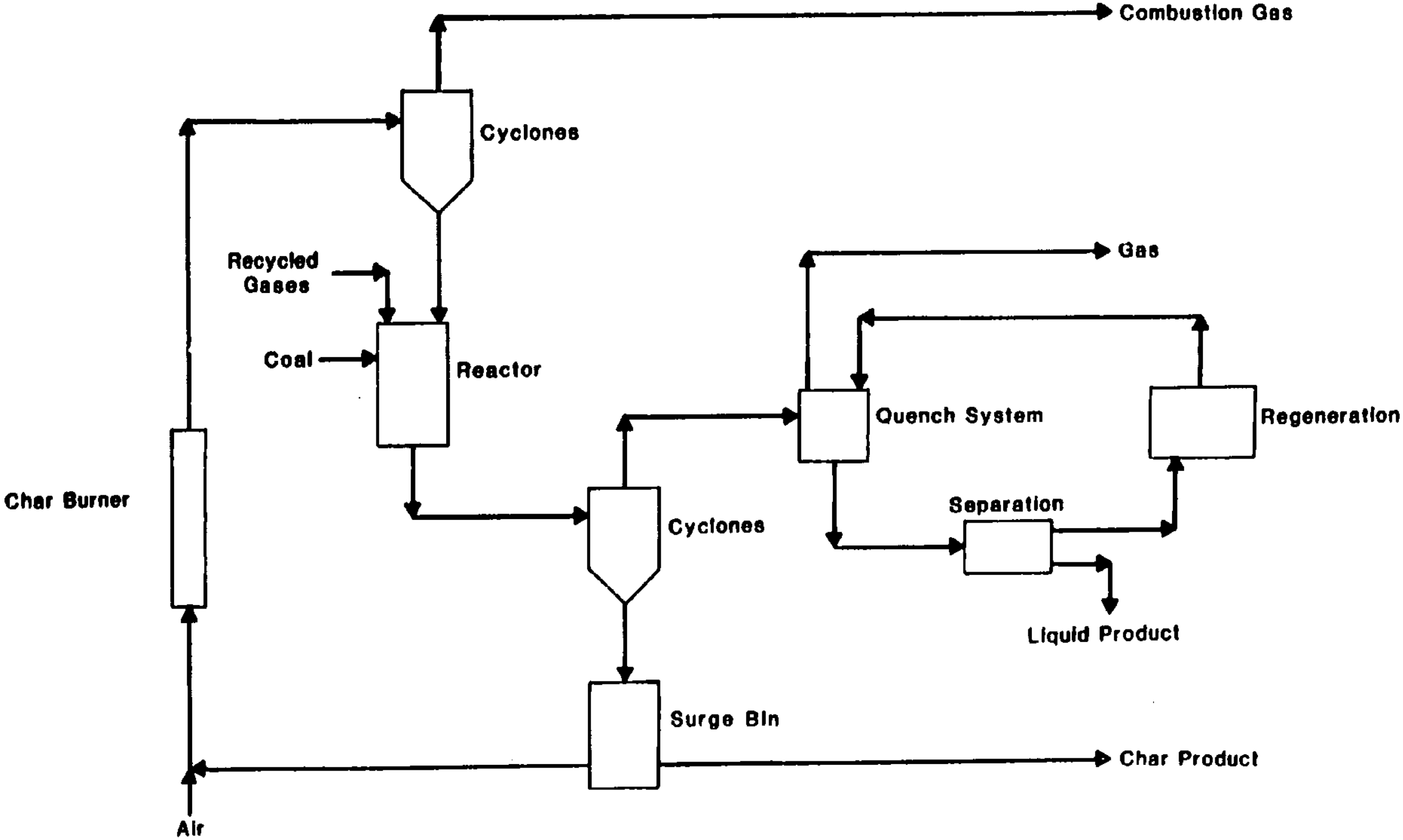

Figure 2-2

Block Flow Diagram for Oxy Flash Pyr is Conceptual Commercial Plant Complex (20,000 Dry Coal)

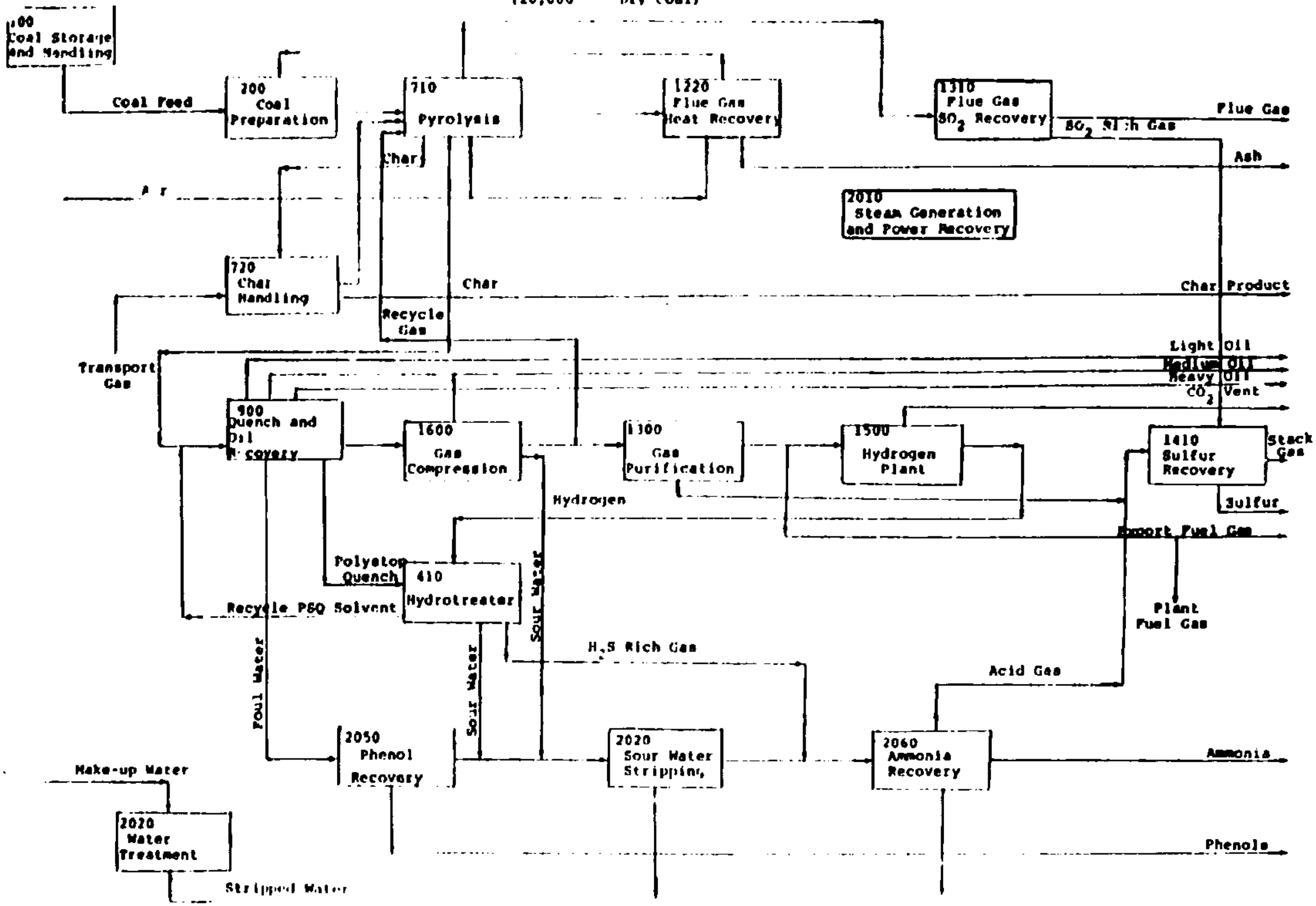

Table 2-1

Relevant Plant Area Numbers for the Occidental Research Corporation Flash Pyrolysis Process

100	COAL STORAGE AND HANDLING
200	COAL PREPARATION
400	HYDROGENATION/REGENERATION
	410 Polystop Media Hydrotreating
700	PYROLYSIS AND CHAR COMBUSTION
	710 Reaction
	720 Char Handling and Combustion
900	OIL QUENCH AND SEPARATION SYSTEM
1200	RAW GAS COOLING
	1220 Flue Gas Quench and Heat Recovery
1300	ACID GAS REMOVAL AND GAS PURIFICATION
	1310 Flue Gas SO_2 Recovery
1400	SULFUR RECOVERY AND TAIL GAS TREATING
	1410 Sulfur Recovery
1500	HYDROGEN PLANT
1600	GAS COMPRESSION
2000	UTILITIES AND SUPPORT SYSTEMS
	2010 Steam Generation and Power Recovery
	2020 Wastewater Treating and Sour Water Stripping
	2050 Aqueous Phenol Recovery
	2060 Aqueous Ammonia Recovery
2100	OFFSITES AND MISCELLANEOUS

Coal is transferred from storage (plant area 100) to preparation, where it is pulverized and dried to approximately 2 percent moisture. Recycled product gas is used to transport the coal pneumatically into the reactor. At this point it is mixed with a stream of hot recycled char which provides the heat for pyrolysis. The reactor operates at low pressure in an entrained flow mode, providing a short residence time in the reaction zone. Heat is rapidly transferred to the feed coal, which reaches its decomposition temperature of approximately 1100°F within 100 milliseconds.

The hot reactor effluent is cycloned for char removal. The hot char is collected in a storage bin, where it is separated to be either recycled for use in the process or sold as char product to an adjoining power plant. Heat is recovered from product char in the char handling unit prior to transport. The recycled char is fed to a second entrained flow vessel where it is partially combusted with air, raising its temperature to approximately 1400°F. After separation of the flue gases, the char is recycled to the reactor. The flue gases are sent to a heat recovery system, after which they are used to dry the pulverized coal in feed coal preparation.

The pyrolysis vapors are rapidly quenched in order to prevent any further degradation reactions. The ORC process utilizes the "Polystop" process (Controlled Flash Pyrolysis (CFP) process) in which solvent quenching is employed to control the pyrolysis chemistry. The volatized products are quenched with a solvent ("Polystop" solvent) in order to produce a lighter liquid product than that obtained from indirect cooling. The interaction of the oil radicals with the solvent minimizes polymerization, producing stable, light liquid products. The product liquid is separated by fractionation from the spent quench solvent mixture. The recovered solvent is regenerated by hydrogenation and recycled to the quench system.

As part of the Polystop process, slipstream reactive gases separated from the liquid products during quenching are recycled to be used in the entrained flow pyrolysis reactor. Utilization of the recycled reactive gases enhances the oil yield of the process.

An overall material flow summary for the process is presented in Table 2-2. Table 2-3 summarizes the calculation of overall process thermal efficiency.

2.3 PLANT SITING AND SIZING ISSUES AND CONSTRAINTS

The ORC Flash Pyrolysis Plant assessed in this study is designed to produce approximately 440 x 10^9 Btu/day of char, gas and synthetic liquid fuel products. A conceptual commercial plant would include coal preparation equipment, as well as the liquefaction equipment integral to the process. On-site facilities for liquid and gaseous effluent treatment would also be required. The resources of the area must be capable of supplying approximately 8 million tons of run of mine (ROM) coal per year. The pyrolysis plant must be situated near a power plant which will consume the char. The name plate capacity for the power plant is about 1500 MW.

2.4 RAW MATERIAL AND SUPPORT SYSTEM REQUIREMENTS

2.4.1 Coal Quantities and Quality

The conceptual commercial plant analyzed in this study would require approximately 8 million tons per year of coal (ROM). The system is designed to process all coal types. Oil yields of about 35 wt % MAF (1.9 bbl/ton) from a bituminous coal (West Kentucky #9) and 25 wt % MAF (1.4 bbl/ton) from a subbituminous

Table 2-2

Gross Material Flows for the ORC Flash Pyrolysis Process

Input Streams	lb/hr
Coal Feed (dried to 2% moisture)	1,683,333
Air	1,371,417
Output Streams	
Char Product	790,000
Light Oil	190,500
Medium Oil	114,083
Heavy Oil	81,083
Fuel Gas	64,417
Sulfur	7,250
Ammonia	4,333
Phenols	3,750
Flue Gas	1,660,750
Stack Gas	160,417
CO_2 Vent	117,250
Ash	1,333

Table 2-3

ORC Energy Balance Based on Subbituminous Wyoming Coal
Pyrolysis Products

Input	Mass Flow Rate	Btu Content mmBtu/Day
Coal	20,200 TPD	473,842
Electricity Consumption	(dry)	
(Heat rate: 9000 Btu/kWh)		8,237
Total Input		482,079
Products		
Char	9,480 TPD	248,376
Fuel Gas	30 MM SCFD	23,580
Product Oil	22,910 BPD	139,000
Heavy Oil	5,000 BPD	31,000
Sulphur, Ammonia, Phenols	184 TPD	3,000
		444,956

Overall Process Efficiency $= \frac{444,956}{482,079} = 92.3\%$

coal (Monarch Seam, Wyoming) have been obtained in the ORC process. This assessment is based upon use of only subbituminous coal.

2.4.2 Catalysts and Other Required Materials

The ORC Flash Pyrolysis process is non-catalytic; however, a catalyst is utilized in the hydrogenation process. Requirements for other process chemicals will depend on coal types and vary according to acid gas removal requirements, waste water treating needs and other factors. These parameters have been evaluated for commercial scale operations, but have not been disclosed to the public at this writing.

2.4.3 Water Requirements

Raw water required for the process is a variable determined by the designer according to specific site requirements. Plant designs for specific sites are not available.

2.5 EFFECT OF COAL TYPE

The liquid and gaseous products of the ORC process are derived from the vapor produced in the reactor. The Flash Pyrolysis Coal Liquefaction process can accept a wide range of coal types. Variations in feedstock properties would pose no serious problems in liquefaction; however, product yields would vary according to coal type.

The yield distribution is dependent on the type of coal feed and operating conditions of pyrolysis. On a once-through basis, the yields for both subbituminous and bituminous coals are given in Table 2-4.

Table 2-4

Pyrolysis Yield Distribution
(once-through basis)

	Wt. Percent of Dry Coal Feed	
	Bituminous	Subbituminous
Tar	32.0	23.6
Gas	12.3	17.4
Water	2.0	7.0
Char	53.7	52.0

2.6 AIR POLLUTION CONTROL TECHNOLOGY

2.6.1 Ability of Existing Technology to Meet Regulations

No information is available regarding potential specific air pollution control technologies for the ORC process. However, it is reasonable to assume that the methods to be employed would be similar to that which is used in other synthetic fuel plants.

Fugitive particulate emissions may be controlled by the use of electrostatic precipitators (ESP units), baghouses and/or cyclones depending on the volume and temperature of the emissions. Potential particulate emission sources in the process are char cyclone flue gas, ash product, char product, coal preparation, and stack gas.

Sulfur dioxide is removed from stack gases. Tail gas from sulfur recovery is further treated to reduce SO_2 emissions. Pyrolysis gases are purified before used in the plant as H_2 generation feed and plant fuel. The excess is sold as pipeline gas or chemical feedstock.

2.6.2 Air Pollution Control Technology Impacts on Process Efficiency

Air pollution control in the Occidental Flash Pyrolysis process consists of flue and fuel gas desulfurization and particulate removal. As with most other synthetic fuel conceptual designs, these systems are integral to the plant design and do not significantly affect overall process efficiency. However, unlike some systems which are based on sulfur sensitive catalysts, the ORC process employs sulfur removal purely for environmental protection. No estimates are available for efficiency loss due to operation of these systems.

2.7 WATER POLLUTION CONTROL TECHNOLOGY

No information is available regarding aqueous effluents of the ORC process. A water treatment system would be designed according to the needs of the as-built facility. Factors contributing to its design include the nature of organic constituents present; BOD, COD, chlorides and solids.

2.8 SOLID WASTES

No information is available regarding solid wastes from the ORC process. It is assumed that ponding and burial will be the most likely means of waste disposal.

2.9 OSHA ISSUES

Coal storage and preparation will expose workers to coal dust and noise. Ground coal can spontaneously combust. The dangers from fire and coal dust are controlled in the ORC process by storing prepared coal under flue gas which provides an inert atmosphere.

The products of the flash pyrolysis unit, especially the light oils and the tars, are high in carcinogenic and co-carcinogenic polynuclear aromatic hydrocarbons, such as benzene and phenols. Worker exposure to products of the process could be hazardous. Procedures for personal hygiene and protections must be established under proper guidelines.

2.10 PROCESS PERFORMANCE FACTORS

2.10.1 Product Characteristics and Marketability

The primary products of the ORC Flash Pyrolysis process are oil and char. A conceptual commercial facility, processing 20,000 TPD of dry coal has been analyzed in order to determine marketable product yield. The plant will produce about 30,000 BPD of oil and 10,000 TPD of char. Other saleable by-products would be ammonia, sulfur, mixed phenols and fuel gas. The char together with the fuel gas and heavy oil would be capable of supporting the operation of a 1500 MW power plant. The characteristics of the pyrolysis products are presented below:

- Char: Char product obtained from the ORC process has a gross heating value of 13,100 Btu/lb for subbituminous coal. The typical properties of the flash pyrolysis char are presented below:

Proximate, wt %	Char
Moisture	0.7
Volatile Matter	11.6
Ash	12.2

Ultimate, wt %	Char
C	79.6
H	2.3
N	1.2
S	0.6
O (By Diff.)	4.1

This product is sold for use as a fuel for central power plants.

- <u>Coal Liquid Products:</u> The ORC process produces liquid products which may be refined to fuel oils. The oils may be separated into varying proportions of light, medium and heavy oils. The composition of the raw pyrolysis liquid is given below. This liquid has picked up 0.63 lb of H per 100 lb of dry coal during quenching process. The total liquid yield in the conceptual plant is 23 percent of the dry feed coal.

<u>Composition, wt %</u>

C	84.00
H	9.32
N	1.54
S	0.26
O	4.88

The total product oil has an average gross heating value of about 6 MM Btu/bbl.

- <u>Gas:</u> The ORC process produces approximately 4.0 percent of the dry subbituminous coal feed as expert fuel gas. The heating value of this fuel gas is 15,000 Btu/lb (1000 Btu/SCFM).

The market prospects for the ORC process products have not been publicly released.

2.10.2 Capacity Factors, Flexibility, Reliability

Plant designs and specifications are not available to provide this information.

2.11 TECHNOLOGY STATUS AND DEVELOPMENT POTENTIAL

2.11.1 Current Status

The Flash Pyrolysis process has been under active development at ORC since 1969. Exploratory data obtained during the initial phases of development confirmed the basic simplicity of the process and its ability to produce relatively large liquid yields. Initially, the reactor was heated by electric elements wrapped around the wall. Inert gases (i.e., helium and nitrogen) were used for coal transport. Char was not used as the heat carrier. Hot pyrolysis products were passed through a series of cyclones for char recovery, and the gases were then cooled to collect liquid products.

After successful lab tests for the indirectly heated laboratory reactor, a three ton per day char recirculating unit was built in 1971 for further testing. This unit (the Process Development Unit or PDU) processed non-caking coals, municipal solid wastes, and industrial and agricultural wastes.

Early attempts to pyrolyze caking coals in the PDU resulted in reactor plugging in the entrained flow system. Coal pretreatment or preoxidation to avoid agglomeration lowered tar yield; hence, the need for a new method of processing caking coals arose.

After a thorough fundamental study of the caking coal processability, followed by a series of bench-scale reactor tests, a model was developed for designing a reactor to pyrolyze caking coals without any pretreatment or preoxidation. The validity of this model was verified using a 4-inch diameter downflow reactor retrofitted in the PDU. Based on this information, a 10-inch diameter reactor was constructed and tested successfully with caking coals during a previous DOE contract during 1976-78. Smooth and continuous tests of 24 hours duration were carried out.

A 2.5-inch diameter bench-scale reactor (BSR) with a capacity of 4 lb/hr was used in this program to guide the PDU operation. The main purpose of the BSR operations was to extend the data base of tar yields from the pyrolysis of subbituminous coal and to provide tar for characterization to aid in the operation of the PDU tar collection system. Later, it was used to troubleshoot the case of low tar yield obtained during the PDU baseline runs.

The Polystop quenching technology was developed in 1978. In September, 1980, a DOE contract was awarded to ORC to demonstrate the Polystop technology. ORC is currently operating a small-scale pyrolysis unit with char circulation, gas recycling and Polystop quench media circulation capability. The coal feed for the unit is 2 kg/hr, and char circulation is up to 20 kg/hr.

2.11.2 Key Technical Uncertainties

Smooth and continuous operation of the process for periods of several days is uncertain with regard to caking coals. Process yields will have to be proven in large-scale operation.

2.11.3 Availability for Commercial Production

The process is several years away from commercial availability.

2.11.4 Unit Design and Construction Times

Although no commercial size plants for the operation of the ORC process have been developed, it is assumed that design and construction times will be similar to other types of synthetic fuel plants.

2.12 REGIONAL FACTOR INFLUENCING ECONOMICS

No data is available regarding the ORC process's resource, environmental or siting constraints.

CHAPTER THREE: ECONOMIC ANALYSIS

3.1 Introduction and Methodology

3.1.1 Introduction

This section presents economic data on the pyrolysis process. The data is for a conceptual commercial plant of 148 trillion Btu/yr. The economic data in the reference was corrected to 1980 dollars.

3.1.2 Scaling Exponents

The plant size was not scaled, and so no scaling exponents were needed.

3.1.3 Price Indices

Costs for the reference plant were presented in 1981 dollars. These 1981 costs were derived by inflating 1980 prices by 6 percent. To correct the reference costs to 1980 dollars all data was deflated by 6 percent (divided by 1.06).

3.1.4 Economic Criteria

The standard economic criteria described in the Background section were employed.

The construction schedule was estimated by ERCO at 9, 24, 42, 22 and 3 percent in years 1 through 5 of construction.

To make the plant self-sufficient in electricity, the cost of an electric power plant was added to the capital cost estimate. The power plant cost was based on a 48 MW coal fired plant with flue gas desulfurization (3-2). The plant was sized at 48 MW to supply 40 MW at 90 percent capacity.

Sales tax was estimated at 2.5 percent of plant process and support facilities, and contingencies.

3.1.5 Contingencies

Insufficient information on the relative costs and level of development of particular plant areas was available to calculate process contingencies as in the other Technology Assessment Guides (TAG's). Instead, the process contingency of 12 percent of the subtotal of plant costs before sales tax and contingencies as was used in Reference 3-1 was applied. A project contingency of 20 percent was applied, as in Reference 3-1.

3.2 Capital Costs

3.2.1 Itemized Capital Costs

Capital costs by area and unit were not available for this technology. The available data is presented in Table 3-1. During late 1981, an Electric Power Research Institute report on the process will be published, which may include

TABLE 3-1

TOTAL CAPITAL REQUIREMENT: PYROLYSIS[a]

ITEM	COST
Process Capital	425
Support Facilities	179
Electric Power Plant	45.3
Process Contingency	77.9
Project Contingency	129.9
Sales Tax	21.4
Total Plant Investment	878.5
Land	0.9
Paid-Up Royalty	0.9
Start-Up	52.7
Working Capital	53.6
Interest During Construction	496.3
Initial Charge of Catalysts & Chemicals	8.5
Total Capital Requirement	1491.4

[a]Source: (3-1) corrected to 1980 dollars. 127 x 10^{12} Btu/yr capacity. Electric power plant cost from (3-2).

more detailed data. The Total Plant Investment amounts to $878.5 million as shown on Table 3-1. The Total Capital Requirement is $1491.4 million, also shown on Table 3-1. Interest During Construction, at $496.3 million, is a large expense because of the long construction period.

3.2.2 Variability of Capital Cost Estimate

No information was available on the level of detail of the capital cost estimate. It was prepared under the direction of the Electric Power Research Institute, which maintains high standards for its capital cost estimates.

The process has not yet been proven beyond the bench scale stage, and so there is great uncertainty in the costs of scale-up to commercial size. The lack of data about the level of detail of the cost estimate and the small scale of development efforts to date may suggest that the estimate is only accurate within ± 40 percent.

3.3 Operating and Maintenance Costs

3.3.1 Itemized Operating and Maintenance Costs

Itemized operating and maintenance (O&M) costs are presented in Table 3-2. Gross O&M costs total $68.5 million. The largest single expense is Local Taxes and Insurance at $36.4 million. Total labor costs amount to $25.1 million.

The plant produces by-product sulfur, ammonia and phenols, in salable quantities. The credits for these

TABLE 3-2

NET OPERATING AND MAINTENANCE - PYROLYSIS[a]

ITEM	ANNUAL COST (10^6\$)	PERCENT OF TOTAL
Gross Operating and Maintenance		
Administration and General Overhead	7.6	11.1
Local Taxes and Insurance	24.9	36.4
Labor		
Process	5.6	8.2
Maintenance	7.8	11.4
Supervision	3.8	5.5
Total	17.2	25.1
Maintenance Materials	10.6	15.5
Catalysts and Chemicals	7.7	11.2
Utilities	.5	.7
Total	68.5	100.0
By-Product Credits	(10^6\$)	
Sulfur	(1.0)	
Ammonia	(2.3)	
Phenols	(2.4)	
Total	(5.7)	
Net Operating and Maintenance	(10^6\$)	
Gross Operating and Maintenance	68.5	
By-Product Credits	(5.7)	
TOTAL	62.8	

[a]Source: (3-1), adjusted by ERCO to 1980 dollars.

(coal) costs. Both a total product cost and a non-fuel cost can be computed using the formulae given in the Background section.

Non-fuel costs have a capital charge component and an O&M charge component. Based on the total capital requirement of $1,491.9 million from Table 3-1, and the yearly net O&M cost of $62.8 million from Table 3-2, the non-fuel product cost is:

$$P = \frac{\$1{,}491.4 \times 10^6 \times 20\% + \$68.2 \times 10^6}{148 \times 10^{12} \text{ Btu} \times 90\%}$$

$$= \underset{\text{(capital charges)}}{\$2.24/10^6 \text{ Btu}} + \underset{\text{(O\&M costs)}}{\$.51/10^6 \text{ Btu}}$$

$$= \underset{\text{(total non-fuel cost)}}{\$2.75/10^6 \text{ Btu}}$$

Capital charges amount to $\$2.24/10^6$ Btu and O&M costs to $\$.51/10^6$ Btu. The total non-fuel cost will be $\$2.75/10^6$ Btu.

The non-fuel cost, combined with a coal cost, yields a total product cost for the plant's outputs. The overall coal-to-hydrocarbon output efficiency of the plant is 95.4 percent. With coal assumed to be $\$1.50/10^6$ Btu, the fuel component of energy costs would be $\$1.57/10^6$ Btu. When combined with the non-fuel cost, this yields an average product cost of $\$4.32/10^6$ Btu.

by-products total $5.7 million, as is also shown in Table 3-2. Net O&M costs, which include both gross O&M costs and by-product credits, total $62.8 million.

3.3.2 Variability of O&M Costs

Insufficient data were available to evaluate the variability of the O&M cost estimates. However, no major cost item was omitted. In general, the O&M costs are in accordance with the capital cost estimate. The variability of the O&M cost estimate probably lies within the ± 40 percent of the capital cost estimate.

3.4 Effect of Technology Development on Costs

The flash pyrolysis process has not yet been demonstrated beyond the bench-scale level. Therefore a great deal of technical development is possible.

The data presented in the references available, however, were insufficient to permit a judgment as to the effect of technology development on costs. As was pointed out in the Background section, the experience factor for the synthetic fuel plants assessed in this volume is typically 2-6 percent.

3.5 Total Product Costs

The total cost of the products has three discrete components: capital charges associated with plant capital costs, plant operating and maintenance (O&M) costs, and fuel

References

3-1. Durai-Swamy, K. and W. Deslate (Occidental Research Corporation), "Occidental's Flash Pyrolysis Coal Liquefaction Process and Its Application to Power Generation." Paper presented at the Conference on Coal Pyrolysis, February 25-26, 1981.

3-2. Electric Power Research Institute, "Technical Assessment Guide." Report PS-1201-SR, July 1979. Pages 8-11.