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Solar Fuels and Chemicals System Design Study - Production and Regeneration of Activated Carbon Final Report Volume 3 - Appendices

Babcock and Wilcox
A McDermott Company
Nuclear Equipment Division
Barberton, Ohio 44203

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SOLAR FUELS AND CHEMICALS SYSTEM DESIGN STUDY - PRODUCTION AND REGENERATION OF ACTIVATED CARBON FINAL REPORT VOLUME 3 - APPENDICES

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ABSTRACT

This report describes the conceptual design of a solar thermal central receiver system that both produces activated carbon from coal and regenerates spent activated carbon. The system design uses molten carbonate salt that is heated in the receiver to transfer heat to an activated carbon plant located near the base of the receiver tower. Capital and operating cost estimates are described, and market and economic analyses are presented to assess the attractiveness of the proposed system. Technical uncertainties are identified as the basis for a development plan to bring the proposed system to maturity.

SOLAR THERMAL TECHNOLOGY
FOREWORD

The research and development described in this document was conducted within the U.S. Department of Energy's (DOE) Solar Thermal Technology Program. The goal of the Solar Thermal Technology Program is to advance the engineering and scientific understanding of solar thermal technology, and to establish the technology base from which private industry can develop solar thermal power production options for introduction into the competitive energy market.

Solar thermal technology concentrates solar radiation by means of tracking mirrors or lenses onto a receiver where the solar energy is absorbed as heat and converted into electricity or incorporated into products as process heat. The two primary solar thermal technologies, central receivers and distributed receivers, employ various point and line-focus optics to concentrate sunlight. Current central receiver systems use fields of heliostats (two-axis tracking mirrors) to focus the sun's radiant energy onto a single tower-mounted receiver. Parabolic dishes up to 17 meters in diameter track the sun in two axes and use mirrors or Fresnel lenses to focus radiant energy onto a receiver. Troughs and bowls are line-focus tracking reflectors that concentrate sunlight onto receiver tubes along their focal lines. Concentrating collector modules can be used alone or in a multi-module system. The concentrated radiant energy absorbed by the solar thermal receiver is transported to the conversion process by a circulating working fluid. Receiver temperatures range from 100^{o}C in low-temperature troughs to over 1500^{o}C in dish and central receiver systems.

The Solar Thermal Technology Program is directing efforts to advance and improve promising system concepts through the research and development of solar thermal materials, components, and subsystems, and the testing and performance evaluation of subsystems and systems. These efforts are carried out through the technical direction of DOE and its network of national laboratories who work with private industry. Together they have established a comprehensive, goal directed program to improve performance and provide technically proven options for eventual incorporation into the Nation's energy supply.

To be successful in contributing to an adequate national energy supply at reasonable cost, solar thermal energy must eventually be economically competitive with a variety of other energy sources. Component and system-level performance targets have been developed as quantitative program goals. The performance targets are used in planning research and development activities, measuring progress, assessing alternative technology options, and making optimal component developments. These targets will be pursued vigorously to insure a successful program.

The production of fuels and chemicals using solar thermal energy would broaden the Program's impact on fossil fuel displacement and establish the full potential of solar thermal technology. This report describes the conceptual design of a solar thermal central receiver plant that both produces activated carbon from coal and regenerates spent activated carbon. Technology development needs are described, and market and economic analyses are presented.

Information in this report should be considered preliminary since the work was carried only through the conceptual stage. A key factor in sizing many of the components is the corrosion rates for the materials selected. Corrosion data for some of the materials specified are limited and subject to interpretation.

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MATERIALS EVALUATION FOR THE SOLAR FUELS AND CHEMICALS SYSTEM DESIGN STUDY

INTRODUCTION AND BACKGROUND

Selection of an appropriate material to contain the ternary eutectic carbonate salt at elevated temperatures was a key issue of the Solar Fuels and Chemicals Systems Design Study. Preliminary evaluation during the proposal phase resulted in the selection of silicon carbide for use in the manufacture of the receiver panels and other high temperature components. New information raised questions as to the suitability of silicon carbide in this environment.

The project team has evaluated a number of materials for compatibility with the carbonate salt and at the required process temperatures. In evaluating materials, consideration was given to two alternate methods of operating the chemical process for the regeneration of spent carbon and the production of activated carbon. The baseline operating method provides energy input to both the regeneration and production processes from the carbonate salt; this requires a maximum salt inlet temperature of 1150°C (2100°F). The alternate operating method provides a portion of the energy input to the regeneration process from fossil fuel and energy input to the production process for the carbonate salt. This alternate method permits a reduction in the maximum salt temperature to 954°C (1750°F). For both the baseline and the alternate chemical processes, a variety of ceramic and metal materials were evaluated, including:

- Silicon Carbide
- Alumina
- Cordierite
- Graphite
- Mullite
- High chromium alloys
- Aluminum containing alloys
- High nickel alloys
- Cobalt containing alloys
- Stainless steels

The criteria considered in the material selection process included:

- Salt temperature
- Corrosion resistance
- Good thermal shock resistance
- Reasonable thermal conductivity
- Adequate strength

B&W gathered information for the material selection based on personal contacts with, and published information supplied by, various organizations, including:

- B&W Lynchburg Research Center
- B&W Alliance Research Center
- Olin Chemical
- Black & Veatch
- Sandia National Laboratories
- Solar Energy Research Institute (SERI)
- Rockwell International
- Material vendors

CONCLUSIONS

A suitable material was not found for the higher temperature chemical process incorporating regeneration of spent carbon. Section 4.2.5 of this report addresses long range plans to develop a material suitable for the 1150°C (2100°F) carbonate salt service required for the regeneration process.

For the nearer term, the chemical process will use natural gas to fire the regeneration portion of the process and molten salt at 954°C (1750°F) to provide energy input for the production of activated carbon. Inconel 600 will be used in contact with the carbonate salt for corrosion resistance. The Inconel 600 will be combined with other materials to provide the mechanical strength for component design. For example, in the receiver, a co-extruded tube of Inconel 600 and Inconel 617 will be used while in the chemical process furnaces, the Inconel 600 will be combined with strength materials suitable to a coal environment. Section 4.2.1 encompasses material development for carbonate salt in this lower temperature range.

DISCUSSION

Evaluation of the materials of construction for the Solar Fuels and Chemicals Design Study encompassed both ceramics and metals. Initially, the preliminary selection of silicon carbide made in the proposal stage was reviewed in light of additional information [1] obtained on the corrosive effects of the carbonate salt on silicon carbide. Several articles [2,3] reported etching of silicon when exposed to molten carbonate salt at 900^{o}C (1652^{o}F). It appears that silicon is oxidized by the carbonate salt and then absorbed into the molten salt. The exact mechanism and its associated kinetics have not been determined. The reported results were confirmed by the ceramic specialists at B&W's Lynchburg Research Center and by Olin. The corrosion rate of silicon carbide in the 900^{o}C (1652^{o}F) carbonate salt is too severe to consider it as a viable material in this environment.

A question was raised concerning the need for the presence of oxygen to facilitate the corrosion process of the silicon carbide [3]. Increasing the oxygen concentration into the molten carbonate salt increased the corrosion rate of a silicon carbide test coupon. Silicon carbide has not been tested for corrosion resistance in a oxygen free atmosphere, therefore, the conclusion that oxygen is needed in combination with the carbonate salt to corrode silicon carbide cannot be reached.

In addition to silicon carbide, a variety of ceramics were reviewed as candidate materials (See Table 1.0 for the evaluation). The principal ceramics evaluated were cordierite, graphite, mullite, and alumina [4]. Graphite and cordierite were rejected as a result of high corrosion rates in a 900^{o}C (1652^{o}F) eutectic carbonate salt solution as reported by SERI [5]. Both mullite and alumina were considered inadequate due to poor thermal shock properties.

A 99.8% pure solution of alumina exhibited a higher level of corrosion resistance than any other ceramic or alloy tested [5]. A composite ceramic of alumina and a material with high thermal shock resistance could possibly be a solution to the high temperature material requirements of the regeneration portion of this project. This and other development work in the ceramics field are addressed in Section 4.2.5.

Several metal alloys were considered for use in a molten carbonate salt environment (See Table 2.0 for the evaluation). The Solar Energy Research Institute (SERI) tested a variety of alloys in a static 900°C (1652°F) solution of the ternary eutectic carbonate salt [5]. The results exhibit a measurable corrosion rate for each of these alloys. Based on quantitative tests and qualitative observation, Inconel 600 (70% nickel) was judged the most resistant alloy tested. Soon after being exposed to the carbonate salt, Inconel 600 formed a protective oxidized layer. This protective layer's durability increased with an increased percentage of oxygen dissolved in the molten salt [6]. In contrast, an oxygen free carbonate salt formed a resistant surface that was subject to spalling.

Rockwell International has also used high temperature carbonate salts on several research projects. Presently, Rockwell is employing a carbonate salt at 900°C (1652°F) to destroy various hazardous wastes [7]. Their preliminary corrosion tests led them to use Inconel 600 as the material to fabricate a large vat to contain the hot carbonate salt. The vat has been used on numerous occasions for up to two months at a time in contact with the 900°C (1652°F) carbonate salt. The vat is exposed to an air environment while in use. Rockwell's qualitative observation is that the oxidized layer that originally formed, does not spall and has protected the Inconel 600 from further corrosion [8].

The limited corrosion data for Inconel 600 in a molten carbonate salt environment was used to estimate a corrosion allowance for the system components for the 20 year plant life. Several data points for corrosion tests of about two days' duration indicated a corrosion rate of about 1.8 mm/year (0.071 in./year). A 60 day corrosion test indicated a corrosion rate of 0.365 mm/year (0.0144 in./year). One method used to estimate corrosion for the plant life was to linearly extrapolate the rate of the longest test to 20 years; this resulted in a total corrosion of about 7.3 mm (0.29 in.). A second method extrapolated the total corrosion as a function of time along a parabolic curve, which assumes the rate of corrosion decreases with time. Such an extrapolation of the data points resulted in corrosion of about 0.76 mm (0.030 in.) in 20 years. Thus, the two methods of data extrapolation result in an order of magnitude range on the corrosion estimate for the plant life.

Establishing a corrosion allowance for the purpose of component design in this study is most critical for the heat transfer tubing in the receiver and the salt heater. (It should be noted that such corrosion allowance may also be critical to the design of such components as pumps and valves; however, detailed designs of these components are not considered in this study.) Because the base of corrosion data ia so small and the duration of the tests is relatively short compared to the 20 year plant life, the extrapolated range of corrosion can only be regarded as a rough estimate of what might be expected. The judgment was made to provide the heat transfer tubing with a 1.6 mm (0.062 in.) Inconel 600 liner to account for the effects of corrosion over the 20 year plant life. This value falls within the range of the extrapolated corrosion values for 20 years and is on the order of the maximum practical for the small diameter heat transfer tubing to be used in the receiver and the salt heater. The alternative of assuming more corrosion for the 20 year plant life would be to require replacement of the affected parts at specified intervals during the plant life. This would obviously be detrimental to the economic evaluation of the plant in terms of additional capital and maintenance costs and lost revenue. The judgment was made that the baseline economic evaluation should be performed on the basis that future materials development work, as outlined in the Development Plan in Section 4.0, would support the design of components which could be built for 20 year plant life without the need for replacement. Whether the material development would support the use of Inconel 600 or some other material as the corrosion resistant material is not known at this time. However, the assumption of the 1.6 mm (0.062 in.) Inconel 600 tube liner is considered reasonable in terms of developing conceptual component designs and estimating capital costs.

TABLE 1.0

CERAMICS CONSIDERED FOR MOLTEN CARBONATE SALT SERVICE

Material	900°C Corrosion	Temperature Range °C/°F	Thermal Shock	Tube Availability	Strength
Silicon Carbide	.3 um/min (poor)	1650/3000	excellent	readily available	high comp./ low tens.
Cordierite	20 um/day	980/1800	good	obtainable	good comp./ low tens.
Mullite	20 um/day	980/1800	poor	NA	good comp./ low tens.
Graphite	dissolves	NA	good	obtainable	good comp./ good tens.
Alumina (99.8%)	.1 um/day (good)	1150/2100	poor	thick wall only	good comp./ low tens.

TABLE 2.0

ALLOYS CONSIDERED FOR MOLTEN CARBONATE SALT SERVICE

Material	900°C Corrosion	Temperature Range °C/°F	Thermal Shock	Tube Availability	Strength
Incoloy 800 H	10 um/day	980/1800	excellent	readily available	excellent
Cabot 214	11 um/day	815/1500	excellent	readily available	good
Haynes 556	5 um/day	815/1500	excellent	readily available	good
Stainless 316	10 um/day	815/1500	excellent	readily available	good
Inconel 600	1 um/day (good)	815/1500	excellent	readily available	good
Inconel 617	NA	980/1800	excellent	readily available	excellent

REFERENCES

1) Telephone conversation with Bob Bradshaw of Sandia National Laboratories (415-422-3229).

2) J.W. Faust, Jr., J.M. Liaw, "Tables of Etchants for SiC", U. South Carolina Press; (1974).

3) V.J. Jennings, "The Etching of Silicon Carbide", Lanchester College of Technology; (Oct., 1968).

4) Telephone conversation with Pam Burke of New Castle Refractories (412-654-7711).

5) R.T. Coyle, R.J. Copeland, R.W. Burrows, R.M. Goggin, "High Temperature Molten Salts for Use in Solar Thermal Energy Systems", SERI: (June, 1983).

6) Telephone conversation with Dr. Tom Coyle of the Solar Energy Research Institute (303-231-1202).

7) R.L. Gay, A.G. Pard, J.C. Newcomb, K.M. Barclay, S.J. Yosim, "Development of a Metal Molten Salt Combustor for Volume Reduction of Intermediate - Level Liquid Waste", Rockwell International; (July, 1981).

8) Telephone conversation with Dr. Don McKenzie of Rockwell International (818-700-4398).

9) Telephone conversation with Dr. Gene Clark of Turbine Metal Technology (818-352-8721).

10) Telephone conversation with Brian Proven of Huntington Steel (216-464-8705).

11) Telephone conversation with Mike Rothman of Cabot Corporation (317-456-6223).

APPENDIX B

EQUIPMENT SPECIFICATIONS

Appendix B - Equipment Specifications

This Appendix is the equipment list for the entire Solar Fuels and Chemicals process for the production of activated carbon and the regeneration of spent carbon. The equipment list is divided into the systems listed below. The individual pieces of equipment in each system are listed with information on the manufacturer, the quantity, the capacity, the materials of construction, the design temperature and pressure, and any other pertinent data.

SYSTEM: COAL HANDLING

RAIL CAR DUMP HOPPER

Manufacturer	Beaumont Birch Co.
Number	1
Type	Four-Outlet, Inverted Pyramidal
Process Material	Coal
Capacity	200,000 lb
Primary Equipment Material	Carbon steel; A.R. liner
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	48'L x 14'W x 19.7'H

RAIL HOPPER FEEDERS

Manufacturer	Beaumont Birch Co.
Number	4
Type	Belt
Process Material	Coal
Capacity	30,000 to 400,000 lb/hr
Primary Equipment Material	Rubber, Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	Size of conveyed material: 1 to 5 in. Conveyed material moisture: 10 to 15% Inclination: 14 degrees Length: 48 ft

WET DUST SUPPRESSION PROPORTIONER

Manufacturer	Dust Suppression Systems
Number	1
Type	Water plus surfactant
Process Material	
Capacity	3,000 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	115
Remarks	

ELEVATING CONVEYOR

Manufacturer	Beaumont Birch Co.
Number	1
Type	Belt
Process Material	Coal
Capacity	1 million lb/hr
Primary Equipment Material	Rubber, carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material: 1 to 5 in. Conveyed Material Moisture: 10 to 15% Inclination: 14 degrees Length: Approximately 1,300 ft

BELT SCALE

Manufacturer	Ramsey Engineering Co.
Number	1
Type	Electronic
Process Material	Coal
Capacity	1,200,000 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	

DIVERTER GATE

Manufacturer	Process Equipment Builders
Number	1
Type	Single blade diverter valve
Process Material	Coal
Capacity	1 million lb/hr
Primary Equipment Material	Carbon steel, abrasion-resistant liner
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	

SILO FILL CONVEYOR

Manufacturer	Beaumont Birch Co.
Number	3
Type	Belt
Process Material	Coal
Capacity	1 million lb/hr
Primary Equipment Material	Rubber, carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	Size of Material Conveyed: 1 to 5 in. Conveyed Material Moisture: 10 to 15% Length: Approximately 35 ft

COAL STORAGE SILOS

Manufacturer	Beaumont Birch Co.
Number	4
Type	Cylindrical, single outlet
Process Material	Coal
Capacity	1.5 million lb each
Primary Equipment Material	Carbon steel, stainless steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	30 ft diameter 73 ft high

DUST COLLECTOR

Manufacturer	Carter-Day
Number	1
Type	Fabric filter baghouse
Process Material	Coal dust
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.2
Remarks	Air Flow Rate: 18,000 cfm Fabric Area: 2,572 ft^2 minimum Air-to-Cloth Ratio: 7:1 Media Type: Polyester

FAN

Manufacturer	Twin City Fan
Number	1
Type	SWSI, centrifugal
Process Material	
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.2
Remarks	Air Flow Rate: 18,000 cfm

WEIGH FEEDERS

Manufacturer	Merrick
Number	2
Type	Electronic, belt
Process Material	Coal
Capacity	8,000 to 16,000 lb/hr each
Primary Equipment Material	Rubber, carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material: 1 to 5 in. Conveyed Material Moisture: 10 to 15% Length: Approximately 80 ft

CN-101 CONVEYOR

Manufacturer	Beaumont Birch Co.
Number	1
Type	Belt
Process Material	Coal
Capacity	14,911.7 lb/hr
Primary Equipment Material	Rubber, carbon steel
Design Temperature, F	77
Design Pressure, PSIA	14.7
Remarks	Size Conveyed Material: 1 to 5 in. Conveyed Material Moisture: 10 to 15% Inclination: 14 degrees Length: Approximately 100 ft

SYSTEM: PRETREATMENT

VT-101 ACID MIXER

Manufacturer	Arrow Tank
Number	1
Type	Vertical cylindrical
Process Material	30% coal, 70% acid
Capacity	43,186.7 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	176
Design Pressure, PSIA	Atmospheric
Remarks	

AG-101 AGITATOR

Manufacturer	Lightning Mixers
Number	1
Type	Mounted on acid mixer
Process Material	
Capacity	
Primary Equipment Material	
Design Temperature, F	176
Design Pressure, PSIA	Atmospheric
Remarks	

HE-101 HEATER

Manufacturer	
Number	1
Type	Steam coils immersed in coal slurry
Process Material	Coal slurry
Capacity	764 lb/hr steam
Primary Equipment Material	Carpenter 20
Design Temperature, F	600
Design Pressure, PSIA	75
Remarks	

CP-101 SLURRY PUMP

Manufacturer	Warman
Number	1
Type	Centrifugal
Process Material	Coal slurry
Capacity	43,186.7 lb/hr
Primary Equipment Material	HC-250
Design Temperature, F	176
Design Pressure, PSIA	42
Remarks	

VT-102 ACID TANK

Manufacturer	Arrow Tank
Number	1
Type	Vertical
Process Material	5% H3P04 solution
Capacity	
Primary Equipment Material	FRP lined carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

AG-102 AGITATOR

Manufacturer	Lightning Mixers
Number	1
Type	Mounted on acid tank
Process Material	5 % H_3PO_4
Capacity	
Primary Equipment Material	
Design Temperature, F	Ambient
Design Pressure, PSIA	
Remarks	

CP-102 ACID PUMP

Manufacturer	BIF
Number	1
Type	Metering
Process Material	5 % H_3PO_4
Capacity	146.9 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	177
Design Pressure, PSIA	30
Remarks	

SC-104 ACID SOLUTION DEWATERER

Manufacturer	Derrick-Linatex
Number	1
Type	Model K36-96W-3
Process Material	Coal slurry with phosphoric acid
Capacity	32,217 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	176
Design Pressure, PSIA	
Remarks	

VT-103 COAL WASHER

Manufacturer	Arrow Tank
Number	1
Type	Vertical cylindrical
Process Material	Coal slurry
Capacity	27,950 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

SC-103 ACID SOLUTION DEWATERER

Manufacturer	Derrick-Linatex
Number	1
Type	Model K36-96W-3
Process Material	Coal slurry with phosphoric acid
Capacity	68,341.7 lb/hr
Primary Equipment Material	316 Stainless steel
Design Temperature, F	176
Design Pressure, PSIA	
Remarks	

AG-103 AGITATOR

Manufacturer	Lightning Mixers
Number	1
Type	Tank mounted
Process Material	Coal Slurry
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

CP-103 SLURRY PUMP

Manufacturer	Warmon
Number	1
Type	Centrifugal
Process Material	Coal slurry
Capacity	43,243.9 lb/hr
Primary Equipment Material	CD4MCU wetted parts
Design Temperature, F	78
Design Pressure, PSIA	42
Remarks	

SC-105 DEWATERER

Manufacturer	Derrick-Linatex
Number	1
Type	Model K36-96W-3
Process Material	Coal slurry
Capacity	43,243.9 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	78
Design Pressure, PSIA	
Remarks	

SC-106 DEWATERER

Manufacturer	Derrick-Linatex
Number	1
Type	Model K36-96W-3
Process Material	Coal slurry
Capacity	15,293.8 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	78
Design Pressure, PSIA	
Remarks	

HE-102 DRYER

Manufacturer	
Number	1
Type	Thermoscrew
Process Material	Wet coal
Capacity	15,293.8 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	77-212
Design Pressure, PSIA	
Remarks	Steam supply to heating coils: 75 psig, 600 F Moisture evaporated from coal: 1,609.3 lb/hr

CR-101 CRUSHER

Manufacturer	Gundlach
Number	1
Type	Double roll
Process Material	Coal
Capacity	14,911.7 lb/hr
Primary Equipment Material	A2 tool steel or Mart. CR-MO white iron
Design Temperature, F	77
Design Pressure, PSIA	14.7
Remarks	Feed Size, Maximum: 5 in.
	Product Size, Maximum: 1 in.

CN-102 BUCKET ELEVATOR

Manufacturer	Beaumont Birch Co.
Number	1
Type	Belt type bucket elevator
Process Material	
Capacity	14,911.7 lb/hr
Primary Equipment Material	Rubber, carbon steel
Design Temperature, F	77
Design Pressure, PSIA	14.7
Remarks	Height, Inlet to Outlet: Approx 29 ft
	Size of Conveyed Material: 1 x 0 in.

CR-102 GRINDER

Manufacturer	Gundlach
Number	1
Type	Double roll
Process Material	Coal
Capacity	24,852.8 lb/hr
Primary Equipment Material	A2 tool steel or Mart. CR-MO white iron
Design Temperature, F	80
Design Pressure, PSIA	14.7
Remarks	Feed Size, Maximum: 1 in.
	Product Size, Mesh: 8 x 30 granules

SC-102 SCREEN

Manufacturer	Cleveland Vibrator Company
Number	1
Type	Single, vibrating screen
Process Material	Coal
Capacity	24,852.8 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	80
Design Pressure, PSIA	14.7
Remarks	Screen Opening Size: Pass 8 mesh Screen Size: 4 ft x 8 ft Angle of Decline: 20 degrees 40% recycled back to grinder

CN-104 BUCKET ELEVATOR

Manufacturer	Beaumont Birch Co.
Number	1
Type	Belt type bucket elevator
Process Material	Coal
Capacity	9,941.1 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	80
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material, Mesh: Plus 8 Height, Inlet to Outlet: Approx 18 ft Recycle back to grinder

CN-105 SCREW CONVEYOR

Manufacturer	Martin Conveying Machinery
Number	1
Type	Screw Conveyor
Process Material	Coal
Capacity	9,941.1 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	80
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material, Mesh: Plus 8 Length: Approximately 18 ft

CN-106 SCREW CONVEYOR

Manufacturer	Martin Conveying Machinery
Number	1
Type	Screw
Process Material	Coal
Capacity	14,911.7 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	80
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material, Mesh: 8 x 0 Quantity of Loading Points: 2 Length: Approximately 20 ft From screen to rotary feeder

FE-103 ROTARY AIRLOCK

Manufacturer	Meyer
Number	1
Type	Rotary airlock
Process Material	Coal
Capacity	15,236.7 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	80
Design Pressure, PSIA	14.7
Remarks	Size: 10 in. Rotative Speed: 25 rpm Size of Conveyed Material, Mesh: 8 x 0

FE-101 DUST FEEDER

Manufacturer	Meyer
Number	1
Type	Rotary airlock
Process Material	Dust
Capacity	325 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	77
Design Pressure, PSIA	14.7
Remarks	Size: 10 in. Rotative Speed: 10 rpm

DC-101 DUST COLLECTOR

Manufacturer	Carter-Day
Number	1
Type	Fabric filter baghouse
Process Material	
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.2
Remarks	Air Flow Rate: 10,000 cfm
	Fabric Area: 1,429 ft^2 minimum
	Air-to-Cloth Ratio: 7:1
	Media Type: Polyester

FN-101 FAN

Manufacturer	Twin City Fan
Number	1
Type	SWSI, centrifugal
Process Material	
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.2
Remarks	Air Flow Rate: 10,000 cfm

VT-104 PITCH HOPPER

Manufacturer	Beaumont Birch Co.
Number	1
Type	Inverted Conical
Process Material	Pitch
Capacity	1,444.3 lb
Primary Equipment Material	Carbon steel
Design Temperature, F	77
Design Pressure, PSIA	14.7
Remarks	Height: 8 ft
	Diameter: 4.5 ft
	One hour residence time

PITCH STORAGE SILO

Manufacturer	Beaumont Birch Co.
Number	1
Type	Cylindrical
Process Material	Pitch
Capacity	300,000 lb
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	Diameter: 16 ft
	Silo Height: 55 ft

FE-104 PITCH SILO FEEDER

Manufacturer	Meyer
Number	1
Type	Rotary feeder
Process Material	Pitch
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	
Remarks	

FILTER RECEIVER

Manufacturer	Carter-Day
Number	1
Type	Fabric filter baghouse
Process Material	Pitch
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	
Remarks	Air-to-Cloth Ratio: 3:1

PITCH CONVEYOR AIRLOCK

Manufacturer	Meyer
Number	1
Type	Rotary airlock
Process Material	Pitch
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	
Remarks	

PNEUMATIC CONVEYING BLOWER

Manufacturer	M-D Pneumatics
Number	1
Type	Positive displacement
Process Material	
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	
Remarks	

CR-103 PULVERIZING MILL

Manufacturer	Bepex
Number	1
Type	Pulvocron
Process Material	85.6% Coal, 0.4% Activated Carbon, 9.5% Pitch, 4.5% Moisture
Capacity	21,263.6 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	210
Design Pressure, PSIA	14.7
Remarks	Feed Size, Maximum, Mesh: 8 Product Size, Mesh: 80% minus 200 or 60-65% minus 325

DC-102 DUST COLLECTOR

Manufacturer	Bepex
Number	1
Type	Fabric filter/receiver
Process Material	85.6% Coal, 0.4% Activated Carbon, 9.5% Pitch, 4.5% Moisture
Capacity	21,263.6 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	210
Design Pressure, PSIA	14.7
Remarks	Air Flow Rate: 7,000 to 10,000 cfm

FN-102 FAN

Manufacturer	Bepex
Number	1
Type	SWSI, centrifugal
Process Material	
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	210
Design Pressure, PSIA	
Remarks	Air Flow Rate: 7,000 to 10,000 cfm

FE-102 DUST FEEDER

Manufacturer	Bepex
Number	1
Type	Rotary airlock
Process Material	Dust
Capacity	21,263.6 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

VT-107 DEAERATION BIN

Manufacturer	Bepex
Number	1
Type	Inverted, conical
Process Material	85.6% Coal, 0.4% Activated Carbon, 9.5% Pitch, 4.5% Moisture
Capacity	7,088 lb
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	14.7
Remarks	Diameter: 9 ft Height: 13 ft

FE-105 COMPACTOR FEEDER

Manufacturer	Bepex
Number	1
Type	Variable rate screw feeder
Process Material	85.6% Coal, 0.4% Activated Carbon, 9.5% Pitch, 4.5% Moisture
Capacity	21,263.6 lb/hr maximum
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	14.7
Remarks	

CR-104 COMPACTOR

Manufacturer	Bepex
Number	1
Type	MS double roll
Process Material	85.6% Coal, 0.4% Activated Carbon, 9.5% Pitch, 4.5% Moisture
Capacity	21,263.6 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	200
Design Pressure, PSIA	40,000-60,000
Remarks	Feed Size, Mesh: 80% minus 200 or 60-65% minus 325 Product Size: 1/2 by 1/2 in. pellets

CR-105 GRINDER

Manufacturer	Gundlach
Number	1
Type	Double roll
Process Material	85.6% Coal, 0.4% Activated Carbon, 9.5% Pitch, 4.5% Moisture
Capacity	21,263.6 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	200
Design Pressure, PSIA	14.7
Remarks	Feed Size: 1/2 by 1/2 in. pellets Product Size: 6 x 20 mesh granules

SC-107 SCREEN

Manufacturer	Cleveland Vibrator Company
Number	1
Type	Double deck, vibrating
Process Material	85.6% Coal, 0.4% Activated Carbon 9.5% Pitch, 4.5% Moisture
Capacity	30,374.5 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	200
Design Pressure, PSIA	14.7
Remarks	Top Screen Opening Size, Mesh: Retain plus 6 Bottom Screen Opening Size, Mesh: Retain 20 30% recycled back to grinder

CN-112 BUCKET ELEVATOR

Manufacturer	Beaumont Birch Co.
Number	1
Type	Continuous bucket elevator
Process Material	85.6% Coal, 0.4% Activated Carbon, 9.5% Pitch, 4.5% Moisture
Capacity	9,112.4 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	200
Design Pressure, PSIA	14.7
Remarks	Height, Inlet to Outlet: Approx 14 ft Size of Conveyed Material, Mesh: Plus 6 Recycle back to grinder

CN-113 SCREW CONVEYOR

Manufacturer	Martin Conveying Machinery
Number	1
Type	Screw Conveyor
Process Material	85.6% Coal, 0.4% Activated Carbon, 9.5% Pitch, 4.5% Moisture
Capacity	9,112.4 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	200
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material, Mesh: Plus 6 Recycle back to grinder

CN-114 SCREW CONVEYOR

Manufacturer	Martin Conveying Machinery
Number	2
Type	Screw Conveyor
Process Material	85.6% Coal, 0.4% Activated Carbon, 9.5% Pitch, 4.5% Moisture
Capacity	6,075 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	200
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material, Mesh: Minus 20 Length: 60 ft total Recycle back to pulverizer

CN-115 BUCKET ELEVATOR

Manufacturer	Beaumont Birch Co.
Number	1
Type	Continuous bucket elevator
Process Material	85.6% Coal, 0.4% Activated Carbon, 9.5% Pitch, 4.5% Moisture
Capacity	15,188.6 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	200
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material, Mesh: 6 x 20 Height, Inlet to Outlet: Approx 60 ft

VT-105 STORAGE BIN

Manufacturer	Beaumont Birch Co.
Number	1
Type	Inverted pyramidal
Process Material	85.6% Coal, 9.5% Pitch, 4.5% Moisture 0.4% Activated Carbon
Capacity	364,526.4 lb
Primary Equipment Material	Carbon steel
Design Temperature, F	175
Design Pressure, PSIA	14.7
Remarks	Size of Stored Material, Mesh: 6 x 20 Diameter: 25 ft Height: 48 ft

CN-117 WEIGH FEEDER

Manufacturer	Merrick
Number	1
Type	Belt type, electronic weigh feeder
Process Material	85.6% Coal, 0.4% Activated Carbon, 9.5% Pitch, 4.5% Moisture
Capacity	8,000 to 16,000 lb/hr
Primary Equipment Material	Rubber, carbon steel
Design Temperature, F	175
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material, Mesh: 6 x 20

CN-116 BUCKET ELEVATOR

Manufacturer	Beaumont Birch Co.
Number	1
Type	Belt type, continuous bucket elevator
Process Material	
Capacity	15,188.6 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	175
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material, Mesh: 6 x 20

SYSTEM: CARBONIZATION AND ACTIVATION

FR-201 CARBONIZATION FURNACE

Manufacturer	Olin
Number	1
Type	Multiple hearth
Process Material	Coal
Capacity	15,188.6 lb/hr
Primary Equipment Material	Inconel 617 or Hastelloy X
Design Temperature, F	1,112
Design Pressure, PSIA	14.7
Remarks	Material for cooler sections: Type 310 SS or Incoloy 800 H

FR-202 ACTIVATION FURNACE

Manufacturer	Olin
Number	2
Type	Multiple hearth
Process Material	Carbonized coal
Capacity	8,684 lb/hr
Primary Equipment Material	Salt side: composite silicon carbide Furnace side: Inconel 617 or Hastelloy X
Design Temperature, F	1,472
Design Pressure, PSIA	35
Remarks	21,567 lb/hr steam required

FE-201 ACTIVATION FURNACE OUTLET FEEDER

Manufacturer	
Number	
Type	
Process Material	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

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HE-201 PRODUCT COOLER

Manufacturer	Bepex
Number	1
Type	Thermoscrew
Process Material	Activated carbon
Capacity	3,308.5 lb/hr
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Cooling water supplied at 75 F Product inlet: 1,472 F Product outlet: 180 F

CP-204 PRODUCT COOLER WATER CIRCULATION PUMP

Manufacturer	Ingersoll-Rand
Number	1
Type	Frame mounted end suction
Process Material	Cast iron casing, stainless steel internals
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

VT-201 ACID MIXER

Manufacturer	Arrow Tank
Number	1
Type	Vertical cylindrical
Process Material	Activated carbon
Capacity	6,494.2 lb/hr
Primary Equipment Material	Hastelloy C-276 lined or acid brick lined
Design Temperature, F	180
Design Pressure, PSIA	
Remarks	

AG-201 AGITATOR

Manufacturer	Lightning Mixers
Number	1
Type	Tank mounted
Process Material	
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

HE-202 PRODUCT HEATER

Manufacturer	
Number	1
Type	Immersed coil
Process Material	Activated carbon
Capacity	62 lb/hr
Primary Equipment Material	KBI-10
Design Temperature, F	600
Design Pressure, PSIA	75
Remarks	Coils immersed in activated carbon slurry

VT-202 ACID DILUTION TANK

Manufacturer	Ownes-Corning
Number	1
Type	
Process Material	15% HCL acid solution
Capacity	650.7 lb/hr
Primary Equipment Material	FRP
Design Temperature, F	77
Design Pressure, PSIA	14.7
Remarks	

CP-201 ACID PUMP

Manufacturer	BIF
Number	1
Type	Metering
Process Material	15% HCL acid solution
Capacity	650.7 lb/hr
Primary Equipment Material	Teflon lined wetted parts
Design Temperature, F	77
Design Pressure, PSIA	
Remarks	

CP-202 SLURRY PUMP

Manufacturer	Warman
Number	1
Type	Centrifugal
Process Material	Activated carbon slurry
Capacity	6,494.2 lb/hr (15 gpm)
Primary Equipment Material	HC-250
Design Temperature, F	78
Design Pressure, PSIA	37
Remarks	50 ft TDH

SC-201 ACID SOLUTION DEWATERER

Manufacturer	Derrick-Linatex
Number	1
Type	Model K36-96W-3
Process Material	Activated carbon slurry
Capacity	9,744.2 lb/hr
Primary Equipment Material	Hastelloy C-276
Design Temperature, F	180
Design Pressure, PSIA	
Remarks	

VT-203 PRODUCT WASHER

Manufacturer	Arrow Tank
Number	1
Type	Tank
Process Material	Activated carbon
Capacity	7,065.9 lb/hr (1,300 gallons)
Primary Equipment Material	316 stainless steel
Design Temperature, F	77
Design Pressure, PSIA	
Remarks	

AG-203 AGITATOR

Manufacturer	Lightning Mixers
Number	1
Type	Tank mounted
Process Material	Activated carbon
Capacity	
Primary Equipment Material	316 stainless steel
Design Temperature, F	77
Design Pressure, PSIA	
Remarks	

CP-203 SLURRY PUMP

Manufacturer	Warman
Number	1
Type	Centrifugal
Process Material	Activated carbon slurry
Capacity	7,065.9 lb/hr (16 gpm)
Primary Equipment Material	HC-250
Design Temperature, F	78
Design Pressure, PSIA	
Remarks	40 ft TDH

SC-202 DEWATERING SCREEN

Manufacturer	Derrick-Linatex
Number	1
Type	Model K36-96W-3
Process Material	Activated carbon slurry
Capacity	7,065.9 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	78
Design Pressure, PSIA	
Remarks	

HE-203 PRODUCT DRYER

Manufacturer	Bepex
Number	1
Type	Thermoscrew
Process Material	Wet activated carbon
Capacity	3,815.9 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	78-212
Design Pressure, PSIA	
Remarks	397 lb/hr steam supply to heating coils at 75 psig, 600 F Moisture separated from coal: 506.1 lb/hr

HE-204 FINAL PRODUCT COOLER

Manufacturer	Bepex
Number	1
Type	Thermoscrew
Process Material	Activated carbon
Capacity	3,309.8 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	212-100
Design Pressure, PSIA	
Remarks	0.7 mm Btu/hr duty Cooling water supplied at 75 F

CN-201 CONVEYOR

Manufacturer	Cleveland Vibrator Company
Number	1
Type	Vibrating Trough
Process Material	99.3% Char, 0.7% Activated Carbon
Capacity	8,684 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	1,112
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material, Mesh: 6 x 20

CN-202 BUCKET ELEVATOR

Manufacturer	Beaumont Birch Co.
Number	2
Type	Continuous, chain, bucket elevator
Process Material	99.3 Char, 0.7 Activated Carbon
Capacity	8,684 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	1,112
Design Pressure, PSIA	14.7
Remarks	Height, Inlet to Outlet: Approx 57 ft Size of Conveyed Material, Mesh: 6 x 20

CN-203 CONVEYOR

Manufacturer	Cleveland Vibrator Company
Number	1
Type	Vibrating trough
Process Material	99.3% Char, 0.7% Activated Carbon
Capacity	8,684 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	1,112
Design Pressure, PSIA	14.7
Remarks	

CN-204 CONVEYOR

Manufacturer	Cleveland Vibrator Company
Number	1
Type	Vibrating trough
Process Material	Activated carbon
Capacity	3,308.5 lb/hr
Primary Equipment Material	Incoloy 800 H
Design Temperature, F	1,472
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material, Mesh: 6 x 20

CN-205 CONVEYOR

Manufacturer	Coastal Conveyor
Number	1
Type	Flanged, pocket belt
Process Material	Activated carbon
Capacity	3,308.5
Primary Equipment Material	Rubber, carbon steel
Design Temperature, F	180
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material, Mesh: 6 x 20 Inclination: 30 degrees

FE-202 ROTARY AIR LOCK

Manufacturer	Meyer
Number	1
Type	Rotary airlock
Process Material	Activated carbon
Capacity	3,308.5 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	180
Design Pressure, PSIA	14.7
Remarks	Size: 10 in. Rotative Speed: 30 rpm

SC-203 SCREEN

Manufacturer	Cleveland Vibrator Company
Number	1
Type	Single, vibrating screen
Process Material	Activated carbon, water
Capacity	3,309.8 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	100
Design Pressure, PSIA	14.7
Remarks	Screen Opening Size: Pass minus 20 mesh

CN-208 CONVEYOR

Manufacturer	Beaumont Birch Co.
Number	1
Type	Continuous bucket elevator
Process Material	98% Activated Carbon, 2% Moisture
Capacity	3,250 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	100
Design Pressure, PSIA	14.7
Remarks	Size of Conveyed Material, Mesh: 6 x 20 Height, Inlet to Outlet: Approx 97 ft

ACTIVATED CARBON LOADING SILOS

Manufacturer	Beaumont Birch Co.
Number	2
Type	Cylindrical, single outlet
Process Material	Activated Carbon
Capacity	275,000 lb each
Primary Equipment Material	Carbon steel
Design Temperature, F	100
Design Pressure, PSIA	14.7
Remarks	Diameter: 30 ft Height: 96 ft

DIVERTER GATE

Manufacturer	Beaumont Birch Co.
Number	1
Type	
Process Material	Activated Carbon
Capacity	3,250 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	

TRUCK LOADOUT SPOUT

Manufacturer	Process Equipment Builders
Number	2
Type	Telescoping
Process Material	Activated carbon
Capacity	
Primary Equipment Material	Carbon steel, fabric
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	

TRUCK SCALE

Manufacturer	Toledo Scale
Number	2
Type	Pitless, electronic platform
Process Material	
Capacity	200,000 lbs
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	Size: 10 ft by 100 ft

DC-401 DUST COLLECTOR

Manufacturer	Flex-Kleen
Number	1
Type	Cyclone
Process Material	
Capacity	26,942.5 lb/hr
Primary Equipment Material	Refractory lined steel
Design Temperature, F	1,472
Design Pressure, PSIA	35
Remarks	

FE-401 FEEDER

Manufacturer	Meyer
Number	1
Type	Rotary airlock, machined tips
Process Material	Dust
Capacity	
Primary Equipment Material	310 stainless steel
Design Temperature, F	1,472
Design Pressure, PSIA	35
Remarks	

SYSTEM: OFF-GAS COOLING AND COMPRESSION

FN-401 EXHAUST FAN

Manufacturer	Robinson Industries
Number	1
Type	SWSI, centrifugal
Process Material	
Capacity	28,140.4 lb/hr
Primary Equipment Material	
Design Temperature, F	242
Design Pressure, PSIA	30
Remarks	

HE-401 EVAPORATOR

Manufacturer	Struthers Wells
Number	1
Type	Shell and tube
Process Material	Off-gas
Capacity	26,942.5 lb/hr
Primary Equipment Material	Sandvik 253 MA tubes, 316 SS shell
Design Temperature, F	Gas temp: 1,472-400 Water temp: 240-1,000
Design Pressure, PSIA	35 gas side
Remarks	

HE-402 EVAPORATOR

Manufacturer	Struthers Wells
Number	1
Type	Shell and tube
Process Material	Off-gas
Capacity	26,942.5 lb/hr
Primary Equipment Material	Aluminum bronze tubes, carbon steel shell
Design Temperature, F	Gas temp: 400-250
Design Pressure, PSIA	35
Remarks	

VT-403 STEAM DRUM

Manufacturer	
Number	
Type	
Process Material	
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

HE-403 OFF-GAS COOLER

Manufacturer	Struthers Wells
Number	1
Type	Shell and tube
Process Material	Off-gas
Capacity	28,140.4 lb/hr
Primary Equipment Material	316 stainless steel shell and tubes
Design Temperature, F	Gas temp: 242-95
Design Pressure, PSIA	30
Remarks	13.6 mm Btu/hr duty Cooling water suplied at 75 F

VT-401 KNOCKOUT DRUM

Manufacturer	Arrow Tank
Number	1
Type	Cylindrical
Process Material	Off-gas
Capacity	28,140.4 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	95
Design Pressure, PSIA	30
Remarks	

GC-401 COMPRESSOR

Manufacturer	Quincy
Number	1
Type	Multiple stage
Process Material	Off-gas
Capacity	16,449.5 lb/hr
Primary Equipment Material	
Design Temperature, F	95
Design Pressure, PSIA	
Remarks	

HE-404 INTERCOOLER

Manufacturer	Quincy
Number	1
Type	Shell and tube
Process Material	Off-gas
Capacity	16,449.5 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	95
Design Pressure, PSIA	
Remarks	5.1 mm Btu/hr duty Cooling water supplied at 75 F

VT-402 KNOCKOUT DRUM

Manufacturer	Arrow Tank
Number	1
Type	Cylindrical
Process Material	Off-gas
Capacity	16,449.5 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	95
Design Pressure, PSIA	35
Remarks	

SYSTEM: SPENT CARBON REGENERATION

VT-603 CRUDE WATER STORAGE TANK

Manufacturer	Arrow Tank
Number	1
Type	
Process Material	Crude water
Capacity	1,500 gallon
Primary Equipment Material	316 stainless steel or acid brick lined
Design Temperature, F	70
Design Pressure, PSIA	
Remarks	

CP-601 CRUDE WATER PUMP

Manufacturer	Warman
Number	1
Type	Centrifugal
Process Material	Decanted water from spent carbon slurry
Capacity	20,286 lb/hr
Primary Equipment Material	Cast iron
Design Temperature, F	70
Design Pressure, PSIA	80
Remarks	

FR-601 REGENERATION FURNACE

Manufacturer	Olin
Number	1
Type	Multiple hearth
Process Material	Spent carbon
Capacity	6,394 lb/hr
Primary Equipment Material	Salt side: silicon carbide Furnace side: Inconel 617 or Hastelloy X
Design Temperature, F	1,525
Design Pressure, PSIA	25
Remarks	

VT-604 QUENCH TANK

Manufacturer	Olin
Number	1
Type	
Process Material	
Capacity	17,004 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	130
Design Pressure, PSIA	25
Remarks	

FE-605 QUENCH TANK FEEDER

Manufacturer	Olin
Number	1
Type	
Process Material	
Capacity	17,004 lb/hr
Primary Equipment Material	
Design Temperature, F	130
Design Pressure, PSIA	
Remarks	

ED-602 PRODUCT EDUCTOR

Manufacturer	Schutte & Koerting
Number	1
Type	
Process Material	Regenerated carbon slurry
Capacity	24,295 lb/hr
Primary Equipment Material	HC 250
Design Temperature, F	130
Design Pressure, PSIA	80
Remarks	

020386

CP-602 WATER PUMP

Manufacturer	Warman
Number	1
Type	Centrifugal
Process Material	Decanted water from product
Capacity	19,087 lb/hr
Primary Equipment Material	HC 250
Design Temperature, F	130
Design Pressure, PSIA	30
Remarks	

VT-606 PRODUCT WATER STORAGE TANK

Manufacturer	Arrow Tank
Number	1
Type	
Process Material	Decanted water from product
Capacity	21,691 lb/hr
Primary Equipment Material	316 stainless steel or FRP lined
Design Temperature, F	123
Design Pressure, PSIA	
Remarks	

CP-603 PRODUCT WATER PUMP

Manufacturer	Warman
Number	1
Type	Centrifugal
Process Material	Decanted water from product
Capacity	21,691 lb/hr
Primary Equipment Material	Cast iron
Design Temperature, F	123
Design Pressure, PSIA	80
Remarks	

FL-602 PRODUCT WATER FILTER

Manufacturer	
Number	1
Type	
Process Material	
Capacity	21,691 lb/hr
Primary Equipment Material	Polypropylene
Design Temperature, F	123
Design Pressure, PSIA	80
Remarks	

HE-601 PRODUCT WATER COOLER

Manufacturer	
Number	1
Type	Shell and tube
Process Material	
Capacity	21,691 lb/hr
Primary Equipment Material	
Design Temperature, F	123
Design Pressure, PSIA	80
Remarks	90-10 cu/in. tubes 316 stainless steel shell 0.9 mm Btu/hr duty

HE-602 OFF-GAS HEATER

Manufacturer	
Number	1
Type	Shell and tube
Process Material	
Capacity	12,506 lb/hr
Primary Equipment Material	
Design Temperature, F	500-1200
Design Pressure, PSIA	25
Remarks	Inconel 600 tubes 304 stainless steel shell

FR-602 OFF-GAS INCINERATOR

Manufacturer	UOP
Number	1
Type	
Process Material	Off-gas
Capacity	12,503 lb/hr
Primary Equipment Material	Refractory lined
Design Temperature, F	1200-1500
Design Pressure, PSIA	20
Remarks	

TW-601 SCRUBBER

Manufacturer	UOP
Number	1
Type	
Process Material	
Capacity	41,444 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	1500
Design Pressure, PSIA	20
Remarks	

CP-604 SCRUBBER WATER PUMP

Manufacturer	Warman
Number	1
Type	
Process Material	Scrubber waste water
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

FL-603 SCRUBBER WATER FILTER

Manufacturer	
Number	1
Type	
Process Material	Scrubber waste water
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

HE-603 SCRUBBER WATER COOLER

Manufacturer	
Number	1
Type	Shell and tube
Process Material	
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	90-10 cu/in. tubes 316 stainless steel shell

FN-601 DRAFT FAN

Manufacturer	New York Blower
Number	1
Type	Reverse foil
Process Material	Flue gas
Capacity	14,000 cfm
Primary Equipment Material	304 stainless steel
Design Temperature, F	175
Design Pressure, PSIA	15 in H_2O
Remarks	

020386

ST-601 STACK

Manufacturer	
Number	1
Type	
Process Material	
Capacity	50,245 lb/hr
Primary Equipment Material	304 stainless steel or acid brick lined
Design Temperature, F	175
Design Pressure, PSIA	14.7
Remarks	

SPENT CARBON UNLOADING PIT

Manufacturer	Allen-Sherman-Hoff (A-S-H)
Number	1
Type	Inverted pyramidal
Process Material	Spent carbon
Capacity	
Primary Equipment Material	Carbon steel, 316 stainless steel lined
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	Volume: 1,500 ft^3

EDUCTOR

Manufacturer	A-S-H
Number	1
Type	
Process Material	Spent carbon
Capacity	
Primary Equipment Material	
Design Temperature, F	Ambient
Design Pressure, PSIA	
Remarks	

020386

VT-601 SPENT CARBON STORAGE TANK

Manufacturer	A-S-H
Number	2
Type	Cylindrical, conical bottom, dewatering
Process Material	Spent carbon
Capacity	
Primary Equipment Material	316 stainless steel
Design Temperature, F	70
Design Pressure, PSIA	14.7
Remarks	Diameter: 10 ft Height: 28 ft Volume: 1,500 ft^3

FE-602 SPENT CARBON FEEDER

Manufacturer	
Number	
Type	
Process Material	
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

ED-601 EDUCTOR

Manufacturer	A-S-H
Number	2
Type	
Process Material	Spent Carbon
Capacity	26,670 lb/hr total motive water & product
Primary Equipment Material	Durimet 20
Design Temperature, F	70
Design Pressure, PSIA	
Remarks	

020386

VT-602 FEED TANK WITH AGITATOR

Manufacturer	A-S-H
Number	1
Type	Cylindrical, conical bottom
Process Material	Spent carbon
Capacity	26,670 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	70
Design Pressure, PSIA	14.7
Remarks	Volume: 500 ft^3 Diameter: 10 ft Height: 13 ft

FE-603 FEEDER

Manufacturer	
Number	
Type	
Process Material	
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

SC-601 DEWATERING SCREW

Manufacturer	Continental Screw Conveyor
Number	1
Type	Inclined dewatering screw conveyor
Process Material	Spent carbon
Capacity	6,394 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	70
Design Pressure, PSIA	14.7
Remarks	

FE-604 REGENERATION FURNACE FEEDER

Manufacturer	
Number	
Type	
Process Material	
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Temperature, PSIA	
Remarks	

VT-605 REGENERATED CARBON STORAGE TANK WITH AGITATOR

Manufacturer	A-S-H
Number	1
Type	Cylindrical, conical bottom
Process Material	Regenerated carbon
Capacity	24,295 lb/hr
Primary Equipment Material	316 stainless steel lined
Design Temperature, F	130
Design Pressure, PSIA	14.7
Remarks	Volume: 500 ft^3 Diameter: 10 ft Height: 13 ft

FE-606 REGENERATED CARBON STORAGE TANK FEEDER

Manufacturer	
Number	1
Type	
Process Material	Regenerated carbon
Capacity	24,295 lb/hr
Primary Equipment Material	
Design Temperature, F	130
Design Pressure, PSIA	14.7
Remarks	

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SC-602 DEWATERING SCREW

Manufacturer	Continental Screw Conveyor
Number	1
Type	Inclined dewatering screw conveyor
Process Material	Regenerated carbon
Capacity	5,208 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	130
Design Pressure, PSIA	14.7
Remarks	

CN-602 CONVEYOR

Manufacturer	Beaumont Birch Co.
Number	1
Type	Belt
Process Material	50% Regenerated carbon, 50% Moisture
Capacity	5,208 lb/hr
Primary Equipment Material	Rubber, carbon steel
Design Temperature, F	130
Design Pressure, PSIA	14.7
Remarks	Length: Approximately 260 ft

DIVERTER GATE

Manufacturer	Beaumont Birch Co.
Number	1
Type	Single blade diverter
Process Material	Regenerated carbon
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	

REGENERATED CARBON LOADING SILOS

Manufacturer	Beaumont Birch Company
Number	2
Type	Cylindrical, elevated
Process Material	Regenerated carbon
Capacity	
Primary Equipment Material	Carbon steel, 316 stainless steel lined
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	Volume: 1,500 ft^3 each Diameter: 10 ft Height: 50 ft

TRUCK LOADOUT GATE

Manufacturer	Process Equipment Builders
Number	2
Type	Water collecting
Process Material	Regenerated carbon
Capacity	
Primary Equipment Material	Carbon steel, stainless steel lined
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	

DC-601 DUST COLLECTOR

Manufacturer	Flex-Kleen
Number	1
Type	Cyclone
Process Material	
Capacity	12,506 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	500
Design Pressure, PSIA	25
Remarks	

FE-601 DUST FEEDER

Manufacturer	Meyer
Number	1
Type	Rotary airlock, machined tips
Process Material	
Capacity	3 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	500
Design Pressure, PSIA	25
Remarks	

020386

SYSTEM: TAR RECOVERY AND AMMONIA REMOVAL

VT-301 COLLECTOR MAIN QUENCH TANK

Manufacturer	Olin
Number	1
Type	Rectangular
Process Material	Tar, light oil, gas
Capacity	6,504.6 lb/hr
Primary Equipment Material	
Design Temperature, F	932
Design Pressure, PSIA	14.7
Remarks	

VT-302 DOWNCOMER

Manufacturer	Raymond Kaiser
Number	1
Type	Vertical cylindrical
Process Material	Tar, light oil, gas
Capacity	6,504 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	185
Design Pressure, PSIA	14.7
Remarks	

HE-301 PRIMARY COOLER

Manufacturer	Raymond Kaiser
Number	1
Type	Condensing
Process Material	Tar, light oil, gas
Capacity	
Primary Equipment Material	
Design Temperature, F	185-95
Design Pressure, PSIA	14.7
Remarks	Cooling water supplied at 75 F

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FN-301 EXHAUSTER

Manufacturer	Raymond Kaiser
Number	1
Type	Reverse foil
Process Material	Tar, light oil, gas
Capacity	
Design Temperature, F	113
Design Pressure, PSIA	
Remarks	10-12 in. HG suction 50-55 in. HG discharge

DC-301 TAR PRECIPITATOR

Manufacturer	Raymond Kaiser
Number	1
Type	Condensing
Process Material	Tar
Capacity	1,449.5 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	113
Design Pressure, PSIA	16
Remarks	

VT-303 DECANTER

Manufacturer	Raymond Kaiser
Number	1
Type	Cylindrical, free standing
Process Material	Light oil
Capacity	10,000 gallons
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

CP-301 TAR PUMP

Manufacturer	Raymond Kaiser
Number	1
Type	Centrifugal
Process Material	Tar
Capacity	2,314 lb/hr
Primary Equipment Material	
Design Temperature, F	120
Design Pressure, PSIA	14.7
Remarks	

VT-304 TAR STORAGE TANK

Manufacturer	Raymond Kaiser
Number	1
Type	Cylindrical, free standing
Process Material	Tar
Capacity	15,000 gallons
Primary Equipment Material	Carbon steel
Design Temperature, F	120
Design Pressure, PSIA	15
Remarks	

CP-302 DECANT PUMP

Manufacturer	Raymond Kaiser
Number	1
Type	Centrifugal
Process Material	Light oil
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	120
Design Pressure, PSIA	
Remarks	

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HE-302 FLUSHING LIQUOR COOLER

Manufacturer	Raymond Kaiser
Number	1
Type	Shell and tube
Process Material	Flushing liquor
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	120
Design Pressure, PSIA	
Remarks	

VT-305 FLUSHING LIQUOR HOLDING TANK

Manufacturer	Raymond Kaiser
Number	1
Type	Cylindrical, free standing
Process Material	Flushing liquor
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

CP-303 FLUSHING LIQUOR PUMP

Manufacturer	Raymond Kaiser
Number	1
Type	Centrifugal
Process Material	Flushing liquor
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

VT-306 CRUDE LIQUOR STORAGE TANK

Manufacturer	Raymond Kaiser
Number	1
Type	Cylindrical, free standing
Process Material	Crude liquor
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

CP-304 CRUDE LIQUOR PUMP

Manufacturer	Raymond Kaiser
Number	1
Type	Centrifugal
Process Material	Crude liquor
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

VT-307 CAUSTIC LEG

Manufacturer	Raymond Kaiser
Number	1
Type	Cylindrical
Process Material	50% caustic
Capacity	
Primary Equipment Material	316 stainless steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

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VT-303 CRUDE LIQUOR STILL

Manufacturer	Raymond Kaiser
Number	1
Type	Cylindrical
Process Material	Crude liquor
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	520 lb/hr steam

HE-304 PARTIAL CONDENSER

Manufacturer	Raymond Kaiser
Number	1
Type	Tube bundle
Process Material	Ammonia
Capacity	
Primary Equipment Material	316 stainless steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

VT-308 WASTE LIQUOR SUMP

Manufacturer	Raymond Kaiser
Number	1
Type	
Process Material	Waste liquor
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

TW-301 AMMONIA SCRUBBER

Manufacturer	Raymond Kaiser
Number	1
Type	Cylindrical, free standing
Process Material	Ammonia
Capacity	
Primary Equipment Material	316 stainless steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

CP-305 SCRUBBER PUMP

Manufacturer	Raymond Kaiser
Number	1
Type	Centrifugal
Process Material	Ammonia Liquor
Capacity	
Primary Equipment Material	316 stainless steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

TW-302 AMMONIA SCRUBBER

Manufacturer	Raymond Kaiser
Number	1
Type	Cylindrical, free standing
Process Material	Ammonia
Capacity	
Primary Equipment Material	316 stainless steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

CP-306 SCRUBBER RECYCLE PUMP

Manufacturer	Raymond Kaiser
Number	1
Type	Centifugal
Process Material	Ammonia liquor
Capacity	
Primary Equipment Material	316 stainless steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

HE-305 AMMONIA LIQUOR STILL

Manufacturer	Raymond Kaiser
Number	1
Type	Cylindrical, free standing
Process Material	Ammonia liquor
Capacity	
Primary Equipment Material	316 stainless steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

TW-303 LIQUOR COOLING TOWER

Manufacturer	Raymond Kaiser
Number	1
Type	Natural draft
Process Material	Free ammonia
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

SYSTEM: H_2S REMOVAL AND SULFUR RECOVERY

HE-501 ABSORBER FEED COOLER

Manufacturer	Ametek
Number	1
Type	Shell and tube
Process Material	Gases from coal gasification
Capacity	15,998.5 lb/hr
Primary Equipment Material	Carbon steel
Design Temperature, F	95
Design Pressure, PSIA	350
Remarks	

TW-501 H_2S ABSORBER

Manufacturer	Norton
Number	1
Type	Cylindrical, free standing
Process Material	Off-gases
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	350
Remarks	

HE-502 HEAT EXCHANGER

Manufacturer	Ametek
Number	1
Type	Shell and tube
Process Material	
Capacity	11,765.7 lb/hr
Primary Equipment Material	
Design Temperature, F	77
Design Pressure, PSIA	350
Remarks	

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CP-501 HYDRAULIC TURBINE

Manufacturer	Norton
Number	1
Type	Turbine
Process Material	H_2S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	77
Design Pressure, PSIA	100
Remarks	

VT-501 HIGH PRESSURE FLASH DRUM

Manufacturer	Norton
Number	1
Type	Cylindrical, horizontal
Process Material	H_2S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	100
Remarks	

GC-501 RECYCLE COMPRESSOR

Manufacturer	Norton
Number	1
Type	Reciprocating
Process Material	H_2S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	350
Remarks	

HE-503 RECYCLE COOLER

Manufacturer	Ametek
Number	1
Type	Shell and tube
Process Material	H_2S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	350
Remarks	

VT-502 LOW PRESSURE FLASH DRUM

Manufacturer	Norton
Number	1
Type	Cylindrical, horizontal
Process Material	H_2S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	100
Remarks	

TW-502 H_2S STRIPPER

Manufacturer	Norton
Number	1
Type	Cylindrical, free standing
Process Material	H_2S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	100
Remarks	

CP-502 H_2S RECYCLE PUMP

Manufacturer	Norton
Number	1
Type	Centrifugal
Process Material	H_2S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	400
Remarks	

HE-504 SOLVENT COOLER

Manufacturer	Ametek
Number	1
Type	Shell and tube
Process Material	H_2S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	350
Remarks	

HE-505 STRIPPER CONDENSER

Manufacturer	Ametek
Number	1
Type	Shell and tube
Process Material	H_2S
Capacity	
Primary Equipment Material	Carbon Steel
Design Temperature, F	95
Design Pressure, PSIA	60
Remarks	

VT-503 STRIPPER KNOCKOUT POT

Manufacturer	Arrow Tank
Number	1
Type	Cylindrical, vertical
Process Material	H_2S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	95
Design Pressure, PSIA	60
Remarks	

RC-501 THERMAL REACTOR

Manufacturer	NATCO
Number	1
Type	Shell and tube
Process Material	H_2S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	60
Remarks	

FN-501 THERMAL REACTOR FAN

Manufacturer	NATCO
Number	1
Type	Reverse foil
Process Material	Air
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

HE-506 WASTE HEAT BOILER

Manufacturer	NATCO
Number	1
Type	Furnace
Process Material	H_2O
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	800
Design Pressure, PSIA	40
Remarks	

HE-507 STEAM HEATER

Manufacturer	NATCO
Number	1
Type	Shell and tube
Process Material	Flue gas
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

RC-502 CATALYTIC REACTOR

Manufacturer	NATCO
Number	1
Type	Cylindrical, horizontal
Process Material	Sulfur
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	250
Design Pressure, PSIA	40
Remarks	

HE-503 CONDENSER

Manufacturer	NATCO
Number	1
Type	Shell and tube
Process Material	Sulfur
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	250
Design Pressure, PSIA	40
Remarks	

VT-504 SULFUR RECOVERY VESSEL

Manufacturer	NATCO
Number	1
Type	Cylindrical, horizontal
Process Material	Sulfur
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	250
Design Pressure, PSIA	40
Remarks	

HE-509 STEAM HEATER

Manufacturer	NATCO
Number	1
Type	Shell and tube
Process Material	Sulfur
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	40
Remarks	

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HE-510 CONDENSER

Manufacturer	NATCO
Number	1
Type	Shell and tube
Process Material	Waste gases
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	250
Design Pressure, PSIA	
Remarks	

VT-505 SULFUR KNOCKOUT POT

Manufacturer	NATCO
Number	1
Type	Cylindrical, vertical
Process Material	Waste gases
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

FR-501 INCINERATOR

Manufacturer	NATCO
Number	1
Type	Open furnace
Process Material	Waste gases
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	1,600
Design Pressure, PSIA	16
Remarks	

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SYSTEM: SOLAR COLLECTION

HELIOSTAT

Manufacturer	
Number	797
Type	Sandia Baseline
Process Material	
Capacity	
Primary Equipment Material	Glass and metal
Design Temperature, F	
Design Pressure, PSIA	
Remarks	95.5 m^2 reflective area

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SYSTEM: ELECTRICAL POWER GENERATION

INTERMEDIATE HEAT EXCHANGER

Manufacturer	Babcock & Wilcox
Number	1
Type	U-tube, U-shell
Process Material	Nitrate salt/carbonate salt
Capacity	
Primary Equipment Material	Incoloy 800
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Carbonate salt: 499,000 lb/hr Inlet temp: 1,200 F Outlet temp: 325 F Nitrate salt: 436,000 lb/hr Inlet temp: 580 F Outlet temp: 948 F

SALT CIRCULATION PUMP

Manufacturer	Lawrence
Number	2
Type	Vertical cantilever
Process Material	Nitrate salt
Capacity	558,000 lb/hr
Primary Equipment Material	
Design Temperature, F	580
Design Pressure, PSIA	
Remarks	

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EVAPORATOR

Manufacturer	Babcock & Wilcox
Number	1
Type	U-tube, U-shell
Process Material	Nitrate salt/water
Capacity	50 MBtu/hr
Primary Equipment Material	2-1/4 CR - 1 MO
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

SUPERHEATER

Manufacturer	Babcock & Wilcox
Number	1
Type	U-tube, U-shell
Process Material	Nitrate salt/steam
Capacity	8 MBtu/hr
Primary Equipment Material	304 SS
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

STEAM DRUM

Manufacturer	Babcock & Wilcox
Number	1
Type	
Process Material	Water/steam
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

BOILER WATER CIRCULATION PUMP

Manufacturer	
Number	2
Type	
Process Material	Water
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

TURBINE-GENERATOR

Manufacturer	Elliot
Number	1
Type	Single extraction, condensing
Process Material	Steam
Capacity	3 MW
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Throttle conditions: 720 F, 1,065 PSIA

STEAM CONDENSER

Manufacturer	
Number	1
Type	Surface condenser
Process Material	Turbine exhaust steam
Capacity	
Primary Equipment Material	Carbon steel shell, stainless steel tubes
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

CONDENSATE PUMP

Manufacturer	Goulds
Number	2
Type	Vertical
Process Material	Condensate
Capacity	220 gpm each, @ 120 ft tdh
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Carbon steel head, barrel, and bowls; stainless steel shaft and impellers

DEAERATOR

Manufacturer	ASC Manufacturing Company
Number	1
Type	
Process Material	Water/steam
Capacity	106,000 lb/hr delivered capacity, @ 265 F
Primary Equipment Material	Carbon steel shell, stainless steel internals
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

BOILER FEEDWATER PUMP

Manufacturer	Goulds
Number	2
Type	Multistage, horizontal split case
Process Material	Boiler feedwater
Capacity	220 gpm each @ 3,050 ft
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Forged carbon steel casing, stainles steel internals

CONDENSER EXHAUSTER

Manufacturer	Nash Engineering
Number	1
Type	Two stage, water seal
Process Material	Noncondensible gases/air
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

TURBINE LUBE OIL CONDITIONER

Manufacturer	Keene Corporation
Number	1
Type	Multistage separation/filtration
Process Material	Lubrication oil
Capacity	50 gallons per hour
Primary Equipment Material	Carbon steel housing
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

DEMINERALIZED WATER STORAGE TANK

Manufacturer	CBI Na-Con, Inc.
Number	1
Type	Vertical cylindrical
Process Material	Demineralized water
Capacity	25,000 gallons
Primary Equipment Material	carbon steel
Design Temperature, F	100
Design Pressure, PSIA	Atmospheric
Remarks	

CYCLE MAKEUP WATER PUMP

Manufacturer	Goulds
Number	1
Type	Centrifugal, frame mounted end suction
Process Material	Demineralized water
Capacity	50 gpm @ 20 ft tdh
Primary Equipment Material	Stainless steel casing and internals
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

CYCLE CHEMICAL FEED SUBSYSTEM

Manufacturer	Pulsafeeder
Number	1
Type	
Process Material	
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Subsystem consists of two 100 gallon polypropylene solution tanks and mixers, four positive-displacement diaphragm type metering pumps, and one lot of interconnecting piping, valves, and instrumentation.

DEMINERALIZATION SUBSYSTEM

Manufacturer	Infilco Degremont, Inc.
Number	1
Type	Cation-anion-mixed bed line
Process Material	
Capacity	8,000 gallons per day
Primary Equipment Material	
Design Temperature, F	Ambient
Design Pressure, PSIA	150
Remarks	Complete with regeneration facilities

WATER QUALITY CONTROL SUBSYSTEM

Manufacturer	Waters Equipment
Number	1
Type	Sample rack
Process Material	
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

AIR COMPRESSOR

Manufacturer	Ingersoll-Rand
Number	2
Type	Oil free
Process Material	Air
Capacity	750 scfm
Primary Equipment Material	
Design Temperature, F	110
Design Pressure, PSIA	125
Remarks	

AIR DRYER

Manufacturer	Ingersoll-Rand
Number	2
Type	Dual tower desiccant
Process Material	Compressed air
Capacity	750 scfm
Primary Equipment Material	
Design Temperature, F	
Design Temperature, PSIA	
Remarks	

AIR RECEIVER

Manufacturer	Arrow Tank
Number	2
Type	Vertical cylindrical
Process Material	Compressed air
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Temperature, PSIA	
Remarks	

UNIT TRANSFORMER

Manufacturer	General Electric
Number	1
Type	
Process Material	Oil filled
Capacity	10 MVA
Primary Equipment Material	
Design Temperature, F	
Design Temperature, PSIA	
Remarks	

HIGH VOLTAGE SWITCHING EQUIPMENT

Manufacturer	General Electric
Number	1
Type	
Process Material	
Capacity	Greater than transmission system capacity
Primary Equipment Material	
Design Temperature, F	
Design Temperature, PSIA	
Remarks	

MEDIUM VOLTAGE SWITCHCEAR

Manufacturer	General Electric
Number	3
Type	Metal clad, vacuum 5 kV
Process Material	
Capacity	1,200 amp
Primary Equipment Material	
Design Temperature, F	
Design Temperature, PSIA	
Remarks	

SECONDARY TRANSFORMER

Manufacturer	General Electric
Number	4
Type	Oil filled
Process Material	
Capacity	1,500 kVA, 480-4160 V
Primary Equipment Material	
Design Temperature, F	
Design Temperature, PSIA	
Remarks	

SECONDARY SUBSTATION

Manufacturer	General Electric
Number	4
Type	Outdoor
Process Material	
Capacity	2,000 kVA, 480 V
Primary Equipment Material	
Design Temperature, F	
Design Temperature, PSIA	
Remarks	

MOTOR CONTROL CENTER

Manufacturer	General Electric
Number	8
Type	Outdoor
Process Material	
Capacity	600 amp, 480 V
Primary Equipment Material	
Design Temperature, F	
Design Temperature, PSIA	
Remarks	

SYSTEM: SALT TRANSPORT

COLD SALT STORAGE TANK

Manufacturer	
Number	1
Type	
Process Material	Carbonate salt
Capacity	
Primary Equipment Material	304 stainless steel
Design Temperature, F	957
Design Pressure, PSIA	
Remarks	10,600 ft^3 storage volume

HOT SALT STORAGE TANK

Manufacturer	
Number	1
Type	
Process Material	Carbonate salt
Capacity	
Primary Equipment Material	
Design Temperature, F	1,750
Design Pressure, PSIA	
Remarks	304 stainless steel shell, Inconel 600 annulus

HOT SALT TRANSFER PUMP

Manufacturer	Lawrence
Number	2
Type	Vertical cantilever
Process Material	Carbonate salt
Capacity	330 gpm
Primary Equipment Material	Inconel 600
Design Temperature, F	1,750
Design Pressure, PSIA	265
Remarks	

SALT BOOSTER PUMPS

Manufacturer	Lawrence
Number	2
Type	Vertical cantilever
Process Material	Carbonate salt
Capacity	600 gpm
Primary Equipment Material	Inconel 600
Design Temperature, F	957
Design Pressure, PSIA	800
Remarks	

STANDBY SALT HEATER

Manufacturer	B&W
Number	1
Type	Balanced draft, multi-fuel
Process Material	Carbonate salt
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

SALT SUMP TANK

Manufacturer	Arrow Tank
Number	1
Type	Rectangular
Process Material	Carbonate salt
Capacity	1,500 gallons
Primary Equipment Material	Stainless steel
Design Temperature, F	957
Design Pressure, PSIA	Atmospheric
Remarks	

SALT SUMP PUMP

Manufacturer	Lawrence
Number	1
Type	Vertical cantilever
Process Material	Carbonate salt
Capacity	100 gpm
Primary Equipment Material	316 stainless steel
Design Temperature, F	500
Design Pressure, PSIA	40
Remarks	

COOLING SALT CIRCULATION PUMPS

Manufacturer	Lawrence
Number	2
Type	Vertical cantilever
Process Material	Carbonate salt
Capacity	150 gpm
Primary Equipment Material	Inconel
Design Temperature, F	957
Design Pressure, PSIA	55
Remarks	

SALT SUMP HEATER

Manufacturer	Graphite
Number	1
Type	Tube bundle
Process Material	Carbonate salt
Capacity	
Primary Equipment Material	316 stainless steel
Design Temperature, F	600
Design Pressure, PSIA	75
Remarks	

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SYSTEM: COOLING WATER

COOLING TOWER

Manufacturer	Marley Cooling Tower Company
Number	1
Type	Mechanical draft
Process Material	Circulating water
Capacity	8,000
Primary Equipment Material	Wood
Design Temperature, F	
Design Pressure, PSIA	
Remarks	15 F range, 30 F approach

CIRCULATING WATER PUMP

Manufacturer	Goulds
Number	3
Type	Vertical turbine
Process Material	Circulating water
Capacity	4,000 gpm each @ 35 ft tdh
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Carbon steel head, stainless steel shafts, bronze impellers

ACID STORAGE TANK

Manufacturer	Arrow Tank
Number	1
Type	
Process Material	
Capacity	5,000 gallons
Primary Equipment Material	Carbon steel, coated
Design Temperature, F	Ambient
Design Pressure, PSIA	Atmospheric
Remarks	

ACID FEED PUMP

Manufacturer	Milton Roy
Number	2
Type	Remote head
Process Material	Concentrated sulfuric acid
Capacity	
Primary Equipment Material	Alloy 20
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

INHIBITOR FEED SUBSYSTEM

Manufacturer	Milton Roy
Number	1
Type	
Process Material	
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Subsystem consist of 1-100 gallon polypropylene solution tank and mixer, two positive displacement diaphragm type metering pumps, and one lot of piping, valves, and instrumentation

CHLORINATION EQUIPMENT

Manufacturer	Wallace & Tiernan
Number	1
Type	Gas solution
Process Material	Chlorine gas
Capacity	2,000 pound per day
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

SYSTEM: PROCESS WATER

PROCESS WATER STORAGE TANK

Manufacturer	CBI Na-Con, Inc.
Number	1
Type	
Process Material	Process water
Capacity	112,000 gallon
Primary Equipment Material	Carbon steel
Design Temperature, F	100
Design Pressure, PSIA	14.7
Remarks	

PROCESS WATER PUMP

Manufacturer	Goulds
Number	2
Type	Centrifugal, frame mounted end suction
Process Material	Process water
Capacity	170 gpm each @ 75 ft tdh
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Cast iron casing with stainless steel internals

PROCESS WATER RETURN UNIT

Manufacturer	Weinman
Number	3
Type	
Process Material	Process Water
Capacity	60 gpm/60 gallon storage each
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Each unit consists of pump mounted on tank 40 psi pump discharge pressure

RECYCLE WATER PUMPS

Manufacturer	Goulds
Number	2
Type	Centrifugal, frame mounted end suction
Process Material	Treated process water
Capacity	150 gpm each @ 25 ft tdh
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Cast iron casing with stainless steel internals

RECYCLED WATER STORAGE TANK

Manufacturer	CBI Na-Con, Inc.
Number	1
Type	Vertical cylindrical
Process Material	Treated process water
Capacity	87,000 gallon
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

SYSTEM: GAS STORAGE

OFF-GAS STORAGE TANK

Manufacturer	CBI Na-Con, Inc.
Number	2
Type	Spherical
Process Material	Off-gas
Capacity	2.7 million scf each @ 165 psi
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

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SYSTEM: FIRE PROTECTION

FIREWATER STORAGE TANK

Manufacturer	CBI Na-Con, Inc.
Number	1
Type	Vertical cylindrical
Process Material	Water
Capacity	300,000 gallons
Primary Equipment Material	Carbon steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	

ELECTRIC FIRE PUMP

Manufacturer	Fairbanks-Morse
Number	1
Type	Horizontal split case
Process Material	Water
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Cast iron casing, bronze impellers, carbon steel shaft

DIESEL DRIVEN FIRE PUMP

Manufacturer	Fairbanks-Morse
Number	1
Type	Horizontal split case
Process Material	Water
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Cast iron casing, bronze impellers, carbon steel shaft

SYSTEM: WASTEWATER TREATMENT

CARBON FILTERS

Manufacturer	Infilco Degremont, Inc.
Number	2
Type	Pressurized filter
Process Material	Wastewater (coal washdown)
Capacity	75 gpm
Primary Equipment Material	Activated carbon
Design Temperature, F	Ambient
Design Pressure, PSIA	150
Remarks	

ACCELATOR REACTION TANK

Manufacturer	Infilco Degremont, Inc.
Number	1
Type	Size 7A
Process Material	Wastewater (coal washdown)
Capacity	150 gpm
Primary Equipment Material	Stainless steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.7
Remarks	

SYSTEM: SEWAGE TREATMENT

SEWAGE TREATMENT PLANT

Manufacturer	Environmental Conditioners, Inc.
Number	1
Type	Activated Sludge
Process Material	Wastewater (sanitary wastes)
Capacity	5,000 gallons per day
Primary Equipment Material	Concrete, stainless steel
Design Temperature, F	Ambient
Design Pressure, PSIA	14.5
Remarks	

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APPENDIX C

DESIGN REQUIREMENTS

FOR THE

SOLAR AND CHEMICAL PLANTS

INTRODUCTION

The design requirements for the major components of the solar plant and equipment lists of the chemical facility are included in this appendix. The solar plant components listed are those that received engineering analysis and design during the study. The chemical plant tables are detailed equipment lists that are compiled according to the production phase in which the equipment will be utilized. These tables are limited to materials of construction, flow rate, temperature, and pressure. In addition to these basic parameters, the solar components include additional basic requirements related to their specific functions. The solar plant components will be listed first, followed by the chemical plant equipment lists.

DESIGN REQUIREMENTS

HEAT TRANSPORT SUBSYSTEM

Solar Receiver:

Design Point	Solar Noon, Day 355
Location	Barstow, CA
Insolation Rating	950 W/m^2
Thermal Rating (Absorbed)	41.8 MW (142.6 MM Btu/Hr)
Heat Transfer Fluid	Molten Carbonate Salt; 32.2% Li_2CO_3, 33.3% Na_2CO_3, 34.5% K_2CO_3 by Weight
Molten Salt Inlet Temperature	514°C (957°F)
Molten Salt Outlet Temperature	954°C (1750°F)
Configuration	C-cavity, North Facing
Type	Forced Circulation, Once Through, Two Control Zones.
Operating Range	30-100%
Design Point Efficiency	78%
Heat Transfer Tubes	236 m^2 (2545 Ft^2) 600/617 Coextruded Tubes
Receiver Tower Elevation	85m (280 Ft)
Dry Weight	312,530 Kg (689,000 Lbs)

Fossil Fired Salt Heater:

Fuel	Reaction Furnace Off-Gas
Thermal Rating (Absorbed)	35.0 MW (119.3 MM Btu/Hr)
Molten Salt Inlet Temperature	514°C (957°F)
Molten Salt Outlet Temperature	954°C (1750°F)
Type	Forced Circulation, Once Through
Heating Sections:	
High convective	725m^2 (7801 ft^2) 600/617 Coextruded Tubes
Radiative	50m^2 (539 ft^2) 600/617 Coextruded Tubes
Low convective	548m^2 (5900 ft^2) 304 SS
Design Point Efficiency	83%

Steam Generation:

Design Code	Section VIII, Division 1, ASME
Thermal Rating	17.1 MW (58.3 MM Btu/Hr)
Carbonate Salt Composition	32.2% Li_2CO_3, 33.3% Na_2CO_3, 34.4% K_2CO_3 by Weight
Nitrate Salt Composition	60% $NaNO_3$, 40% KNO_3 by Weight

1. Intermediate Heat Exchanger

Thermal Rating	17.1 MW (58.3 MM Btu/Hr)
Carbonate Salt FLow	62.8 Kg/sec (498,760 lb/hr)
T_{in}	649°C (1200°F)
T_{out}	496°C (925°F)
Nitrate Salt Flow	54.9 Kg/sec (436,000 lb/hr)
T_{in}	304°C (580°F)
T_{out}	509°C (948°F)
Configuration	U-Tube, U-Shell
Design Pressure Tube-side	1.72 MPa (250 psig)
Design Pressure Shell-side	1.72.MPa (250 psig)
Design Temperature	677°C (1250°F)
Heat Transfer Surface	42.7m^2 (460 Ft^2)
Material	Incoloy 800
Dry Weight	3140 Kg (6900 lb)

2. Superheater

Thermal Rating	2.4 MW (8.0 MM Btu/Hr)
Nitrate Salt Flow Rate	54.9 Kg/sec (436,000 lb/hr)
T_{in}	509°C (948°F)
T_{out}	481°C (898°F)
Steam Flow	6.08 Kg/sec (48,290 lb/hr)
(Steam By-Pass)	0.60 Kg/sec (4760 lb/hr)
T_{in}	297°C (567°F)
T_{out}, P_{out}	399°C,7.93 MPa (750°F, 1150 psia)
Configuration	U-Tube, U-Shell
Design Pressure Tube-side	8.96 MPa (1300 psig)
Design Pressure Shell-side	1.72 MPa (250 psig)
Design Temperature	538°C (1000°F)
Heat Transfer Surface	10.1m^2 (109 Ft^2)
Material	304 SS
Dry Weight	1040 Kg (2300 lb)

3. Evaporator

Thermal Rating	14.7 Mw (50.3 MM Btu/hr)
Nitrate Salt Flow	70.3 Kg/sec (558,000 lb/hr)
T_{in}	443°C (829°F)
T_{out}	304°C (580°F)
Total Water/Steam Side Flow	26.7 Kg/sec (212,200 lb/hr)
T_{in}	260°C (500°F)
T_{out}	297°C (567°F)
Steam Flow, T_{out}	6.68 Kg/sec, 297°C (53,050 lb/hr, 567°F)
Configuration	U-Tube, U-Shell
Design Pressure Tube-side	9.65 MPa (1400 psig)
Design Pressure Shell-side	1.72 MPa (250 psig)
Design Temperature	482°C (900°F)
Heat Transfer Surface	156m^2 (1680 ft^2)
Material	2-1/4 CR - 1 MO
Dry Weight	13,290 Kg (29,300 lb)

4. Steam Drum

Steam Flow	6.68 Kg/sec (53,050 lb/hr)
Feedwater Temperature	129°C (265°F)
Operating Temperature	297°C (567°F)
Design Pressure	9.65 MPa (1400 psig)
Design Temperature	316°C (600°F)
Material	Carbon Steel
Dry Weight	7,700 Kg (17,000 lb)

Cold Salt Storage Tank:

Design Code	Section VIII, Division 1, ASME
Design Pressure	0.12 MPa (18 psig)
Design Temperature	538°C (1000°F)
Cold Salt Temperature	514°C (957°F)
Maximum Capacity	521,500 Kg (1,150,000 lb) salt
Material:	
Containment Vessel	304 SS
External Insulation	Block
Exterior	Aluminum Jacket
Base	Insulating Firebrick, Concrete Foundation
Dry Weight	47,600 Kg (105,000 lbs)

Hot Salt Storage Tank:	
Design Code	Section VIII, Division 1, ASME
Design Pressure	0.12 MPa (18 psig)
Containment Vessel Design Temp.	538°C (1000°F)
Hot Salt Temperature	954°C (1750°F)
Maximum Capacity	521,500 Kg (1,150,000 lb) salt
Material:	
Inner Liner	Inconel 600
Internal Insulation	25mm (1") Alumina Spheres
Outer Liner	304 SS
Cold Salt Cooling Tubes	304 SS
Containment Vessel	304 SS
External Insulation	Block
Exterior	Aluminum Jacket
Base	Insulating Firebrick, Concrete Foundation
Dry Weight	512,000 Kg (1,129,000 lb)

HELIOSTAT FIELD

Number of Heliostats	797
Total Mirror Area	76,113 m^2
Single Mirror; Gross Area	98.4 m^2
Single Mirror; Net Area	95.5 m^2
Average Reflectivity	91%

CARBONATE SALT PROPERTIES

Composition	$(Li, Na, K)_2 CO_3$ Ternary Eutectic
Weight Percent	32.2%, 33.3%, 34.5%
Melting Point	397°C (747°F)
Thermal Conductivity	1.9 W/m-°C (1.1 Btu/hr-ft-°F)
Density	$2252-0.474T$ kg/m^3, T in °C ($141.1-0.01643$ T lbm/ft^3, T in°F)
Viscosity	$T \leq 1200$°F: 3.328×10^9 T^{-4} Pa-sec, T in°F (8.05×10^{12} T^{-4}lbm/ft-hr, T in °F)
	$T > 1200$°F: 0.187 $T^{-.67}$ Pa-sec, T in °F ($452T^{-.67}$ lbm/ft-hr, T in °F)
Specific Heat	$1377 + 0.6904T$ J/Kg-°C, T in °C ($0.326 + 0.919 \times 10^{-4}$ T Btu/lbm-°F, T in °F)

NITRATE SALT PROPERTIES

Composition	(Na, K) NO_3
Weight Percent	60%, 40%
Melting Point	$245^{o}C$ ($473^{o}F$)
Thermal Conductivity	$0.441+1.95x10^{-4}T$ W/m-^{o}C, T in ^{o}C ($0.253+6.27x10^{-5}T$ Btu/hr-ft-^{o}F, T in ^{o}F)
Density	2090-0.640T Kg/m^3, T in ^{o}C (131.2-0.02221 T lbm/ft^3, T in^{o}F)

Viscosity:

$0.02271-1.20x10^{-4}T+2.281x10^{-7}T^2-1.474x10^{-10}T^3$ Pa-sec, T in^{o}C

$(54.916-0.2903T+5.516x10^{-4}T^2-3.556x10^{-7}T^3$ lbm/ft-hr, T in$^{o}C)$

Specific Heat	1447+0.1717T J/kg-^{o}C, T in ^{o}C ($0.345+2.28x10^{-5}T$ Btu/lbm-^{o}F, T in^{o}F)

CHEMICAL PLANT

Table 1	Pretreatment
Table 2	Carbonization, Activation, and Product Classification
Table 3	Tar Recovery/Ammonia Compression
Table 4	Off-Gas Cooling and Compression
Table 5	H_2S Removal and Sulfur Recovery
Table 6	Regeneration

TABLE 1

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SOLAR FUELS AND CHEMICALS SYSTEM DESIGN STUDY
CHEMICAL PROCESS
EQUIPMENT LIST BY FLOW

ACTIVATED CARBON PRODUCTION
PRETREATMENT
PAGE 1 OF 2

ITEM NUMBER	EQUIPMENT NAME	MATERIALS OF CONSTRUCTION	FLOW (LB/HR)	TEMPERATURE (F)	PRESSURE (PSIA)	DESCRIPTION
CN-101	COAL CONVEYOR	CARBON STEEL	14911.7	77	14.7	FROM COAL STORAGE, 1"-5" SIZE, 10-15% MOISTURE
CR-101	COAL CRUSHER	A2 TOOL STEEL OR MART. CR-MO WHITE IRON	14911.7	77	14.7	RAW COAL CRUSHED TO 1" SIZE MAXIMUM
CN-102	COAL BUCKET ELEVATOR	CARBON STEEL	14911.7	77	14.7	TO ELEVATION OF GRINDER
CR-102	COAL GRINDER	A2 TOOL STEEL OR MART. CR-MO WHITE IRON	24852.8	80	14.7	1" SIZE GROUND TO 8 X 30 MESH GRANULES
SC-102	COAL SCREEN	CARBON STEEL	24852.8	80	14.7	40% RECYCLED BACK TO GRINDER
CN-104	COAL BUCKET ELEVATOR	CARBON STEEL	24852.8	80	14.7	TO ELEVATION OF GRINDER
CN-105	COAL CONVEYOR	CARBON STEEL	9941.1	80	14.7	RECYCLE BACK TO GRINDER
CN-106	COAL CONVEYOR	CARBON STEEL	14911.7	80	14.7	FROM SCREEN TO ACID MIXER
FE-103	FEEDER/AIRLOCK	CARBON STEEL	14911.7	80	14.7	FEED TO ACID MIXER
FE-101	DUST FEEDER	CARBON STEEL	325.	77	14.7	BOTTOM OF DUST COLLECTOR
DC-101	DUST COLLECTOR	CARBON STEEL	*			CYCLONE, BAGHOUSE OR COMBINATION
FN-101	EXHAUST FAN	CARBON STEEL	*		*	DEPENDS ON AREAS CONTAINED
VT-101	ACID MIXER	316 STAINLESS STEEL	43186.7	176		ONE HOUR RESIDENCE TIME—30% COAL,70% ACID SOLN
AG-101	AGITATOR	CD4MCU				MOUNTED ON ACID MIXER
HE-101	HEATER	CARPENTER 20				764 LB/HR STEAM, IMMERSED COIL IN ACID MIXER
CP-101	SLURRY PUMP	CD4MCU IMPELLER	43186.7	176	*	COAL SLURRY FROM ACID MIXER TO DEWATERER
VT-102	ACID TANK	FRP OR FRP LINED CARBON STEEL	146.3			75% H3PO4 SOLUTION
AG-102	AGITATOR	CF8M				MOUNTED ON ACID TANK
CP-102	ACID PUMP	316 STAINLESS STEEL	146.3	77	*	FROM ACID TANK TO MIXER
SC-103	ACID SOLN DEWATERER	316 STAINLESS STEEL	43186.7	176		SEE FLOW DIAGRAM FOR WATER ADDITION/SEPARATION
SC-104	ACID SOLN DEWATERER	316 STAINLESS STEEL	29422.3	175		DOWN TO 15% MOISTURE
VT-103	COAL WASHER	316 STAINLESS STEEL	15293.3			27950 LB/HR WATER ADDED,ONE HOUR RES TIME
AG-103	AGITATOR	CD4MCU				MOUNTED ON COAL WASHER
CP-103	SLURRY PUMP	CD4MCU IMPELLER,CASING	43243.9	78	*	FROM COAL WASHER TO DEWATERER

* — NUMBERS DEPEND ON PHYSICAL PLANT LAYOUT
1 -- EQUIPMENT ADDED PER REV. 1

TABLE 1 (CONT.)

REV. 1
11-21-85

SOLAR FUELS AND CHEMICALS SYSTEM DESIGN STUDY
CHEMICAL PROCESS
EQUIPMENT LIST BY FLOW

ACTIVATED CARBON PRODUCTION
PRETREATMENT
PAGE 2 OF 2

	ITEM NUMBER	EQUIPMENT NAME	MATERIALS OF CONSTRUCTION	FLOW (LB/HR)	TEMPERATURE (F)	PRESSURE (PSIA)	DESCRIPTION
	SC-105	DEWATERER	CARBON STEEL	43243.9	78		SEE FLOW DIAGRAM FOR SEPARATION
	SC-106	DEWATERER	CARBON STEEL	29479.6	77		SEE FLOW DIAGRAM FOR SEPARATION
	HE-102	DRYER	CARBON STEEL	15293.8	77—212	14.7	DOWN TO 5% MOISTURE, 2090 LB/HR STEAM
	VT-104	PITCH HOPPER	CARBON STEEL	1444.3	120	14.7	ONE HOUR RESIDENCE
1	FE-104	FEEDER/AIRLOCK	CARBON STEEL	1444.3	120	14.7	FEED PITCH TO PULVERIZER
	CR-103	PULVERIZING MILL	CARBON STEEL	21263.6			80% LESS 200 MESH OR 60-65% LESS 325 MESH
	DC-102	DUST COLLECTOR	CARBON STEEL	21262.2			CYCLONE/BAGHOUSE—MATERIAL FROM PULVERIZER
	FN-102	EXHAUST FAN	CARBON STEEL	*		*	DEPENDS ON PHYSICAL LAYOUT
	FE-102	DUST FEEDER	CARBON STEEL	21262.2			BOTTOM OF DUST COLLECTOR
1	VT-107	DEAERATION BIN	CARBON STEEL	21262.2			BETWEEN DUST COLLECTOR AND COMPACTOR
1	FE-105	FEEDER	CARBON STEEL	21262.2			BOTTOM OF DEAERATION BIN
	CR-104	COMPACTOR	CARBON STEEL	21262.2		40—60,000	COMPACT TO PELLETS 1/2" DIA X 1/2" LONG
	CR-105	GRINDER	CARBON STEEL	21262.2			GRIND TO 6 X 20 MESH GRANULES
	SC-107	SCREEN	CARBON STEEL	30374.5	200	14.7	30% RECYCLED BACK TO GRINDER
	CN-112	BUCKET ELEVATOR	CARBON STEEL	21262.2			TO ELEVATION OF GRINDER
	CN-113	CONVEYOR	CARBON STEEL	3112.4	200	14.7	RECYCLE BACK TO GRINDER
	CN-114	CONVEYOR	CARBON STEEL	15186.6	200	14.7	SCREEN TO PULVERIZING MILL
	CN-115	BUCKET ELEVATOR	CARBON STEEL	15186.6	200	14.7	TO ELEVATION OF STORAGE BIN
	VT-105	STORAGE BIN	CARBON STEEL				24 HOUR HOLDING CAPACITY
1	FE-106	FEEDER	CARBON STEEL	15186.6	175	14.7	BOTTOM OF STORAGE BIN
1	CN-117	WEIGH CONVEYOR	CARBON STEEL	15186.6	175	14.7	FEED TO BUCKET ELEVATOR
	CN-116	BUCKET ELEVATOR	CARBON STEEL	15186.6	175	14.7	COAL TO CARBONIZATION FURNACE

* — NUMBERS DEPEND ON PHYSICAL PLANT LAYOUT
1 — EQUIPMENT ADDED PER REV. 1

TABLE 2

REV. 1 — 11-21-85

SOLAR FUELS AND CHEMICALS SYSTEM DESIGN STUDY
CHEMICAL PROCESS
EQUIPMENT LIST BY FLOW

ACTIVATED CARBON PRODUCTION
CARBONIZATION, ACTIVATION, PRODUCT CLASSIFICATION
PAGE 1 OF 1

ITEM NUMBER	EQUIPMENT NAME	MATERIALS OF CONSTRUCTION	FLOW (LB/HR)	TEMPERATURE (F)	PRESSURE (PSIA)	DESCRIPTION
FR-201	CARBONIZATION FURNACE		15188.6		14.7	1112 F, OXYGEN FREE, 2 HOUR RES TIME
CN-201	CONVEYOR	316 STAINLESS STEEL	8684.	1112	14.7	BOTTOM OF CARBONIZATION FURNACE TO BUCKET ELEVATOR
CN-202	BUCKET ELEVATOR	316 STAINLESS STEEL	8684.	1112	14.7	ELEVATE TO ACTIVATION FURNACE
CN-203	CONVEYOR	316 STAINLESS STEEL	8684.	1112	14.7	FEED ACTIVATION FURNACE
FR-202	ACTIVATION FURNACE		8684.			1472 F, 21567 LB/HR STEAM ADDED, 4 HOUR RES TIME
FE-201	FEEDER	INCOLOY 800H	3308.5	1472	14.7	BOTTOM OF ACTIVATION FURNACE
CN-204	CONVEYOR	INCOLOY 800H	3308.5	1472	14.7	TO PRODUCT COOLER
HE-201	PRODUCT COOLER	304 STAINLESS STEEL	3308.5	1472—180	14.7	WATER COOLED CONVEYOR, 1.1 MM BTU/HR
CP-204	WATER PUMP					TEMPERED WATER TO DRYER
CN-205	CONVEYOR	CARBON STEEL	3308.5	180	14.7	PRODUCT COOLER TO ACID MIXER
FE-202	FEEDER/AIRLOCK	CARBON STEEL	3308.5	180	14.7	FEED ACID MIXER
VT-201	ACID MIXER	HAST. C-276 LINED OR ACID BRICK LINED	6494.2	180		ONE HOUR RESIDENCE TIME
AG-201	AGITATOR	CHLORIMET 3				MOUNTED ON ACID MIXER
HE-202	HEATER	KBI-10				62 LB/HR STEAM, IMMERSED COIL IN ACID MIXER
VT-202	ACID DILUTION TANK	FRP	650.7	77		15% HCL SOLUTION
CP-201	ACID PUMP	TEFLON LINED	650.7	77		FROM ACID DILUTION TO ACID MIXER
CP-202	SLURRY PUMP	DURICHLOR	6494.2	79	*	FROM ACID MIXER TO DEWATERER
SC-201	ACID SOLN DEWATERER	HAST.C-276	6494.2	78		SEE FLOW DIAGRAM FOR WATER ADDITION/SEPARATION
VT-203	PRODUCT WASHER	316 STAINLESS STEEL	3815.9	78		3250 LB/HR WATER ADDED
AG-203	AGITATOR	CD4MCU				MOUNTED ON PRODUCT WASHER
CP-203	SLURRY PUMP	CD4MCU IMPELLER	7065.9	78	*	PRODUCT WASHER TO DEWATERER
SC-202	DEWATERER	316 STAINLESS STEEL	7065.9	78		DOWN TO 15% MOISTURE, SEE FLOW DIAGRAM
HE-203	PRODUCT DRYER	CARBON STEEL	3815.9	78—212		DOWN TO 2% MOISTURE, 397 LB/HR STEAM
HE-204	FINAL PRODUCT COOLER	CARBON STEEL	3309.8	212—100		WATER COOLER, 0.7 MM BTU/HR
SC-203	SCREEN	CARBON STEEL	3309.8	100		SCREEN TO 6 X 20 MESH GRANULES, RECYCLE TO PRETREATMENT
CN-208	CONVEYOR	CARBON STEEL	3250.	100	14.7	TO PRODUCT STORAGE

* — NUMBERS DEPEND ON PHYSICAL PLANT LAYOUT
1 — EQUIPMENT ADDED PER REV. 1

TABLE 3

REV. 1
11-21-85

SOLAR FUELS AND CHEMICALS SYSTEM DESIGN STUDY
CHEMICAL PROCESS
EQUIPMENT LIST BY FLOW

ACTIVATED CARBON PRODUCTION
OFFGAS COOLING AND COMPRESSION
PAGE 1 OF 1

ITEM NUMBER	EQUIPMENT NAME	MATERIALS OF CONSTRUCTION	FLOW (LB/HR)	TEMPERATURE (F)	PRESSURE (PSIA)	DESCRIPTION
DC-401	DUST COLLECTOR	REFRACTORY LINED STEEL	26942.5	1472	35	CYCLONE
FE-401	FEEDER	310 STAINLESS STEEL		1472		BOTTOM OF CYCLONE
HE-402	BFW HEATER	ALUMINUM BRONZE TUBES,CS SHELL	26942.5	400--250		COOL TO 250 F
HE-401	EVAPORATOR	SANDVIK 253 MA TUBES, 316 SS SHELL	26942.5	1472--400		PRODUCE 75 PSIG STEAM
1 VT-403	STEAM DRUM					SEPARATE 75 PSIG STEAM
FN-401	EXHAUST FAN	SANDVIK 253 MA	26942.5	1472		DEPENDS ON PHYSICAL LAYOUT
HE-403	OFFGAS COOLER	316 SS TUBES, 316 SS SHELL	28140.4	242--95	30	WATER COOLED, 13.6 MM BTU/HR
VT-401	KNOCKOUT DRUM	316 STAINLESS STEEL	28140.4	95		REMOVE WATER
GC-401	OFFGAS COMPRESSOR	CF-8M CASE, A-286 ROTOR (150 KSI TS)	16449.5	95	30--350	MULTIPLE STAGE
HE-404	INTERCOOLERS	316 SS TUBES, 316 SS SHELL	16443.5			95 F FINAL EXIT TEMPERATURE, 5.1 MM BTU/HR TOTAL
VT-402	KNOCKOUT DRUM	316 STAINLESS STEEL	16449.5	95		REMOVE WATER

* -- NUMBERS DEPEND ON PHYSICAL PLANT LAYOUT
1 -- EQUIPMENT ADDED PER REV. 1

TABLE 4

REV. 1
11-21-85

SOLAR FUELS AND CHEMICALS SYSTEM DESIGN STUDY
CHEMICAL PROCESS
EQUIPMENT LIST BY FLOW

ACTIVATED CARBON PRODUCTION
TAR RECOVERY/AMMONIA REMOVAL
PAGE 1 OF 1

NOTE: THE EQUIPMENT SHOWN ON THIS PAGE IS APPROXIMATE. THE TAR RECOVERY/AMMONIA REMOVAL SYSTEM IS AVAILABLE AS A COMPLETE SUBPROCESS FROM SEVERAL ENGINEERING FIRMS. ACTUAL EQUIPMENT AND DESIGN INFORMATION SHOULD BE OBTAINED FROM THE SELECTED ENGINEERING FIRM AS A RESULT OF COST INQUIRIES. (REFER TO PROCESS FLOW DIAGRAMS FOR NECESSARY INLET CONDITIONS)

ITEM NUMBER	EQUIPMENT NAME	MATERIALS OF CONSTRUCTION	FLOW (LB/HR)	TEMPERATURE (F)	PRESSURE (PSIA)	DESCRIPTION
VT-301	QUENCH TANK					
VT-302	DOWNCOMER					
HE-301	PRIMARY COOLER			105--95		
FN-301	EXHAUSTER					10-12 IN WG SUCTION, 50-55 IN WG DISCHARGE
DC-301	TAR PRECIPITATOR					
VT-303	DECANTER					
CP-301	TAR PUMP		2314.	120	14.7	
VT-304	TAR HOLDING TANK					
CP-307	TAR PUMP					TAR TO STORAGE AREA
CP-302	DECANT PUMP					
HE-302	FLUSHING LIQUOR COOLER					
VT-305	FLUSHING LIQUOR TANK					
CP-303	FLUSHING LIQUOR PUMP					
VT-306	CRUDE LIQUOR STORAGE					
CP-304	CRUDE LIQUOR PUMP					
VT-307	CAUSTIC LEG					
HE-303	CRUDE LIQUOR STILL					520 LB/HR STEAM
HE-304	PARTIAL CONDENSER					
VT-308	WASTE LIQUOR SUMP					
TW-301	AMMONIA SCRUBBER					
CP-305	SCRUBBER PUMP					
TW-302	AMMONIA SCRUBBER					
CP-306	SCRUBBER RECYCLE PUMP					
HE-305	AMMONIA LIQUOR STILL					520 LB/HR STEAM
HE-306	PARTIAL CONDENSER					
TW-303	LIQUOR COOLING TOWER					

* -- NUMBERS DEPEND ON PHYSICAL PLANT LAYOUT
1 -- EQUIPMENT ADDED PER REV. 1

TABLE 5

REV. 1
11-21-85

SOLAR FUELS AND CHEMICALS SYSTEM DESIGN STUDY
CHEMICAL PROCESS
EQUIPMENT LIST BY FLOW

ACTIVATED CARBON PRODUCTION
H2S REMOVAL AND SULFUR RECOVERY
PAGE 1 OF 1

ITEM NUMBER	EQUIPMENT NAME	MATERIALS OF CONSTRUCTION	FLOW (LB/HR)	TEMPERATURE (F)	PRESSURE (PSIA)	DESCRIPTION
HE-501	COOLER					32--36 F EXIT TEMPERATURE
TW-501	H2S ABSORBER					
HE-502	HEAT EXCHANGER					
CP-501	HYDRAULIC TURBINE					
VT-501	HIGH PRESS FLASH DRUM					
GC-501	RECYCLE COMPRESSOR					
HE-503	RECYCLE COOLER					
VT-502	LOW PRESS FLASH DRUM					
TW-502	H2S STRIPPER					
CP-502	RECYCLE PUMP					
HE-504	SOLVENT COOLER			32		
HE-505	STRIPPER CONDENSER					
VT-503	STRIPPER KNOCK OUT POT					
RC-501	THERMAL REACTOR					
FN-501	FAN					
HE-506	WASTE HEAT BOILER					
HE-507	HEATER					
RC-502	CATALYTIC REACTOR					
HE-508	CONDENSER					
VT-504	SULFUR STORAGE					
HE-509	HEATER					
HE-510	CONDENSER					
VT-505	KNOCK OUT POT					
FR-501	INCINERATOR					

NOTE: THE EQUIPMENT SHOWN ON THIS PAGE IS APPROXIMATE. THE H2S REMOVAL/SULFUR RECOVERY SYSTEM IS AVAILABLE AS A COMPLETE SUBPROCESS FROM SEVERAL ENGINEERING FIRMS. ACTUAL EQUIPMENT AND DESIGN INFORMATION SHOULD BE OBTAINED FROM THE SELECTED ENGINEERING FIRM AS A RESULT OF COST INQUIRIES.
(REFER TO PROCESS FLOW DIAGRAMS FOR NECESSARY INLET CONDITIONS)

* -- NUMBERS DEPEND ON PHYSICAL PLANT LAYOUT
1 -- EQUIPMENT ADDED PER REV. 1

TABLE 6

REV. 1
11-21-85

SOLAR FUELS AND CHEMICALS SYSTEM DESIGN STUDY
CHEMICAL PROCESS
EQUIPMENT LIST BY FLOW

SPENT ACTIVATED CARBON REGENERATION
REGENERATION

	ITEM NUMBER	EQUIPMENT NAME	MATERIALS OF CONSTRUCTION	FLOW (LB/HR)	TEMPERATURE (F)	PRESSURE (PSIA)	DESCRIPTION
	VT-601A,B	SPENT CARBON STORAGE	CARBON STEEL	7674.	70	14.7	TWO TANKS OF DIFFERENT SIZE
1	FE-602A,B	FEEDER	CARBON STEEL	7674.	70	14.7	SPENT ACTIVATED CARBON FROM STORAGE
	ED-601A,B	EDUCTOR	DURIMET 20	26670.	70	40	MOVE SPENT CARBON TO FEED TANK USING WATER
	VT-602	FEED TANK	316 STAINLESS STEEL	26670.	70		FEED TANK FOR REGENERATION FURNACE
1	AG-602	AGITATOR	316 STAINLESS STEEL	26670.	70		AGITATOR FOR FEED TANK
1	FE-603	FEEDER	316 STAINLESS STEEL	26670.	70		TO DEWATERING SCREW
	SC-601	DEWATERING SCREW	CARBON STEEL	26670.	70		REDUCE TO 40% MOISTURE
	VT-603	CRUDE WATER STORAGE	316 STAINLESS STEEL OR ACID BRICK	20286.	70	14.7	RECIRCULATION TANK
	CP-601	CRUDE WATER PUMP	CAST IRON	20286.	70	80	RECIRCULATE TO EDUCTOR
1	FE-604	FEEDER	CARBON STEEL	6394.	70		FEED REGENERATION FURNACE
	FR-601	REGENERATION FURNACE		6394.			DRYING (250-300 F) BAKING (300-1400 F) REGEN (1800 F)
	VT-604	QUENCH TANK	316 STAINLESS STEEL	17004.			BOTTOM OF REGENERATION FURNACE
1	FE-605	FEEDER	316 STAINLESS STEEL				BOTTOM OF QUENCH TANK
	ED-602	PRODUCT EDUCTOR	DURIMET 20	24295.			MOVE REGENERATED CARBON TO STORAGE
	VT-605	REGEN CARBON STORAGE	316 STAINLESS STEEL LINED	24295.	130	14.7	SAME SIZE AS LARGEST SPENT CARBON TANK
	AG-601	AGITATOR					MOUNTED ON REGENERATED CARBON STORAGE TANK
1	FE-606	FEEDER					TO DEWATERING SCREW
	SC-602	DEWATERING SCREW	CARBON STEEL	24295.			REDUCE TO 40--50% MOISTURE
	CP-602	WATER PUMP	CD4MCU IMPELLER	19007.	130	14.7	RECIRCULATE TO PRODUCT EDUCTOR
	FL-602	PRODUCT WATER FILTER	POLYPROPYLENE	21691.	123	80	FILTER RECIRCULATION WATER
	VT-606	PRODUCT WATER STORAGE	316 STAINLESS STEEL OR FRP LINED	21691.	123	14.7	RECIRCULATION TANK
	CP-603	PRODUCT WATER PUMP	CAST IRON	21691.	123	80	RECIRCULATE TO PRODUCT EDUCTOR
	HE-601	PRODUCT WATER COOLER	90-10 CU/NI TUBES, 316 SS SHELL	21691.	123--90	80	COOL RECIRCULATION WATER, 0.9 MM BTU/HR
	CN-602	CONVEYOR	CARBON STEEL	5200.	130	14.7	REGENERATED CARBON TO SHIPPING

* -- NUMBERS DEPEND ON PHYSICAL PLANT LAYOUT
1 -- EQUIPMENT ADDED PER REV. 1

TABLE 6 (CONTD)

REV. 1 | SOLAR FUELS AND CHEMICALS SYSTEM DESIGN STUDY | SPENT ACTIVATED CARBON REGENERATION

11-21-85 | CHEMICAL PROCESS | REGENERATION

EQUIPMENT LIST BY FLOW | PAGE 2 OF 2

ITEM NUMBER	EQUIPMENT NAME	MATERIALS OF CONSTRUCTION	FLOW (LB/HR)	TEMPERATURE (F)	PRESSURE (PSIA)	DESCRIPTION
DC-601	DUST COLLECTOR	CARBON STEEL	12506.	500	25	CYCLONE--REGENERATION FURNACE OFFGAS
FE-601	DUST FEEDER	CARBON STEEL				BOTTOM OF DUST COLLECTOR
HE-602	OFF GAS HEATER	INCONEL 600 TUBES, 304 SS SHELL	12506.	500--1200	25	USE MOLTEN SALT TO PREHEAT WASTE GAS TO INCINERATOR
FR-602	OFFGAS INCINERATOR	REFRACTORY LINED	12503.	1200--1500	20	DISPOSE OF WASTE GAS
TW-601	SCRUBBER	316 STAINLESS STEEL	41444.	1500	20	SCRUB INCINERATOR FLUE GAS
CP-604	SCRUBBER PUMP	CF-8				RECIRCULATE SCRUBBER WATER
1 FL-603	WATER FILTER					FILTER RECIRCULATION WATER
HE-603	SCRUBBER COOLER	90-10 CU/NI TUBES, 316 SS SHELL				COOL SCRUBBER WATER
FN-601	DRAFT FAN	304 STAINLESS STEEL	50245.	175		EXHAUST GAS FROM SCRUBBER TO STACK
ST-601	STACK	304 SS LINED OR ACID BRICK	50245.	175	14.7	DISCHARGE TO ATMOSPHERE

* -- NUMBERS DEPEND ON PHYSICAL PLANT LAYOUT
1 -- EQUIPMENT ADDED PER REV. 1

APPENDIX D

ECONOMIC ASSESSMENT

SUPPORTING DATA

APPENDIX D - ECONOMIC ASSESSMENT SUPPORTING DATA

TABLE D-1

PLANT CAPITAL COST SUMMARY

Plant direct costs:	$	%
0 **Land**	3,735,200	4
0.1 Collector Field-401,000 sq.mtrs	135,200	0
0.2 Total Required Land (300 A.)	3,600,000	4
0.2.1 Improved (20 A.)	240,000	0
0.2.2 Unimproved (280 A.)	3,360,000	4
1 **Structures & Improvements**	8,166,000	10
1.1 On-site Improvements	3,998,000	5
1.1.1 Civil Work	1,677,400	2
1.1.1.1 Cleaning and Grubbing	62,000	0
1.1.1.2 Site Grading	600,000	1
1.1.1.3 Site Drainage	123,000	0
1.1.1.4 Roads-Paved	270,400	0
1.1.1.5 Crushed Rock Surfacing	602,000	1
1.1.1.6 Landscaping	20,000	0
1.1.2 Waste Treatment Facilities	489,000	1
1.1.2.1 Evaporation Ponds	489,000	1
1.1.3 Water Supply and Distribution	381,600	0
1.1.4 General Fire Protection	1,150,000	1
1.1.5 Electrical (site)	100,000	0
1.1.6 Railroad Track	180,000	0
1.1.9 Other On-site Improvements	20,000	0
1.1.9.1 Fencing	20,000	0
1.3 Buildings and Structures	4,168,000	5
1.3.1 Administration/Control/Maintenance Building	1,092,000	1
1.3.2 Waste Water Treatment Building	46,000	0
1.3.3 Coal Pretreatment Building	1,320,000	2
1.3.4 Cooling Tower Basin	38,000	0
1.3.5 Coal Unloading Building	1,672,000	2
2 **Power Generation System**	32,868,963	38
2.1 Collector System	4,603,000	5
2.1.1 Heliostats (Quantity - 797)	4,560,000	5
2.1.2 Meteorological Subsystem	8,000	0
2.1.3 Washer Truck	35,000	0
2.2 Receiver System	5,954,044	7
2.2.1 Receiver	4,719,044	5
2.2.1.1 Absorption Panel Assembly	2,282,433	3
2.2.1.2 Structural Steel	410,400	0
2.2.1.3 Hot and Cold Surge Tanks	271,440	0
2.2.1.5 Insulation	53,900	0
2.2.1.6 Air Tank and Compressor	56,550	0
2.2.1.7 Door Assembly	209,000	0
2.2.1.8 Shipping	30,468	0
2.2.1.9 Erection	1,176,600	1
2.2.1.10 Engineering	126,053	0
2.2.1.6000 Piping	65,000	0
2.2.1.7000 Heat Tracing	37,200	0
2.2.2 Receiver Tower	1,235,000	1

2.3 Thermal Transport System	7,777,950	9
2.3.1 Salt Circulating System	499,600	1
2.3.1.5000 Process Equipment	89,600	0
2.3.1.5000.4 Pumps	34,600	0
2.3.1.5000.5 Tanks for Pumps	55,000	0
2.3.1.6000 Piping	410,000	0
2.3.1.6000.1 Pipe and Fittings	200,000	0
2.3.1.6000.3 Valves	210,000	0
2.3.2 Salt Booster System	2,925,000	3
2.3.2.5000 Process Equipment	295,000	0
2.3.2.5000.4 Pumps	240,000	0
2.3.2.5000.5 Tank	55,000	0
2.3.2.6000 Piping	2,630,000	3
2.3.2.6000.1 Pipe and Fittings	2,030,000	2
2.3.2.6000.3 Valves	600,000	1
2.3.3 Salt Transfer System	2,869,500	3
2.3.3.5000 Process Equipment	225,500	0
2.3.3.5000.4 Pumps	170,500	0
2.3.3.5000.5 Tanks	55,000	0
2.3.3.6000 Piping	2,644,000	3
2.3.3.6000.1 Pipe and Fittings	1,984,000	2
2.3.3.6000.3 Valves	660,000	1
2.3.4 Salt Prep. & Makeup System	190,500	0
2.3.4.5000 Process Equipment	73,000	0
2.3.4.5000.4 Pumps	18,000	0
2.3.4.5000.5 Tanks	55,000	0
2.3.4.6000 Piping	117,500	0
2.3.4.6000.1 Pipe and Fittings	57,500	0
2.3.4.6000.3 Valves	60,000	0
2.3.5 Other Thermal Transport System Costs	1,293,350	2
2.3.5.1 Heat Tracing	32,000	0
2.3.5.2 Insulation	31,000	0
2.3.5.3 Misc.	10,000	0
2.3.5.4 Salt Inventory	1,114,350	1
2.3.5.5 Standby System Foundations	106,000	0
2.4 Thermal Storage System	2,636,819	3
2.4.2 Hot Storage Tank	2,175,401	3
2.4.2.1 Insulation	1,915,088	2
2.4.2.1.1 Exterior	279,896	0
2.4.2.1.1.1 Roof & Walls	218,912	0
2.4.2.1.1.2 Firebrick	60,984	0
2.4.2.1.2 Interior	1,635,192	2
2.4.2.1.2.1 Ceiling	52,992	0
2.4.2.1.2.2 Annulus	483,000	1
2.4.2.1.2.3 Alumina Spheres	1,099,200	1
2.4.2.2 Cooling Circuit	25,163	0
2.4.2.2.1 Headers	6,644	0
2.4.2.2.6000 Piping	18,519	0
2.4.2.8 Foundation (Hot Salt Tank)	50,000	0
2.4.2.5000 Process Equipment	185,150	0
2.4.2.5000.5 Tanks	185,150	0

2.4.3 Cold Storage Tank	401,418	0
2.4.3.1 Insulation	225,168	0
2.4.3.1.1 Roof & Walls	164,184	0
2.4.3.1.2 Firebrick	60,984	0
2.4.3.8 Foundation (Cold Salt Tank)	38,000	0
2.4.3.5000 Process Equipment	138,250	0
2.4.3.5000.5 Tanks	138,250	0
2.4.7000 Electrical	60,000	0
2.4.7000.9 Heat Tracing	60,000	0
2.5 Control/Electrical System	5,601,800	7
2.5.1 Control	3,656,800	4
2.5.1.1 Solar	3,200,000	4
2.5.1.2 Process	342,600	0
2.5.1.3 Thermal Transport	45,700	0
2.5.1.4 Cogeneration	68,500	0
2.5.2 Electrical	1,945,000	2
2.5.2.1 Solar	200,000	0
2.5.2.2 Process	495,000	0
2.5.2.3 Thermal Transport	885,000	0
2.5.2.4 Cogeneration	365,000	0
2.6 Steam Generation System	1,645,741	2
2.6.1 Nitrate Salt System	805,692	1
2.6.1.1 Intermediate Heat Exchanger	317,892	0
2.6.1.5000 Process Equipment	225,500	0
2.6.1.5000.4 Pumps	170,500	0
2.6.1.5000.5 Tanks	55,000	0
2.6.1.6000 Piping	262,300	0
2.6.1.6000.1 Pipe and Fittings	92,300	0
2.6.1.6000.3 Valves	170,000	0
2.6.2 Steam System	836,549	1
2.6.2.1 Superheater	106,493	0
2.6.2.2 Steam Drum	147,800	0
2.6.2.3 Evaporator	336,756	0
2.6.2.4 Circulating Pumps	72,000	0
2.6.2.5 Piping	102,300	0
2.6.2.6 Valves	16,400	0
2.6.2.7 Insulation	39,800	0
2.6.2.8 Start-up Heater	15,000	0
2.6.7000 Electrical	3,500	0
2.6.7000.9 Heat Tracing	3,500	0
2.7 Salt Heater	4,649,610	5
2.7.1 Regenerative Air Heater	183,400	0
2.7.2 Fans and Drives	126,900	0
2.7.3 Materials and Fabrication	1,689.180	2
2.7.4 Erection	1,538,310	2
2.7.5 Excess Piping Material	950,000	1
2.7.6 Shipping	143,820	0
2.7.6000 Electrical	18,000	0
2.7.7000.9 Heat Trace	18,000	0

4 Cogeneration Plant	2,869,655	3
4.1 Turbine/Generator	782,000	1
4.2 Substation	300,000	0
4.3 Transformers	280,000	0
4.4 Heat Rejection System	571,005	1
4.4.1 Condensor	118,750	0
4.4.2 Cooling Tower	70,000	0
4.4.3 Circ. Water Pumps	73,155	0
4.4.5 Recycled Water Storage Tank	60,000	0
4.4.6 Recycle Water Pumps	6,600	0
4.4.7 Circ. Water Chem. Feed System	91,000	0
4.4.8 Piping	125,000	0
4.4.9 Valves	26,500	0
4.5 Feedwater/Steam System	533,650	1
4.5.1 Condensate Pumps	25,800	0
4.5.2 Deaerator	28,750	0
4.5.3 Feedwater Pumps	138,000	0
4.5.4 Makeup Water Pump	3,600	0
4.5.5 Demin. H2O Storage Tank	44,000	0
4.5.6 Demin. System	187,000	0
4.5.7 Piping	72,500	0
4.5.8 Valves	34,000	0
4.6 Other Cogen. System Costs	403,000	0
4.6.1 Equipment Support Structures	300,000	0
4.6.2 Misc. Mech. Systems	5,000	0
4.6.3 Water Conditioning Equip.	98,000	0
5 Process Plant Systems/Equipment	24,557,800	29
5.1 Regeneration Process	2,348,000	3
5.1.1 Spent Carbon Receiving System	338,000	0
5.1.2 Furnace	1,241,900	1
5.1.2.1 Air Cooled Steel Hearth	720,000	1
5.1.2.2 Installation	330,000	0
5.1.2.3 Plat Coils	191,900	0
5.1.3 Regen. Carbon Production System	207,300	0
5.1.4 Waste Byproduct Treatment	298,800	0
5.1.5 Storage and Shipping System	262,000	0
5.2 Activation Process	9,479,200	11
5.2.1 Activated Carbon Production	646,000	1
5.2.2 Activation Furnace	2,137,800	2
5.2.2.1 Air Cooled Steel Hearth	670,000	1
5.2.2.2 Installation	320,000	0
5.2.2.3 Plate Coils	1,147,800	1
5.2.3 Off-gas Cooling & Compression	450,400	1
5.2.4 Sulfur Recovery	700,000	1
5.2.5 Gas Storage Tanks	3,000,000	3
5.2.6 Storage and Shipping System	1,245,000	1
5.2.7 H2S Removal	1,300,000	2
5.3 Waste Water Treatment	315,000	0
5.3.1 Process Waste Water Treatment	180,000	0
5.3.2 Sanitary Waste Water Treatment	135,000	0

5.4 Carbonization Process	6,450,700	8
5.4.1 Pretreatment System	2,406,000	3
5.4.2 Carbonization Furnace	844,700	1
5.4.2.1 Air Cooled Steel Hearth	355,000	0
5.4.2.2 Installation	170,000	0
5.4.2.3 Plate Coils	319,700	0
5.4.3 Tar Recovery & Ammonia Removal	3,200,000	4
5.6 Coal Handling Equipment	3,596,000	4
5.6.1 Coal Unloading Facilities	345,000	0
5.6.2 Elevating Conveyor	691,000	1
5.6.3 Coal Storage Silos	2,066,000	2
5.6.4 Misc. Conveyors	173,000	0
5.6.5 Misc. Equipment	8,000	0
5.6.6 Dust Collection System	313,000	0
5.9 Miscellaneous Plant Systems/Equipment Costs	2,368,900	3
5.9.1 Equip. Support Structures	1,265,000	1
5.9.2 Misc. Mechanical System	1,103,900	1
9 Plant Level–Indirect Costs	13,699,000	16
9.9000 Indirect Costs	11,789,000	14
9.9000.3 Engineering Services	7,859,000	9
9.9000.6 Construction Management	3,930,000	5
9.9400 Start-up Costs	1,910,000	2
Total Direct Costs	85,896,618	100
Total (Overnight Const)	85,896,618	100
Total In-Service Cost	85,896,618	100
Total Capital Requirement	85,896,618	100

TABLE D-2

CAPACITY SUMMARY: WORLDWIDE

Producer	GAC Estimated Annual Capacity* (Millions of Pounds)	PAC Estimated Annual Capacity* (Millions of Pounds)	Total Capacity (Millions of Pounds)
United States	200	148	348
Western Europe[1]	109	114	223
Japan	87	55	142
Other Asian Countries[2]	31	16	47
TOTAL	427	333	760

* Estimated capacity as of January, 1985.

1 Includes Belgium, France, W. Germany, Netherlands, United Kingdom
2 Includes Malaysia, Phillippines, Singapore, Sri Lanka, Taiwan

TABLE D-3

SUPPLY/DEMAND SUMMARY: WESTERN EUROPE

ALL ACTIVATED CARBON - 1983
(Millions of Pounds)

o Capacity*	223
o Production	170
o Imports	15.5
o Exports	35
o Consumption	150

o Capacity Utilization = 76%

GRANULAR ACTIVATED CARBON (GAC) - 1983

Producer Country	GAC Estimated Annual Capacity* (Millions of Pounds)	GAC Estimated Market Share (Percent)
o Belgium	20	18
o France	22	20
o West Germany	21	19
o Netherlands	40	37
o United Kingdom	26	6
TOTAL ESTIMATED GAC CAPACITY	109	100%

* Also estimated capacity as of January, 1985.

TABLE D-4

SUPPLY/DEMAND SUMMARY: JAPAN

ALL ACTIVATED CARBON - 1983
(Millions of Pounds)

o	Capacity*	143
o	Production	123
o	Imports	10
o	Exports	5
o	Consumption	118

o Capacity Utilization = 87%

GRANULAR ACTIVATED CARBON (GAC) - 1983

TOTAL ESTIMATED GAC CAPACITY* = 87 Million Pounds

* Also estimated capacity as of January, 1985.

TABLE D-5

U. S. PRODUCERS OF ACTIVATED CARBON[a]

Company and Plant Location	Annual Capacity as of January 1985 (millions of pounds	Raw Material	Trade Name	Type Primary	End Uses
The Carbon Company Blue Lake, CA Redding, CA[b]	5	Redwood sawdust, peach pits	PACarb RECarb	Powdered, granular	Water purification, corn sweetening, miscellaneous
CECA, Inc.[c] (owned by Elf Aquitaine, France) Activated Carbon Division Pryor, OK	25	Western sub-bituminous coal	CECARBON	granular	Water purification, wastewater treatment, corn sweetening
CVI Incorporated Barneby-Cheney Company, subsidiary[d] Columbus, OH	7	Primarily coconut shells, charcoal, coal, and wood	Adsorbit HECA III DACOR	Nearly all granular; impregnated	Primarily gas phase for specialty uses
Husky Oil Company (owned by Husky Oil Limited) (Canada) Husky Industries, Inc., subsidiary Romeo, FL	30	Wood	Husky Watercarb	Powdered	Water purification

TABLE D-5 (Cont'd)

U. S. PRODUCERS OF ACTIVATED CARBON

Company and Plant Location	Annual Capacity as of January 1985 (millions of pounds)	Raw Material	Trade Name	Type	Primary End Uses
ICI Americas Inc.[e] (owned by Imperial Chemical Industries PLC (U.K.)) Chemicals Division Marshall, TX	85	Lignite, wood, bituminous coal	DARCO HYDRODARCO	Powdered, granular	Sugar refining, chemical purification dry cleaning, water purification
Merck & Co., Inc. Calgon Corporation subsidiary[f] Catlettsburg, KY Neville Island, PA	100	Bituminous coal coconut shell, charcoal	Pittsburgh Filtrasorb Calgon	Powdered, granular	Water purification, industrial gas and liquid phase
Westvaco Corporation Chemical Division Carbon Department Covington, VA	85	Wood, bituminous coal	Nuchar	Powdered, granular	Water purification, corn sweetening, chemicals and pharmaceuticals, pulsed bed adsorbers for liquid applications

TABLE D-5 (Cont'd)

U. S. PRODUCERS OF ACTIVATED CARBON

Company and Plant Location	Annual Capacity as of January 1985 (millions of pounds	Raw Material	Trade Name	Type	Primary End Uses
Witco Chemical Corporation Inorganic Specialties Div.					
Fostoria, OH[g]	5	Petroleum base residues, coconut shells, coal	Colombia Witcarb	Granular, extruded	Gas-phase applications, catalysts, industrial liquid and water purification, solvent recovery
Petrolia, PA	5				
TOTAL[h]	348				

a. Two companies are not producers, but supply activated carbon to the U.S. market: American Norit Co., Inc., of Jacksonville, Florida, supplies powdered and granular grades from the Netherlands; North American Carbon, Inc., of Columbus, Ohio imports from France and Mexico.

b. Plant is primarily for reactivating carbon.

c. Purchased activated carbon plant from Kennecott Corporation in 1982.

d. U. S. production of activated carbon is limited; most activated carbon products are purchased as finished products from overseas.

e. American Norit Co., Inc. has an agreement to buy ICI's activated carbon department, including the manufacturing facilities, in June 1985.

f. Purchased from Merck by Calgon group of employees by spring, 1985; new name to be Calgon Carbon Corporation.

g. Purchased this plant from Union Carbide in 1981.

h. One industry source estimated total U.S. capacity for activated carbon in 1985 to be 283 million pounds instead of 348 million pounds.

TABLE D-6
WESTERN EUROPEAN PRODUCERS OF ACTIVATED CARBON

Company and Plant Location	Annual Capacity as of January 1985 (thousands of metric tons)	Raw Material	Type	Remarks
BELGIUM				
Baltimore Aircoil-Chemviron sa (Owned 63% by Calgon Corporation, USA and 37% by Baltimore Aircoil Co., USA (owned by Merck & Co. Inc., USA)				
Feluy	10	Coal	Mostly granular	
FRANCE				
CECA SA (owned 99.97% by Compagnie Financiere de Paris et des Pays-Bas SA - PARIBAS)				
Parentis-en-Born	12	Wood, coal coconut shells	Powdered, granular	
Societe Pica SA				
Vierzon	8		Coconut shells granular	Powdered,
GERMANY, FEDERAL REPUBLIC OF				
Bayer AG				
Leverkusen	10	Lignite/peat	Powdered, granular	
Bergwerkaverband GmbH (owned 100% by Bergbau-Forschung GmbH)				
Essen	3	Coal	Powdered, granular	

TABLE D-6 (Cont'd)
WESTERN EUROPEAN PRODUCERS OF ACTIVATED CARBON

Company and Plant Location	Annual Capacity as of January 1985 (thousands of metric tons	Raw Material	Type	Remarks
GERMANY, FEDERAL REPUBLIC OF (Continued)				
Degussa				
(owned over 25% by GfC Gesellachaft fuer Chemiewerte mbH)				
Brilon-Wald	6	Wood, coal	na	
ITALY				
Anticromos SpA				
(owned 100% by CECA SA (France))				
Legnano	3	Wood only	Powdered	
Ing. A. Bonaccorsi & C.Srl				
Ferrara	--	--	--	Mainly regeneration.
NETHERLANDS				
Norlt NV				
Klazienaveen	36	Peat	Both	
Zaanstad a				
UNITED KINGDOM				
Chemviron, Ltd.				
Grays	--	Coconut shells	na	Essentially a regeneration unit of 2 thousand metric tons capacity.
Thomas Ness Ltd.				
(owned 100% by NCB (Coal Products) Ltd.)				
Coedely	2	Coal	na	Currently not producing.

TABLE D-6 (Cont'd)
WESTERN EUROPEAN PRODUCERS OF ACTIVATED CARBON

Company and Plant Location	Annual Capacity as of January 1985 (thousands of metric tons	Raw Material	Type	Remarks
UNITED KINGDOM (Continued)				
Norit-Clydesdale Co. Ltd. (owned 100% by Norit NV (Netherlands))				
Glasgow	10	Wood	Powdered	Expansion to 10 thousand metric tons per year by 1982. Process is chemical activation with phosphoric acid.
Sutcliffe Speakman				
Leigh	5	Coconut shells/ coal	na	
Total	105			

a. Have regeneration plants in Zaanstad and in Ravenna, Italy, the latter newly completed in 1984.

SOURCE: CEH estimates.

TABLE D-7

ASIAN PRODUCERS OF ACTIVATED CARBON- 1984

Company and Plant Location	Annual Capacity by Type (metric tons)	Raw Material	Trade Name	Remarks
JAPAN				
Cataler Industrial Co., Ltd.[a] Fukuroi, Shizuoka Perfecture	Powdered 600 Granular 4,400	Coconut Shell Coal	KINTAL	---
Fuji Tanso Co., Ltd.b (100% owned subsidiary of Fujisawa Pharmaceutical Co., Ltd.) Sera, Hirochima Prefecture	Powdered 1,200	Sawdust	FUJI(P)	
	Granular 1,800[c]	Coconut shell, coal	FUJISAWA	--
Futamura Chemical Industry Co., Ltd. Minokamo, Gifu Prefecture	Powdered 13,000	Coconut shell		Production is about 70% of capacity for GAC and 85% for PAC.
	Granular 2,400	Coal	TAIKO	
Hakata Chemical Co., Ltd. Hakata Ehime Prefecture AGI Toll manufacture for Takeda Chemical Ind.	Granular 800	Coconut shell	SHIRAS	
Hokuetsu Tanso Kogyo Co., Ltd. Yokohama, Kanagawa Prefecture	Powdered 1,800	Charcoal	HOKUETSU	Production is 1,300 tons of PAC. Production of GAC is greater than 75% of capacity.
	Granular 2,000	Coconut shell, coal		
Hokutan Chemical Industry Co., Ltd. Toda, Saitama Prefecture	Granular 1,000	Coal, coconut per year. shell	STARCOAL	Production is 600 tons

TABLE D-7 (Continued)
ASIAN PRODUCERS OF ACTIVATED CARBON - 1984

Company and Plant Location		Annual Capacity by Type (metric tons)	Raw Material	Trade Name	Remarks
JAPAN (Continued)					
Kitamura Chemical Laboratory Ohyodo, Nara Prefecture	Powdered	700 1,000	Sawdust	KINTSURU	----
Kuraray Co., Ltd. Kuraray Chemical Co., Ltd. Bizen, Okayama Prefecture	Granular	7,000 8,000[c]	Coal, coconut shell	KURARAYCOAL	Primary use is for rare gas adsorption.
Kureha Chemical Industry Co., Ltd. Iwaki, Fukushima Prefecture	Granular	500	Resinous pitch	BAC	Primary use is for water treatment.
Marubishi Carbon Co., Ltd. Okayama, Okayama Prefecture	Powdered	1,200	Sawdust	M-COAL	Production is 750 tons per year by steam process.
Minabe Chemical Ind. Co., Ltd. Minabe, Wakayama Prefecture	Powdered	4,000	Sawdust	SHIRASAGI	Toll manufacture for Takeda Chemical Industries, Ltd.
Mitsubishi Chemical Industries Ltd. Kitakyushu, Fukuoka Prefecture	Granular	3,000	Coal	DIAHOP E	-----
Nippon Teppun Co., Ltd. Kashiwa, Chiba Prefecture	Powdered Granular	480 720	Coal	ZEOCOAL	Sole distributor is Mitsui Mining & Smelting Co.
Sankyo Sangyo Ltd. Amagasaki, Hyogo Prefecture	Granular	1,200	Coconut Shell	DIASORB	Production is 960 tons per year

Table D-7 (Continued)
ASIAN PRODUCERS OF ACTIVATED CARBON - 1984

Company and Plant Location	Annual Capacity by Type (metric tons)	Raw Material	Trade Name	Remarks
JAPAN (Continued)				
Shinagawa Carbon Co., Ltd. Shogawa, Toyama Prefecture	Powdered 360 Granular 120	Sawdust Coconut shell	 KURO HAT	
Taihei Chemical Industrial Co., Ltd Kasugai, Aichi Prefecture	Powdered 1,200	Sawdust	UEMEACHI MA PROCOAL	PAC production is 1,200 tons annually, GAC - 600 tons
Gujohachiman, Gifu Prefecture	Granular 1,200	Coconut shell	YASHICOAL	
Takeda Chemical Industries, Ltd. Shimizu, Shizuoka Prefecture	Granualar 6,000	Coconut shell	SHIRASAGI	Total annual capacity is 12 thousand to 13 tons per year for Takeda, Minabe, and Hakata. Primary end use of GAC is in rare gas absorption. Total PAC production for Takeda is 6 thousand tons, including Minabe production and imports from Century Chemical Works, Malaysia.
Tsuorumicoal Co., Ltd Yokohama, Kanagawa Prefecture	Granular 5,400 (mostly)	Coconut shell, coal, charcoal	TSUORUMICOAL	
Total	Granular 39,540 Powdered 24,840			
Total Japan	64,380			

Table D-7 (Continued)
ASIAN PRODUCERS OF ACTIVATED CARBON - 1984

Company and Plant Location	Annual Capacity by Type (metric tons)	Raw Material	Trade Name	Remarks
KOREA, REPUBLIC OF				
Yoolin Chemical Industrial Co., Ltd.				
Kimpo	na		na	
MALAYSIA				
Century Chemical Works Co. (joint venture of Takeda Chemical Industries, Ltd. (25%)(Japan), Tosin Sangyo KK. (20%)(Japan), and Wah Seong Trading Co. (55%)(Malaya))				
Prai Industrial Complex near Penag	Powdered 2,000	Sawdust	na	Steam process for PAC. Some exports to Japan.
PHILLIPPINES				
Cenapro Chemical Corporation (joint venture of Kuraray (Japan), Marubeni Trading Co., (Japan), and Cenapro Group (Phillippines))				
Mendue, Cebu	Granular 5,000	Coconut shell	na	About 90% of production exported to Japan.
Davao Central Chemical Corporation (joint venture of Takdea Chemical Ind. (Japan), Mitsubishi Corporation (Japan, and local capital in the Philippines))				
Davao	Granular 2,500	Coconut shell	na	Exported to Japan.

Table D-7 (Continued)
ASIAN PRODUCERS OF ACTIVATED CARBON - 1984

Company and Plant Location	Annual Capacity by Type (metric tons)	Raw Material	Trade Name	Remarks
PHILLIPPINES (Continued)				
Pacific Activated Carbon Company (joint centure of Cataler Industrial Co., Ltd. (10%) (Japan), C. Itho & Co., (25%) (Japan), and H.N. Montenegro & Associates Inc. (65%) (Phillippines)				
Misamis, Mindanao	Granular 1,200	Coconut shell	na	
Phillippine-Japan Active Carbon Company (joint venturi of Futamura Chemical Industry Co., (Japan) and Kowa Co. (Japan))				
Mindanao	Granular 3,000	Coconut shell	na	
Total Phillippines	Powdered 0 Granular 11,700			
SINGAPORE				
Singapore Activated Carbon Company				
Singapore	Powdered 600	na		
SRI LANKA				
Hayleys Lts.				
Colombo	Granular 1,000	Coconut shell	na	

Table D-7 (Continued)
ASIAN PRODUCERS OF ACTIVATED CARBON - 1984

Company and Plant Location	Annual Capacity by Type (metric tons)	Raw Material	Trade Name	Remarks
TAIWAN				
Ho Tai Industrial Co., Ltd. Shu-Lin, Taipei	Powdered 3,600		na	
Taiwan Avtive Carbon Industry Co., Ltd. To Cheng, Taipei	Powdered 1,200		na	
Taipei Chemical Ind. Co., Ltd. Chu-Pei, Hsinchu	Granular 1,200		na	
Total Taiwan	Powdered 4,800 Granular 1,200 6,000			
Total Asian	21,300			

a. Cataler Industrial Co., Ltd. and Daiichi Tanso Co., Ltd. merged in December 1981.

b. Distribution channel transferred to 100% owned subsidiary, Daisan Kogyo Co., Ltd.

c. Data include annual capacity for regenerated carbon.

d. Taihei Chemical Industry Co. (Japan) and Kowa Company (Japan) have withdrawn from the joint venture.

SOURCE: CEH estimates.

TABLE D-8

ANALYSIS FOR BASELINE SOLAR PLANT WITH 0% ESCALATION

ECONOMIC ANALYSIS FOR SOLAR FUELS AND CHEMICALS SYSTEMS DESIGN STUDY

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Capital Expenditures												
Land	3735	0	0									
Plant and Equipment												
Solar	12531	12531	12531	1128	1128	1128	1128	1128	1128	1128	1128	1128
Non-Solar	1489	1489	1489	134	134	134	134	134	134	134	134	134
Chemical	12871	12871	12871	1931	1931	1931	1931	1931	1931	1931	1931	1931
Total Conventional	14360	14360	14360	2065	2065	2065	2065	2065	2065	2065	2065	2065
Total Plant and Equipment	26891	26891	26891	3192	3192	3192	3192	3192	3192	3192	3192	3192
Revenues												
Activated Carbon				23213	23213	23213	23213	23213	23213	23213	23213	23213
Regenerated Carbon				7000	7000	7000	7000	7000	7000	7000	7000	7000
Sulfur				0	0	0	0	0	0	0	0	0
Electricity				537	537	537	537	537	537	537	537	537
Tars and Oils				967	967	967	967	967	967	967	967	967
Synthetic Gas				0	0	0	0	0	0	0	0	0
Total Revenue (+)				31716	31716	31716	31716	31716	31716	31716	31716	31716
Sales, General and Administrative Expense (-)				3806	3806	3806	3806	3806	3806	3806	3806	3806
Depreciation Expense (-)												
Solar Portion of Plant				5808	8688	8549	8785	9022	1128	1128	1128	1128
Conventional Portion of Plant				3612	11081	10180	9381	9444	9507	9262	8155	7048
Total Expense	0	0	0	9420	19768	18728	18166	18466	10634	10389	9283	8176
Operating Costs												
Power Plant (-)				1374	1374	1374	1374	1374	1374	1374	1374	1374
Chemical Plant (-)				10695	10695	10695	10695	10695	10695	10695	10695	10695
Income Before Tax				6422	-3927	-2887	-2325	-2624	5207	5452	6559	7665
Taxes												
State, 8%				514	-314	-231	-186	-210	417	436	525	613
Federal, 46%				2701	-1679	-1239	-1001	-1128	2187	2290	2759	3227
Other Taxes, 1%				37	37	37	37	37	37	37	37	37
Investment Tax Credit, 10%	2689	2689	2689	319	319	319	319	319	319	319	319	319
Total Taxes (-)				2932	-2275	-1752	-1469	-1620	2321	2444	3001	3558
Net Income From Operations				3489	-3927	-2887	-2325	-2624	2886	3008	3557	4107
Depreciation Expense (+)	0	0	0	9420	19768	18728	18166	18466	10634	10389	9283	8176
Net Cash Flow From Operations				12909	15842	15842	15842	15842	13520	13397	12840	12283
Working Capital Requirements				3806	3806	3806	3806	3806	3806	3806	3806	3806
Incremental Working Capital	-26891	-26891	-28794	-1903	0	0	0	0	0	0	0	0
Total Net Cash Flows	-27937	-24202	-26105	7814	12649	12649	12649	12649	10328	10205	9648	9091

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Capital Expenditures												
Land												
Plant and Equipment												
Solar	1128	1128	1128	1128	1128	1128	1128	1128	1128	1128	1128	
Non-Solar	134	134	134	134	134	134	134	134	134	134	134	
Chemical	1931	1931	1931	1931	1931	1931	1931	1931	1931	1931	1931	
Total Conventional	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	
Total Plant and Equipment	3192	3192	3192	3192	3192	3192	3192	3192	3192	3192	3192	
Revenues												
Activated Carbon	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	
Regenerated Carbon	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	
Sulfur	0	0	0	0	0	0	0	0	0	0	0	
Electricity	537	537	537	537	537	537	537	537	537	537	537	
Tars and Oils	967	967	967	967	967	967	967	967	967	967	967	
Synthetic Gas	0	0	0	0	0	0	0	0	0	0	0	
Total Revenue (+)	31716	31716	31716	31716	31716	31716	31716	31716	31716	31716	31716	
Sales, General and Administrative Expense (-)	3806	3806	3806	3806	3806	3806	3806	3806	3806	3806	3806	
Depreciation Expense (-)												
Solar Portion of Plant	1128	1128	1128	1128	1128	1128	1128	1241	1368	1695	2586	
Conventional Portion of Plant	5942	2065	2065	2158	2163	2260	2466	2776	3258	4104	6169	
Total Expense	7070	3192	3192	3285	3291	3388	3594	4017	4626	5800	8755	
Operating Costs												
Power Plant (-)	1374	1374	1374	1374	1374	1374	1374	1374	1374	1374	1374	
Chemical Plant (-)	10695	10695	10695	10695	10695	10695	10695	10695	10695	10695	10695	
Income Before Tax	8772	12649	12649	12556	12550	12454	12248	11825	11216	10042	7086	
Taxes												
State, 8%	702	1012	1012	1005	1004	996	980	946	897	803	567	
Federal, 46%	3695	5336	5336	5297	5294	5253	5166	4987	4729	4233	2982	
Other Taxes, 1%	37	37	37	37	37	37	37	37	37	37	37	
Investment Tax Credit, 10%	319	319	319	319	319	319	319	319	319	319	319	
Total Taxes (-)	4115	6066	6066	6019	6016	5968	5864	5651	5345	4754	3267	
Net Income From Operations	4657	6583	6583	6537	6534	6486	6384	6174	5871	5288	3820	
Depreciation Expense (+)	7070	3192	3192	3285	3291	3388	3594	4017	4626	5800	8755	
Net Cash Flow From Operations	11727	9776	9776	9822	9825	9874	9978	10190	10497	11088	12575	
Working Capital Requirements	3806	3806	3806	3806	3806	3806	3806	3806	3806	3806	3806	
Incremental Working Capital	0	0	0	0	0	0	0	0	0	0	0	3806
Total Net Cash Flows	8534	6583	6583	6630	6633	6681	6785	6998	7305	7895	9382	3806

Net Present Value For Discount Rate = 5% is 39322
10% is 5070
12% is -4195
15% is -15120

Internal Rate of Return is 11.04% 0

TABLE D-8 (CONT.)

DEPRECIATION SCHEDULE																							
Solar Portion of Plant	1000	2757	2632	2632	2632				169	248	237	237	237										
		1000	2757	2632	2632	2632																	
			1000	2757	2632	2632	2632																
				169	248	237	237	237		169	248	237	237	237									
					169	248	237	237	237		169	248	237	237	237								
						169	248	237	237	237		169	248	237	237	237							
							169	248	237	237	237		169	248	237	237	237						
								169	248	237	237	237		169	248	237	237	237					
															169	248	237	237	237				
																169	248	237	237	237			
																	169	248	237	237	237		
																		169	248	237	237	237	
																			169	248	237	237	237
																				282	282	282	282
																					376	376	376
																						564	564
																							1128
Total Depreciation Expense for Solar Solar Portion of Plant				5008	8688	8549	8785	9022	1128	1128	1128	1128	1128	1128	1128	1128	1128	1128	1128	1241	1348	1695	2586
Conventional Portion Of Plant	1149	2010	1723	1436	1434	1436	1292	1292	1292	1292				165	289	248	206	206	206	186	186	186	186
		1149	2010	1723	1436	1436	1436	1292	1292	1292	1292												
			1149	2010	1723	1436	1436	1436	1292	1292	1292	1292											
				165	289	248	206	206	206	186	186	186	186		165	289	248	206	206	206	186	186	372
					165	289	248	206	206	206	186	186	186	186		258	258	258	258	258	258	258	258
						165	289	248	206	206	206	186	186	186	186		295	295	295	295	295	295	295
							165	289	248	206	206	206	186	186	186	186		344	344	344	344	344	344
								165	289	248	206	206	206	186	186	186	186		413	413	413	413	413
									165	289	248	206	206	206	186	186	186	186		516	516	516	516
										165	289	248	206	206	206	186	186	186	186		688	688	688
											165	289	248	206	206	206	186	186	186	186		1032	1032
												165	289	248	206	206	206	186	186	186	186		2065
													165	289	248	206	206	206	186	186	186	186	
Total Depreciation Expense for Conventi nal Conventional Portion of Plant				3612	11081	10180	9381	9444	9507	9262	8155	7048	5942	2065	2065	2150	nu	2260	2464	2774	3258	4104	6169

TABLE D-8 (CONT.)

ANNUAL OPERATION AND MAINTENANCE EXPENSES (costs in thousands of dollars)

- Power Plant																				
Variable Costs																				
Fuel	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240
Fixed Costs																				
Operating Labor (16 X $35,000)	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560
Maintenance Labor (10 X $35,000)	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350
Maintenance Materials and Contracts																				
Materials	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113
Contracts	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
Operating Consumables																				
Salt Replacement (5%/yr)	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59
Miscellaneous Supplies	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Total Fixed Costs	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134
Total Power Plant O&M Costs	1374	1374	1374	1374	1374	1374	1374	1374	1374	1374	1374	1374	1374	1374	1374	1374	1374	1374	1374	1374
- Chemical Plant																				
Activated Carbon Production																				
Variable Costs																				
Raw Materials																				
Coal	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196
Coal Tar Pitch	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846
Phosphoric Acid (75%)	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339
Hydrochloric Acid (30%)	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151
Total Variable Costs	4533	4533	4533	4533	4533	4533	4533	4533	4533	4533	4533	4533	4533	4533	4533	4533	4533	4533	4533	4533
Fixed Costs																				
Operating Labor (33 personnel)	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186
Fringe Benefits (20% of labor)	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237
Maintenance Labor (3% of capital costs)	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158
Maintenance Materials and Contracts	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158
Operating Supplies (10% of operating labor)	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Plant Overhead (80% of all labor)	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047
Total Fixed Costs	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905
Total Production Costs - Activated Carbon	10438	10438	10438	10438	10438	10438	10438	10438	10438	10438	10438	10438	10438	10438	10438	10438	10438	10438	10438	10438
Regeneration of Spent Carbon																				
Operating Labor (5 personnel)	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214
Fringe Benefits (20% of operating labor)	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
Total Production Costs - Regenerated Carbon	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257
Total Chemical Plant O&M Costs	10695	10695	10695	10695	10695	10695	10695	10695	10695	10695	10695	10695	10695	10695	10695	10695	10695	10695	10695	10695

TABLE D-8 (CONT.)

PLANT PRODUCTION AND REVENUE PROJECTIONS (revenue in thousands of dollars)

		Unit cost																				
Activated Carbon (lbs)	- Production		24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000
	- Price	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	- Revenue		23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213
Regenerated Carbon (lbs)	- Production		20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000
	- Price	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	- Revenue		7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000
Synthetic Gas (MMBtu)	- Production		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	- Price	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
	- Revenue		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electricity (kWh)	- Production		8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000
	- Price	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314	0.06314
	- Revenue		537	537	537	537	537	537	537	537	537	537	537	537	537	537	537	537	537	537	537	537
By-product Tars (tons)	- Production		9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765
	- Price	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00
	- Revenue		967	967	967	967	967	967	967	967	967	967	967	967	967	967	967	967	967	967	967	967
Product Selling Price and Fuel/Feedstock Cost Escalation Factor			1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

RAW MATERIALS AND FUEL (total costs in thousands of dollars)

Coal (tons)	Quantity	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920
	Unit Cost	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
	Total Cost	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196
Coal Tar Pitch (tons)	Quantity	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545
	Unit Cost	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333
	Total Cost	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846
Phosphoric Acid (tons)	Quantity	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565
	Unit Cost	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
	Total Cost	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339
Hydrochloric Acid (tons)	Quantity	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256
	Unit Cost	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
	Total Cost	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151
Natural Gas (MMBtu)	Quantity	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690
	Unit Cost	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
	Total Cost	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240	240

TABLE D-9

FINANCIAL ANALYSIS FOR BASELINE SOLAR PLANT

WITH 3% ESCALATION RATE

ECONOMIC ANALYSIS FOR SOLAR FUELS AND CHEMICALS SYSTEMS DESIGN STUDY

	1992	1993	1994	1995	1996	1997	1998	1999	2000
Capital Expenditures									
Land	3735	0	0						
Plant and Equipment									
Solar	12531	12531	12531	1128	1128	1128	1128	1128	1128
Non-Solar	1489	1489	1489	134	134	134	134	134	134
Chemical	12871	12871	12871	1931	1931	1931	1931	1931	1931
Total Conventional	14360	14360	14360	2065	2065	2065	2065	2065	2065
Total Plant and Equipment	26891	26891	26891	3192	3192	3192	3192	3192	3192
Revenues									
Activated Carbon				23213	23909	24626	25365	26126	26910
Regenerated Carbon				7000	7210	7426	7649	7879	8115
Sulfur				0	0	0	0	0	0
Electricity				537	553	569	586	604	622
Tars and Oils				967	996	1026	1056	1088	1121
Synthetic Gas				0	0	0	0	0	0
Total Revenue (+)				31716	32668	33648	34657	35697	36768
Sales, General and									
Administrative Expense (-)				3806	3920	4038	4159	4284	4412
Depreciation Expense (-)									
Solar Portion of Plant				5808	8688	8549	8785	9022	1128
Conventional Portion of Plant				3612	11081	10180	9381	9444	9507
Total Expense	0	0	0	9420	19768	18728	18166	18466	10634
Operating Costs									
Power Plant (-)				1374	1381	1388	1396	1404	1412
Chemical Plant (-)				10695	10831	10971	11115	11264	11417
Income Before Tax				6422	-3233	-1478	-179	280	8892
Taxes									
State, 8%				514	-259	-118	-14	22	711
Federal, 46%				2701	-1385	-642	-93	101	3746
Other Taxes, 1%				37	37	37	37	37	37
Investment Tax Credit, 10%	2689	2689	2689	319	319	319	319	319	319
Total Taxes (-)				2932	-1926	-1043	-389	-158	4176
Net Income From Operations				3489	-3233	-1478	-179	280	4717
Depreciation Expense (+)	0	0	0	9420	19768	18728	18166	18466	10634
Net Cash Flow From Operations				12909	16536	17251	17987	18746	15351
Working Capital Requirements				3806	3920	4038	4159	4284	4412
Incremental Working Capital	-26891	-26891	-28794	-1903	-114	-118	-121	-125	-129
Total Net Cash Flows	-27937	-24202	-26105	7814	13229	13941	14674	15428	12030

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Capital Expenditures															
Land															
Plant and Equipment															
Solar	1128	1128	1128	1128	1128	1128	1128	1128	1128	1128	1128	1128	1128	1128	
Non-Solar	134	134	134	134	134	134	134	134	134	134	134	134	134	134	
Chemical	1931	1931	1931	1931	1931	1931	1931	1931	1931	1931	1931	1931	1931	1931	
Total Conventional	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	2065	
Total Plant and Equipment	3192	3192	3192	3192	3192	3192	3192	3192	3192	3192	3192	3192	3192	3192	
Revenues															
Activated Carbon	27717	28549	29405	30287	31196	32132	33096	34089	35111	36165	37250	38367	39518	40704	
Regenerated Carbon	8358	8609	8867	9133	9407	9690	9980	10280	10588	10906	11233	11570	11917	12275	
Sulfur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Electricity	641	660	680	700	721	743	765	788	812	836	861	887	914	941	
Tars and Oils	1154	1189	1225	1261	1299	1338	1378	1420	1462	1506	1551	1598	1646	1695	
Synthetic Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Revenue (+)	37871	39007	40177	41382	42624	43903	45220	46576	47974	49413	50895	52422	53995	55615	
Sales, General and															
Administrative Expense (-)	4544	4681	4821	4966	5115	5268	5426	5589	5757	5930	6107	6291	6479	6674	
Depreciation Expense (-)															
Solar Portion of Plant	1128	1128	1128	1128	1128	1128	1128	1128	1128	1128	1241	1368	1695	2586	
Conventional Portion of Plant	9262	8155	7048	5942	2065	2065	2158	2163	2260	2466	2776	3258	4104	6169	
Total Expense	10389	9283	8176	7070	3192	3192	3285	3291	3388	3594	4017	4626	5800	8755	
Operating Costs															
Power Plant (-)	1420	1429	1438	1447	1456	1466	1476	1486	1497	1508	1519	1530	1542	1555	
Chemical Plant (-)	11574	11737	11904	12076	12254	12436	12625	12818	13018	13224	13436	13654	13879	14110	
Income Before Tax	9942	11878	13838	15824	20607	21539	22407	23391	24314	25158	25817	26321	26295	24521	
Taxes															
State, 8%	795	950	1107	1266	1649	1723	1793	1871	1945	2013	2065	2106	2104	1962	
Federal, 46%	4190	5009	5839	6679	8704	9098	9466	9882	10273	10630	10908	11122	11111	10360	
Other Taxes, 1%	37	37	37	37	37	37	37	37	37	37	37	37	37	37	
Investment Tax Credit, 10%	319	319	319	319	319	319	319	319	319	319	319	319	319	319	
Total Taxes (-)	4704	5678	6664	7663	10070	10540	10976	11471	11936	12360	12692	12946	12932	12040	
Net Income From Operations	5238	6200	7174	8160	10536	11000	11431	11920	12378	12797	13125	13375	13362	12481	
Depreciation Expense (+)	10389	9283	8176	7070	3192	3192	3285	3291	3388	3594	4017	4626	5800	8755	
Net Cash Flow From Operations	15628	15483	15350	15230	13729	14192	14716	15211	15766	16391	17141	18001	19162	21236	
Working Capital Requirements	4544	4681	4821	4966	5115	5268	5426	5589	5757	5930	6107	6291	6479	6674	
Incremental Working Capital	-132	-136	-140	-145	-149	-153	-158	-163	-168	-173	-178	-183	-189	-194	3806
Total Net Cash Flows	12303	12154	12017	11893	10387	10846	11366	11856	12406	13026	13771	14626	15781	17849	3806

Net Present Value For Discount Rate = 5% is 80882
10% is 28743
12% is 15148
15% is -502

Internal Rate of Return is 14.89% 1

TABLE D-9 (CONT.)

DEPRECIATION SCHEDULE																							
Solar Portion of Plant	1800	2757	2632	2632	2632				169	248	237	237	237										
		1800	2757	2632	2632	2632																	
			1800	2757	2632	2632	2632																
				169	248	237	237	237		169	248	237	237	237									
					169	248	237	237	237		169	248	237	237	237								
						169	248	237	237	237		169	248	237	237	237							
							169	248	237	237	237		169	248	237	237	237						
								169	248	237	237	237		169	248	237	237	237					
															169	248	237	237	237				
																169	248	237	237	237			
																	169	248	237	237	237		
																		169	248	237	237	237	
																			169	248	237	237	237
																				282	282	282	282
																					376	376	376
																						564	564
																							1128
Total Depreciation Expense for Solar Solar Portion of Plant				5808	8688	8549	8785	9022	1128	1128	1128	1128	1128	1128	1128	1128	1128	1128	1128	1241	1368	1695	2586
Conventional Portion Of Plant	1149	2010	1723	1436	1436	1436	1292	1292	1292	1292				165	289	248	206	206	206	186	186	186	186
		1149	2010	1723	1436	1436	1436	1292	1292	1292	1292												
			1149	2010	1723	1436	1436	1436	1292	1292	1292	1292											
				165	289	248	206	206	206	186	186	186	186		165	289	248	206	206	206	186	186	372
					165	289	248	206	206	206	186	186	186	186		258	258	258	258	258	258	258	258
						165	289	248	206	206	206	186	186	186	186		295	295	295	295	295	295	295
							165	289	248	206	206	206	186	186	186	186		344	344	344	344	344	344
								165	289	248	206	206	206	186	186	186	186		413	413	413	413	413
									165	289	248	206	206	206	186	186	186	186		516	516	516	516
										165	289	248	206	206	206	186	186	186	186		688	688	688
											165	289	248	206	206	206	186	186	186	186		1032	1032
												165	289	248	206	206	206	186	186	186	186		2065
													165	289	248	206	206	206	186	186	186	186	
Total Depreciation Expense for Conventi nal Conventional Portion of Plant				3612	11081	10180	9381	9444	9507	9262	8155	7048	5942	2065	2065	2158	2163	2260	2466	2776	3258	4104	6169

TABLE D-9 (CONT.)

ANNUAL OPERATION AND MAINTENANCE EXPENSES (costs in thousands of dollars)

- Power Plant																				
Variable Costs																				
Fuel	240	247	254	262	270	278	286	295	304	313	322	332	342	352	363	374	385	396	408	421
Fixed Costs																				
Operating Labor (16 X $35,000)	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560	560
Maintenance Labor (10 X $35,000)	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350
Maintenance Materials and Contracts																				
Materials	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113
Contracts	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
Operating Consumables																				
Salt Replacement (5%/yr)	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59	59
Miscellaneous Supplies	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Total Fixed Costs	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134	1134
Total Power Plant O&M Costs	1374	1381	1388	1396	1404	1412	1420	1429	1438	1447	1456	1466	1476	1486	1497	1508	1519	1530	1542	1555
- Chemical Plant																				
Activated Carbon Production																				
Variable Costs																				
Raw Materials																				
Coal	2196	2262	2330	2400	2472	2546	2623	2701	2782	2866	2952	3040	3132	3226	3322	3422	3525	3630	3739	3852
Coal Tar Pitch	1846	1902	1959	2018	2078	2141	2205	2271	2339	2409	2482	2556	2633	2712	2793	2877	2963	3052	3144	3238
Phosphoric Acid (75%)	339	349	360	370	382	393	405	417	429	442	456	469	483	498	513	528	544	560	577	594
Hydrochloric Acid (30%)	151	155	160	165	170	175	180	185	191	197	203	209	215	221	228	235	242	249	257	264
Total Variable Costs	4533	4669	4809	4953	5102	5255	5412	5575	5742	5914	6092	6274	6463	6656	6854	7062	7274	7492	7717	7948
Fixed Costs																				
Operating Labor (33 personnel)	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186
Fringe Benefits (20% of labor)	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237
Maintenance Labor (3% of capital costs)	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158
Maintenance Materials and Contracts	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158	1158
Operating Supplies (10% of operating labor)	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Plant Overhead (80% of all labor)	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047
Total Fixed Costs	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905	5905
Total Production Costs - Activated Carbon	10438	10574	10714	10858	11007	11160	11318	11480	11647	11819	11997	12180	12368	12562	12761	12967	13179	13397	13622	13853
Regeneration of Spent Carbon																				
Operating Labor (5 personnel)	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214
Fringe Benefits (20% of operating labor)	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
Total Production Costs - Regenerated Carbon	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257
Total Chemical Plant O&M Costs	10695	10831	10971	11115	11264	11417	11574	11737	11904	12076	12254	12436	12625	12818	13018	13224	13436	13654	13879	14110

TABLE D-9 (CONT.)

PLANT PRODUCTION AND REVENUE PROJECTIONS (revenue in thousands of dollars)

		Unit cost																				
Activated Carbon (lbs)	- Production		24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000
	- Price	0.93	0.93	0.96	0.99	1.02	1.05	1.08	1.11	1.14	1.18	1.21	1.25	1.29	1.33	1.37	1.41	1.45	1.49	1.54	1.58	1.63
	- Revenue		23213	23909	24626	25365	26126	26910	27717	28549	29405	30287	31196	32132	33096	34089	35111	36165	37250	38367	39518	40704
Regenerated Carbon (lbs)	- Production		20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000
	- Price	0.35	0.35	0.36	0.37	0.38	0.39	0.41	0.42	0.43	0.44	0.46	0.47	0.48	0.50	0.51	0.53	0.55	0.56	0.58	0.60	0.61
	- Revenue		7000	7210	7426	7649	7879	8115	8358	8609	8867	9133	9407	9690	9980	10280	10588	10904	11233	11570	11917	12275
Synthetic Gas (MBtu)	- Production		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	- Price	3.30	3.30	3.40	3.50	3.61	3.71	3.83	3.94	4.06	4.18	4.31	4.43	4.57	4.71	4.85	4.99	5.14	5.30	5.45	5.62	5.79
	- Revenue		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electricity (kWh)	- Production		8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000	8500000
	- Price	0.06314	0.06314	0.06503	0.06699	0.06899	0.07106	0.07320	0.07539	0.07765	0.07998	0.08238	0.08485	0.08740	0.09002	0.09272	0.09550	0.09837	0.10132	0.10436	0.10749	0.11072
	- Revenue		537	553	569	586	604	622	641	660	680	700	721	743	765	788	812	836	861	887	914	941
By-product Tars (tons)	- Production		9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765
	- Price	99.00	99.00	101.97	105.03	108.18	111.43	114.77	118.21	121.76	125.41	129.17	133.05	137.04	141.15	145.38	149.75	154.24	158.87	163.63	168.54	173.60
	- Revenue		967	996	1026	1056	1088	1121	1154	1189	1225	1261	1299	1338	1378	1420	1462	1506	1551	1598	1646	1695
Product Selling Price and Fuel/Feedstock Cost Escalation Factor			1.000	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030

RAW MATERIALS AND FUEL (total costs in thousands of dollars)

Coal (tons)	Quantity	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920
	Unit Cost	44	45	47	48	50	51	53	54	56	57	59	61	63	65	67	69	71	73	75	77
	Total Cost	2196	2262	2330	2400	2472	2546	2623	2701	2782	2866	2952	3040	3132	3226	3322	3422	3525	3630	3739	3852
Coal Tar Pitch (tons)	Quantity	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545
	Unit Cost	333	343	353	364	375	386	398	410	422	434	448	461	475	489	504	519	534	550	567	584
	Total Cost	1846	1902	1959	2018	2078	2141	2205	2271	2339	2409	2482	2556	2633	2712	2793	2877	2963	3052	3144	3238
Phosphoric Acid (tons)	Quantity	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565
	Unit Cost	600	618	637	656	675	696	716	738	760	783	806	831	855	881	908	935	963	992	1021	1052
	Total Cost	339	349	360	370	382	393	405	417	429	442	456	469	483	498	513	528	544	560	577	594
Hydrochloric Acid (tons)	Quantity	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256
	Unit Cost	120	124	127	131	135	139	143	148	152	157	161	166	171	176	182	187	193	198	204	210
	Total Cost	151	155	160	165	170	175	180	185	191	197	203	209	215	221	228	235	242	249	257	264
Natural Gas (MBtu)	Quantity	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690	72690
	Unit Cost	3.30	3.40	3.50	3.61	3.71	3.83	3.94	4.06	4.18	4.31	4.43	4.57	4.71	4.85	4.99	5.14	5.30	5.45	5.62	5.79
	Total Cost	240	247	254	262	270	278	286	295	304	313	322	332	342	352	363	374	385	396	408	421

TABLE D-10

FINANCIAL ANALYSIS FOR NATURAL GAS PLANT

WITH 0% ESCALATION RATE

ECONO ECONOMIC ANALYSIS FOR SOLAR FUELS AND CHEMICALS SYSTEMS DESIGN STUDY

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Capital Expenditures												
Land	747	0	0									
Plant and Equipment	13410	13410	13410	2012	2012	2012	2012	2012	2012	2012	2012	2012
Revenues												
Activated Carbon				23213	23213	23213	23213	23213	23213	23213	23213	23213
Regenerated Carbon				7000	7000	7000	7000	7000	7000	7000	7000	7000
Sulfur				0	0	0	0	0	0	0	0	0
Tars and Oils				967	967	967	967	967	967	967	967	967
Total Revenue (+)				31180	31180	31180	31180	31180	31180	31180	31180	31180
Sales, General and Administrative Expense (-)				3742	3742	3742	3742	3742	3742	3742	3742	3742
Depreciation Expense (-)	0	0	0	3379	6075	5512	4908	5109	5310	5089	5270	5451
Operating Costs				11794	11794	11794	11794	11794	11794	11794	11794	11794
Income Before Tax				12265	9569	10133	10736	10535	10334	10555	10374	10193
Taxes												
State, 8%				981	766	811	859	843	827	844	830	815
Federal, 46%				5187	4046	4285	4540	4455	4370	4463	4387	4310
Other Taxes, 1%				7	7	7	7	7	7	7	7	7
Investment Tax Credit, 10%	1416	1341	1341	201	201	201	201	201	201	201	201	201
Total Taxes (-)				5975	4618	4902	5205	5104	5003	5114	5023	4932
Net Income From Operations				6290	4951	5231	5531	5431	5331	5441	5351	5261
Depreciation Expense (+)	0	0	0	3379	6075	5512	4908	5109	5310	5089	5270	5451
Net Cash Flow From Operations				9670	11026	10743	10439	10540	10641	10530	10621	10712
Working Capital Requirements				3742	3742	3742	3742	3742	3742	3742	3742	3742
Incremental Working Capital	-14157	-13410	-15281	-1871	0	0	0	0	0	0	0	0
Total Net Cash Flows	-12741	-12069	-13940	5787	9014	8731	8427	8529	8630	8518	8610	8701

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Capital Expenditures												
Land												
Plant and Equipment	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	
Revenues												
Activated Carbon	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	
Regenerated Carbon	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	
Sulfur	0	0	0	0	0	0	0	0	0	0	0	
Tars and Oils	967	967	967	967	967	967	967	967	967	967	967	
Total Revenue (+)	31180	31180	31180	31180	31180	31180	31180	31180	31180	31180	31180	
Sales, General and Administrative Expense (-)	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742	
Depreciation Expense (-)	5632	2012	2012	2102	2108	2202	2403	2705	3174	3999	6010	
Operating Costs	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	
Income Before Tax	10012	13633	13633	13542	13536	13443	13241	12940	12470	11646	9634	
Taxes												
State, 8%	801	1091	1091	1083	1083	1075	1059	1035	998	932	771	
Federal, 46%	4234	5766	5766	5728	5725	5685	5600	5473	5274	4925	4074	
Other Taxes, 1%	7	7	7	7	7	7	7	7	7	7	7	
Investment Tax Credit, 10%	201	201	201	201	201	201	201	201	201	201	201	
Total Taxes (-)	4841	6663	6663	6617	6614	6567	6466	6314	6078	5663	4651	
Net Income From Operations	5171	6970	6970	6925	6922	6875	6775	6626	6392	5983	4983	
Depreciation Expense (+)	5632	2012	2012	2102	2108	2202	2403	2705	3174	3999	6010	
Net Cash Flow From Operations	10803	8981	8981	9027	9030	9077	9178	9330	9564	9981	10993	
Working Capital Requirements	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742	
Incremental Working Capital	0	0	0	0	0	0	0	0	0	0	0	3742
Total Net Cash Flows	8792	6970	6970	7015	7018	7066	7167	7319	7555	7970	8982	3742

Net Present Value For Discount Rate = 5% is 61540
10% is 29151
12% is 20885
15% is 11259

Internal Rate of Return is 20.07% 1

TABLE D-10 (CONT.)

DEPRECIATION SCHEDULE	1073	1877	1609	1341	1341	1341	1207	1207	1207	1207													
		1073	1877	1609	1341	1341	1341	1207	1207	1207	1207												
			1073	1877	1609	1341	1341	1341	1207	1207	1207	1207											
														161	282	241	201	201	201	181	181	181	181
				161	282	241	201	201	201	181	181	181	181		161	282	241	201	201	201	181	181	342
					161	282	241	201	201	201	181	181	181	181		251	251	251	251	251	251	251	251
						161	282	241	201	201	201	181	181	181	181		287	287	287	287	287	287	287
							161	282	241	201	201	201	181	181	181	181		335	335	335	335	335	335
								161	282	241	201	201	201	181	181	181	181		402	402	402	402	402
									161	282	241	201	201	201	181	181	181	181		503	503	503	503
										161	282	241	201	201	201	181	181	181	181		671	671	671
											161	282	241	201	201	201	181	181	181	181		1006	1006
												161	282	241	201	201	201	181	181	181	181		2012
													161	282	241	201	201	201	181	181	181	181	
Total Depreciation Expense Portion of Plant				3379	6075	5512	4908	5109	5310	5089	5270	5451	5632	2012	2012	2102	2108	2202	2403	2705	3174	3999	6010

ANNUAL OPERATION AND MAINTENANCE EXPENSES (costs in thousands of dollars)

- Chemical Plant																				
Activated Carbon Production																				
Variable Costs																				
Raw Materials																				
Coal	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196
Coal Tar Pitch	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846
Phosphoric Acid (75%)	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339
Hydrochloric Acid (30%)	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151
Natural Gas	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95
Electricity	868	868	868	868	868	868	868	868	868	868	868	868	868	868	868	868	868	868	868	868
Total Variable Costs	5496	5496	5496	5496	5496	5496	5496	5496	5496	5496	5496	5496	5496	5496	5496	5496	5496	5496	5496	5496
Fixed Costs																				
Operating Labor (33 personnel)	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186
Fringe Benefits (20% of labor)	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237
Maintenance Labor (3% of capital costs)	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207
Maintenance Materials and Contracts	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207
Operating Supplies (10% of operating labor)	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Plant Overhead (80% of all labor)	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086
Total Fixed Costs	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041
Total Production Costs - Activated Carbon	11537	11537	11537	11537	11537	11537	11537	11537	11537	11537	11537	11537	11537	11537	11537	11537	11537	11537	11537	11537
Regeneration of Spent Carbon																				
Operating Labor (5 personnel)	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214
Fringe Benefits (20% of operating labor)	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
Total Production Costs - Regenerated Carbon	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257
Total Chemical Plant O&M Costs	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794

TABLE D-10 (CONT.)

PLANT PRODUCTION AND REVENUE PROJECTIONS (revenue in thousands of dollars)

		Unit cost																				
Activated Carbon (lbs)	- Production		24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000
	- Price	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	- Revenue		23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213	23213
Regenerated Carbon (lbs)	- Production		20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000
	- Price	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	- Revenue		7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000	7000
Synthetic Gas (MBtu)	- Production		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	- Price	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
	- Revenue		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
By-product Tars (tons)	- Production		9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765
	- Price	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00	99.00
	- Revenue		967	967	967	967	967	967	967	967	967	967	967	967	967	967	967	967	967	967	967	967
Product Selling Price and Fuel/Feedstock Cost Escalation Factor			1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

RAW MATERIALS AND FUEL (total costs in thousands of dollars)

Coal (tons)	Quantity	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920
	Unit Cost	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
	Total Cost	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196	2196
Coal Tar Pitch (tons)	Quantity	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545
	Unit Cost	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333	333
	Total Cost	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846	1846
Phosphoric Acid (tons)	Quantity	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565	565
	Unit Cost	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600	600
	Total Cost	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339
Hydrochloric Acid (tons)	Quantity	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256
	Unit Cost	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
	Total Cost	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151
Natural Gas (MBtu)	Quantity	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900
	Unit Cost	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
	Total Cost	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95
Electricity (kWh)	Quantity	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000
	Unit Cost	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500	0.08500
	Total Cost	868	868	868	868	868	868	868	868	868	868	868	868	868	868	868	868	868	868	868	868

TABLE D-11

FINANCIAL ANALYSIS FOR NATURAL GAS PLANT

WITH 3% ESCALATION RATE

ECONOMIC ANALYSIS FOR SOLAR FUELS AND CHEMICALS SYSTEMS DESIGN STUDY

	1992	1993	1994	1995	1996	1997	1998	1999	2000
Capital Expenditures									
Land	747	0	0						
Plant and Equipment	13410	13410	13410	2012	2012	2012	2012	2012	2012
Revenues									
Activated Carbon				23213	23909	24626	25365	26126	26910
Regenerated Carbon				7000	7210	7426	7649	7879	8115
Sulfur				0	0	0	0	0	0
Tars and Oils				967	996	1026	1056	1088	1121
Total Revenue (+)				31180	32115	33078	34071	35093	36146
Sales, General and Administrative Expense (-)				3742	3854	3969	4088	4211	4337
Depreciation Expense (-)	0	0	0	3379	6075	5512	4908	5109	5310
Operating Costs				11794	11959	12129	12303	12484	12669
Income Before Tax				12265	10228	11469	12771	13289	13829
Taxes									
State, 8%				981	818	918	1022	1063	1106
Federal, 46%				5187	4325	4850	5401	5620	5849
Other Taxes, 1%				7	7	7	7	7	7
Investment Tax Credit, 10%	1416	1341	1341	201	201	201	201	201	201
Total Taxes (-)				5975	4949	5574	6229	6490	6761
Net Income From Operations				6290	5278	5895	6542	6799	7067
Depreciation Expense (+)	0	0	0	3379	6075	5512	4908	5109	5310
Net Cash Flow From Operations				9670	11353	11406	11450	11908	12378
Working Capital Requirements				3742	3854	3969	4088	4211	4337
Incremental Working Capital	-14157	-13410	-15281	-1071	-112	-116	-119	-123	-126
Total Net Cash Flows	-12741	-12069	-13940	5707	9229	9279	9319	9774	10240

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Capital Expenditures															
Land															
Plant and Equipment	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	
Revenues															
Activated Carbon	27717	28549	29405	30287	31196	32132	33096	34089	35111	36165	37250	38367	39518	40704	
Regenerated Carbon	8350	8609	8867	9133	9407	9690	9980	10280	10588	10906	11233	11570	11917	12275	
Sulfur	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Tars and Oils	1154	1189	1225	1261	1299	1338	1378	1420	1462	1506	1551	1598	1646	1695	
Total Revenue (+)	37230	38347	39497	40682	41903	43160	44455	45788	47162	48577	50034	51535	53081	54674	
Sales, General and Administrative Expense (-)	4468	4602	4740	4882	5028	5179	5335	5495	5659	5829	6004	6184	6370	6561	
Depreciation Expense (-)	5089	5270	5451	5632	2012	2012	2102	2108	2202	2403	2705	3174	3999	6010	
Operating Costs	12840	13057	13260	13469	13684	13906	14134	14369	14611	14860	15117	15382	15654	15935	
Income Before Tax	14813	15418	16046	16699	21179	22064	22884	23817	24690	25484	26208	26795	27058	26168	
Taxes															
State, 8%	1185	1233	1284	1336	1694	1765	1831	1905	1975	2039	2097	2144	2165	2093	
Federal, 46%	6265	6521	6787	7064	8959	9334	9681	10076	10445	10782	11088	11336	11448	11071	
Other Taxes, 1%	7	7	7	7	7	7	7	7	7	7	7	7	7	7	
Investment Tax Credit, 10%	201	201	201	201	201	201	201	201	201	201	201	201	201	201	
Total Taxes (-)	7257	7561	7877	8206	10460	10905	11318	11788	12227	12627	12991	13286	13419	12970	
Net Income From Operations	7556	7857	8169	8493	10719	11158	11566	12029	12463	12858	13217	13509	13640	13197	
Depreciation Expense (+)	5089	5270	5451	5632	2012	2012	2102	2108	2202	2403	2705	3174	3999	6010	
Net Cash Flow From Operations	12645	13127	13620	14126	12730	13170	13668	14137	14665	15261	15922	16683	17638	19207	
Working Capital Requirements	4468	4602	4740	4882	5028	5179	5335	5495	5659	5829	6004	6184	6370	6561	
Incremental Working Capital	-130	-134	-138	-142	-146	-151	-155	-160	-165	-170	-175	-180	-186	-191	3742
Total Net Cash Flows	10504	10981	11471	11972	10572	11007	11501	11966	12488	13079	13735	14491	15441	17005	3742

Net Present Value For Discount Rate = 5% is 90085
10% is 49225
12% is 37018
15% is 23129
Internal Rate of Return is 23.66% 0

TABLE D-11 (CONT.)

DEPRECIATION SCHEDULE	1073	1877	1609	1341	1341	1341	1207	1207	1207	1207													
		1073	1877	1609	1341	1341	1341	1207	1207	1207	1207												
			1073	1877	1609	1341	1341	1341	1207	1207	1207	1207											
														161	282	241	201	201	201	181	181	181	181
				161	282	241	201	201	201	181	181	181	181		161	282	241	201	201	201	181	181	362
					161	282	241	201	201	201	181	181	181	181		251	251	251	251	251	251	251	251
						161	282	241	201	201	201	181	181	181	181		287	287	287	287	287	287	287
							161	282	241	201	201	201	181	181	181	181		335	335	335	335	335	335
								161	282	241	201	201	201	181	181	181	181		402	402	402	402	402
									161	282	241	201	201	201	181	181	181	181		503	503	503	503
										161	282	241	201	201	201	181	181	181	181		671	671	671
											161	282	241	201	201	201	181	181	181	181		1006	1006
												161	282	241	201	201	201	181	181	181	181		2012
													161	282	241	201	201	201	181	181	181	181	
Total Depreciation Expense Portion of Plant				3379	6075	5512	4908	5109	5310	5089	5270	5451	5632	2012	2012	2102	2108	2202	2403	2705	3174	3999	6010
ANNUAL OPERATION AND MAINTENANCE EXPENSES (costs in thousands of dollars)																							
- Chemical Plant																							
Activated Carbon Production																							
Variable Costs																							
Raw Materials																							
Coal				2196	2262	2330	2400	2472	2546	2623	2701	2782	2866	2952	3040	3132	3226	3322	3422	3525	3630	3739	3852
Coal Tar Pitch				1846	1902	1959	2018	2078	2141	2205	2271	2339	2409	2482	2556	2633	2712	2793	2877	2963	3052	3144	3238
Phosphoric Acid (75%)				339	349	360	370	382	393	405	417	429	442	456	469	483	498	513	528	544	560	577	594
Hydrochloric Acid (30%)				151	155	160	165	170	175	180	185	191	197	203	209	215	221	228	235	242	249	257	264
Natural Gas				95	98	101	104	107	111	114	117	121	124	128	132	136	140	144	149	153	158	162	167
Electricity				868	894	921	948	977	1006	1036	1067	1099	1132	1166	1201	1237	1274	1313	1352	1393	1434	1477	1522
Total Variable Costs				5496	5661	5831	6006	6186	6371	6562	6759	6962	7171	7386	7608	7836	8071	8313	8562	8819	9084	9356	9637
Fixed Costs																							
Operating Labor (33 personnel)				1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186	1186
Fringe Benefits (20% of labor)				237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237	237
Maintenance Labor (3% of capital costs)				1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207
Maintenance Materials and Contracts				1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207	1207
Operating Supplies (10% of operating labor)				119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119	119
Plant Overhead (80% of all labor)				2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086	2086
Total Fixed Costs				6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041	6041
Total Production Costs - Activated Carbon				11537	11702	11872	12047	12227	12412	12604	12800	13003	13212	13427	13649	13877	14112	14354	14604	14860	15125	15398	15678
Regeneration of Spent Carbon																							
Operating Labor (5 personnel)				214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214	214
Fringe Benefits (20% of operating labor)				43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
Total Production Costs - Regenerated Carbon				257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257	257
Total Chemical Plant O&M Costs				11794	11959	12129	12303	12484	12669	12860	13057	13260	13469	13684	13904	14134	14369	14611	14860	15117	15382	15654	15935

TABLE D-11 (CONT.)

PLANT PRODUCTION AND REVENUE PROJECTIONS (revenue in thousands of dollars)

		Unit cost						
Activated Carbon (lbs)	- Production		24960000	24960000	24960000	24960000	24960000	24960000
	- Price	0.93	0.93	0.96	0.99	1.02	1.05	1.08
	- Revenue		23213	23909	24626	25365	26124	26910
Regenerated Carbon (lbs)	- Production		20000000	20000000	20000000	20000000	20000000	20000000
	- Price	0.35	0.35	0.36	0.37	0.38	0.39	0.41
	- Revenue		7000	7210	7426	7649	7879	8115
Synthetic Gas (MBtu)	- Production		0	0	0	0	0	0
	- Price	3.30	3.30	3.40	3.50	3.61	3.71	3.83
	- Revenue		0	0	0	0	0	0
By-product Tars (tons)	- Production		9765	9765	9765	9765	9765	9765
	- Price	99.00	99.00	101.97	105.03	108.18	111.43	114.77
	- Revenue		967	996	1026	1056	1088	1121
Product Selling Price and Fuel/Feedstock Cost Escalation Factor			1.000	1.030	1.030	1.030	1.030	1.030

Activated Carbon (lbs)	- Production	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000	24960000
	- Price	1.11	1.14	1.18	1.21	1.25	1.29	1.33	1.37	1.41	1.45	1.49	1.54	1.58	1.63
	- Revenue	27717	28549	29405	30287	31196	32132	33096	34089	35111	36165	37250	38367	39518	40704
Regenerated Carbon (lbs)	- Production	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000	20000000
	- Price	0.42	0.43	0.44	0.46	0.47	0.48	0.50	0.51	0.53	0.55	0.56	0.58	0.60	0.61
	- Revenue	8358	8609	8867	9133	9407	9690	9980	10280	10588	10906	11233	11570	11917	12275
Synthetic Gas (MBtu)	- Production	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	- Price	3.94	4.06	4.18	4.31	4.43	4.57	4.71	4.85	4.99	5.14	5.30	5.45	5.62	5.79
	- Revenue	0	0	0	0	0	0	0	0	0	0	0	0	0	0
By-product Tars (tons)	- Production	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765	9765
	- Price	118.21	121.76	125.41	129.17	133.05	137.04	141.15	145.38	149.75	154.24	158.87	163.63	168.54	173.60
	- Revenue	1154	1189	1225	1261	1299	1338	1378	1420	1462	1506	1551	1598	1646	1695
Product Selling Price and Fuel/Feedstock Cost Escalation Factor		1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030

RAW MATERIALS AND FUEL (total costs in thousands of dollars)

Coal (tons)	Quantity	49920	49920	49920	49920	49920	49920
	Unit Cost	44	45	47	48	50	51
	Total Cost	2196	2262	2330	2400	2472	2546
Coal Tar Pitch (tons)	Quantity	5545	5545	5545	5545	5545	5545
	Unit Cost	333	343	353	364	375	386
	Total Cost	1846	1902	1959	2018	2078	2141
Phosphoric Acid (tons)	Quantity	565	565	565	565	565	565
	Unit Cost	600	618	637	656	675	696
	Total Cost	339	349	360	370	382	393
Hydrochloric Acid (tons)	Quantity	1256	1256	1256	1256	1256	1256
	Unit Cost	120	124	127	131	135	139
	Total Cost	151	155	160	165	170	175
Natural Gas (MBtu)	Quantity	28900	28900	28900	28900	28900	28900
	Unit Cost	3.30	3.40	3.50	3.61	3.71	3.83
	Total Cost	95	98	101	104	107	111
Electricity (kWh)	Quantity	10210000	10210000	10210000	10210000	10210000	10210000
	Unit Cost	0.08500	0.08755	0.09018	0.09288	0.09567	0.09854
	Total Cost	868	894	921	948	977	1006

Coal (tons)	Quantity	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920	49920
	Unit Cost	53	54	56	57	59	61	63	65	67	69	71	73	75	77
	Total Cost	2623	2701	2782	2866	2952	3040	3132	3226	3322	3422	3525	3630	3739	3852
Coal Tar Pitch (tons)	Quantity	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545	5545
	Unit Cost	398	410	422	434	448	461	475	489	504	519	534	550	567	584
	Total Cost	2205	2271	2339	2409	2482	2556	2633	2712	2793	2877	2963	3052	3144	3238
Phosphoric Acid (tons)	Quantity	565	565	565	565	565	565	565	565	565	565	565	565	565	565
	Unit Cost	716	738	760	783	806	831	855	881	908	935	963	992	1021	1052
	Total Cost	405	417	429	442	456	469	483	498	513	528	544	560	577	594
Hydrochloric Acid (tons)	Quantity	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256	1256
	Unit Cost	143	148	152	157	161	166	171	176	182	187	193	198	204	210
	Total Cost	180	185	191	197	203	209	215	221	228	235	242	249	257	264
Natural Gas (MBtu)	Quantity	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900	28900
	Unit Cost	3.94	4.06	4.18	4.31	4.43	4.57	4.71	4.85	4.99	5.14	5.30	5.45	5.62	5.79
	Total Cost	114	117	121	124	128	132	136	140	144	149	153	158	162	167
Electricity (kWh)	Quantity	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000	10210000
	Unit Cost	0.10149	0.10454	0.10768	0.11091	0.11423	0.11766	0.12119	0.12483	0.12857	0.13243	0.13640	0.14049	0.14471	0.14905
	Total Cost	1036	1067	1099	1132	1166	1201	1237	1274	1313	1352	1393	1434	1477	1522

TABLE D-12

COSTS FOR COMPARISON TO FIVE YEAR R&D PLAN 1986-1990

Plant Rating - 35,000 kWt
Heliostat Field - 76,000 M^2
Storage Capacity - 84,000 kWh_t

Component	Account No.	Cost	Unit Cost
Concentrators	2.1	$4,603,000	$ 60/M^2
Receiver	2.2	$5,954,000	$ 78/M^2
Transport	2.3	$7,777,950	$102/$M^2$
Storage	2.4	$2,636,819	$ 31/kWh_t
Conversion	2.6	$ 400,000	
	5.1.2.3	$ 191,900	
	5.2.2.3	$1,147,800	
	5.4.2.3	$ 319,700	
		$2,059,400	$ 59/kW_t
Balance of Plant	1.1.1	$ 838,700	
	1.1.9	$ 20,000	
	1.3	$ 546,000	
	2.5.1	$3,314,200	
	2.5.2	$1,085,000	
		$5,803,900	$ 76/M^2
System	0	$3,735,200	
	9	$5,767,000	
	+ Total Direct	$28,835,000	
Total System Costs		$38,340,000	$1095/$kW_t$

APPENDIX E

USES AND APPLICATIONS FOR ACTIVATED CARBON

APPENDIX E

USES AND APPLICATIONS FOR ACTIVATED CARBON

A. LIQUID PHASE APPLICATIONS

Sugar Decolorizing

Activated carbon is used as a decolorizing agent in the refining process for cane and beet sugars, as well as in the purification of corn sweeteners. Collectively, these decolorizing applications currently represent the largest single market for activated carbon.

Cane and Beet Sugar - Several processes for decolorizing cane sugar have been developed that have a potentially strong impact on the demand for activated carbon by the sugar refining industry. These processes either significantly reduce or totally eliminate the role that activated carbon has in sugar decolorizing.

One of the methods is the Talofloc process, developed and licensed by the English firm of Tate and Lyle, which can totally eliminate the need for an activated carbon decolorizing agent in sugarcane decolorizing. The small capital cost of this process is particularly attractive; it is estimated to cost only 10% of conventional carbon systems. Also, no regeneration facilities are required, thus the high costs of energy required for regeneration and the associated regulatory problems are avoided.

Another competitive process is based on ion exchange resins, which selectively remove color bodies. One disadvantage of ion exchange resins is the exclusive selection of specific ionic bodies. If a wide spectrum of ionic bodies is present, effective removal is reduced.

The main causes for declining demand of activated carbon for cane and beet sugar refining are the decreasing consumption of cane and beet sugar and the increase in alternative decolorization processes. The declining sugar consumption is partially attributed to the availability of lower-priced high-fructose corn syrup (HFCS). Declining annual consumption is forecast for activated carbon use in cane and beet sugar through 1988.

Corn Syrups - The overall use of activated carbon in corn sweetener processing (as in cane and beet sugar processing) is estimated to have changed little over the past few years. Some industry sources believe that the major growth for activated carbon in corn sweetener processing has already occurred (most regeneration facilities are in place) and that the use of powdered activated carbon will decrease through 1988, due to continuing changeover from 100% virgin carbon use to on-site regeneration of powdered carbon. It is very difficult to predict the actual annual consumption of activated carbon in HFCS applications because of the unknown factors prevalent in new regeneration facilities. Whether or not they run successfully has a major impact on activated carbon consumption.

Drinking Water

Taste and Odor Control - Activated carbon, particularly powdered activated carbon, has been used for many years to adsorb compounds causing an unpleasant taste and odor sometimes found in drinking water systems. It is estimated that over 50 utilities currently use granular activated carbon for taste and odor control, and a high percentage of these use the granular carbon as a combined filtration-adsorption medium.

In addition to its major use in municipal potable water treatment, activated carbon (granular) is used in special filters and in disposable cartridges for the removal of taste and odor-causing organics and residual chlorine in industrial, commercial, and residential installations. For residential markets, the activated carbon is often impregnated with appropriate chemicals to inhibit the growth of bacteria on the carbon.

Organic Compounds - Considerable attention has been given to reports of potentially hazardous organic compounds in the water supplies of many of the nation's largest communities. In particular, trihalomethanes (THMs) such as chloroform, which is a suspected carcinogen, are formed from the interaction of chlorine with natural organic materials found in water. While many organic chemicals can undergo this reaction, it is believed that naturally occurring products (primarily humic acids) that enter the water supply are important precursors for trihalomethane formation.

Both ozonization and chlorine dioxide treatments are considerably less expensive than carbon adsorption as a method for reducing trihalomethane or chloroform from drinking water systems. Effective removal of chloroform precursors (or the organic contaminants) requires much higher levels of activated carbon treatment than would ordinarily be used for taste and odor control. Treatment costs, therefore, which include provisions for carbon regeneration, would be significant.

Interest in granular activated carbon (GAC) was at its highest in the late 1970's because of the anticipated market potential for drinking water treatment resulting from proposed EPA regulations. However the anticipated market for GAC through the proposed EPA rulings did not materialize. As a result, a market once throught to be ripe for explosive growth of activated carbon consumption has been downgraded to one with an approximate 3% annual rate through 1988.

Groundwater

Groundwater contamination has become a matter of increasing concern to federal and state governments as well as to the public, especially within the last five years.

Public drinking water accounts for about 14% of groundwater use in the United States, agricultural uses for 67%, water for rural households and livestock for 6% and self-supplied industrial water for the remaining 13%. Groundwater is a major source of drinking water in the United States; approximately 50% of U.S. drinking water is from the ground.

The major causes of groundwater contamination are haphazard and improper waste disposal, chemical spills, and leachates from lagoons and dumpsites. The method of treatment depends on the contaminant as well as the final use of the groundwater. The typical way to purify groundwater is to remove the source of contamination. Once the source has been eliminated - assuming that is possible - the water is usually pumped out, treated, and returned to the ground.

Of the two techniques currently in use to clarify groundwater from organic contaminants, air stripping (aeration) is less expensive than GAC treatment in fixed or moving bed units. However, in some cases, the air must be purified with GAC after stripping. Also, GAC is more effective than aeration for nonvolatile organics, and conversely aeration is commonly used for removal of volatile organics.

The current consumption of GAC for groundwater treatment for all uses (except drinking water) is estimated at 4-5 million pounds. High growth is anticipated for GAC, but from this very low base. Some industry sources, however, believe the growth will be very high. Certain areas of the country such as "Silicon Valley" in northern California are showing high interest in the treatment of groundwater contamination. Another site that offers a potential market for GAC under the EPA Superfund Fund is the Santa Ana Watershed Project in Riverside, California (in the Los Angeles basin). To clean up this site, a total of about 2-4 million pounds will be needed beginning in 1985. As more hazardous sites are decontaminated, good growth for GAC can be expected through 1988.

Wastewater Treatment

Wastewater treatment generally involves one or more processes that remove suspended particulate matter, precipitate and remove inorganic compounds, remove organic compounds, and disinfect to destroy microorganisms.

Basically, there are three major types of carbon adsorption systems appropriate for wastewater treatment: 1) tertiary activated carbon treatments in sequence with primary and secondary (biological) processes, 2) independent physical-chemical activated carbon treatment (IPC) with various pretreatments (but no secondary biological treatment), and 3) combined biological/activated carbon treatment, in which carbon is added to biological aeration tanks. A number of other wastewater treatment processes using granular or powdered carbon adsorption have also been demonstrated. The choice of an appropriate carbon treatment depends on the nature and contaminant loading of the raw wastewater, the scale of operation, the specific federal or local requirements for effluent quality, and the economic and technical trade-offs among the available treatment techniques, including carbon regeneration.

Municipal Wastewater - Activated carbon demand for municipal wastewater treatment is defined primarily by the requirements of the operating tertiary and IPC municipal treatment plants and by the initial fill requirements of plants that will be operating shortly. These plants use GAC, with provisions for on-site regeneration. After the initial fill requirements are met, consumption levels are on a make-up basis and depend on losses incurred during regeneration (commonly 5-10% per regeneration cycle).

The use of activated carbon to treat municipal wastewater currently faces an uncertain future. One of the primary concerns of current activated carbon operators is the relatively high cost of operating and maintaining such treatment plants. As concluded in a recent EPA study, another problem has been inadequate process and design of some carbon treatment plants. The current trend in municipal wastewater treatment seems to be toward less costly processes without carbon. Requests for federal or state funding for tertiary activated carbon systems are now being very closely reviewed before grants are made.

While demand for activated carbon appears to be declining, there are several factors that could renew the growth of demand. Probably the most important consideration is the potential increased demand for water, especially in heavily developed regions, and the increase in reuse of water. Heavier burdens will be placed on water utility districts to treat and supply quality water from impure sources. Currently, the most widespread treatment technology in the United States uses activated carbon.

Industrial Wastewater - In industrial wastewater treatment, activated carbon adsorption processes are used to remove hazardous material, upgrade water for reuse, provide the level of effluent quality required for discharge into waterways, or pretreat effluents prior to discharge into municipal treatment plants. Depending on the precise nature of the waste stream and the required effluent quality, carbon adsorption may be used as the only treatment process before biological treatment in order to remove materials that could inhibit the process, or after biological treatment as a tertiary or polishing step.

Many industrial activated carbon treatment facilities are contracted on a service basis, where the responsibility for installing the appropriate system, establishing operational standards, testing, regenerating the carbon, and maintaining effluent quality is assumed by the adsorption service vendor. These systems are often most appropriate for point-of-origin treatment in which waste stream volume is relatively low and the contamination level is high. For large wastewater treatment facilities, activated carbon systems and on-site regeneration facilities are commonly operated directly by the user.

Mining and Mineral Processing

The mining industry has traditionally been a small consumer of activated carbon. High-grade ores usually produced sufficient yield using traditional methods. However, with the increased use of low-grade ores and the increased value of minerals such as gold and silver, old techniques are being modified and new techniques are being developed to maximize yield while minimizing cost. Since activated carbon has proved to be cost-effective in improving process yields, its use by the mining and mineral processing industry has increased with the usage of low-grade ores. Currently, there are at least five applications of activated carbon:

Water treatment

Metallic ion adsorption

Catalyst

Adsorption of excess reagents

Adsorption of natural organic contaminants

The consumption of carbon in 1983 by the mining and mineral processing industries is estimated to have been 7 million pounds, a large percentage of it being powdered activated carbon (PAC). Since granular carbon is more readily applied to continuous operations, the demand for granular carbon is expected to grow faster than for powdered carbon. An annual growth rate of 3% per year for activated carbon is anticipated for the period of 1983 through 1988 for mining uses.

Pharmaceuticals

Pharmaceutical applications of activated carbon include four principal uses:

Extraction of the product from fermentation broths (e.g., antibiotics, vitamins, steroids, etc.); the adsorbed biochemical product is recovered from the carbon by solvent extraction followed by distillation.

Purification of process water used in the pharmaceutical plant.

Removal of impurities from solutions of the product, or an intermediate, by adsorption.

Purification of liquid products, such as intravaneous solutions.

These applications are estimated to have consumed about 9 million pounds of activated carbon in 1983. Demand is expected to grow slowly at 2.5% annually for the next five years. As with foods, the FDA has legal responsibility for operations in the drug industry that include activated carbon. Since the pharmaceutical industry must meet extremely stringent quality and purity requirements almost all of the activated carbon needs are filled by virgin carbon.

The recent developments in genetic engineering may also stimulate demand for activated carbon. As genetically improved microbes increase the number and volume of drugs and chemicals produced by fermentation, the use of activated carbon for their extraction should grow.

Food Processing and Fats and Oils

Activated carbon, in either powder or granular form, is commonly used in the food processing and fats and oils industries to remove color or odor-causing contaminants from product streams or feed streams. Typical applications include:

Upgrading the quality of feedwater by removing (by adsorption) chlorine, humic acids, and other potentially harmful substances. Typical industries that treat feedwater include vegetable and fruit canneries.

Purification of cooking oils, mayonnaise, gelatines and pectins, monosodium glutamate, and vinegars by passing them through activated carbon beds to remove color or taste impurities.

Fats and oils, such as soybean oil, sunflower seed oil, corn oil, and animal shortening must be treated to remove color and odor-causing contaminants. Activated carbon, usually in powder form, is used alone or with such materials as activated clay.

Demand is estimated at about 3 million pounds for carbon in nonedible products. Total consumption for food processing and fats and oils is estimated to have been 7 million pounds in 1983, with a forecast growth of 2.0% annually from 1983 through 1988.

Beverages

Typical applications of activated carbon in beverages include filtration of beer and wine before bottling to remove colloidal material that appears as "haze" in the chilled product. Competitive technology uses enzymes or tannic acid to accomplish haze control.

Activated carbon is used to remove traces of taste and odor from vodka. Carbon is also used to remove fusel oil from whiskey. Total carbon usage is only about three million pounds per year in all beverage treatment, and low growth is anticipated for the next five years for this application.

Dry Cleaning

Activated carbon is used to remove dyes and other impurities from perchloroethylene and other hydrocarbon dry-cleaning solvents. The solvents are cleaned by treatment with powdered carbon or, more frequently, granular carbon packed in disposable filter cartridges.

Cartridge filters can combine a fibrous material (to remove particulate matter) and activated carbon (to remove chemical contaminants). All-carbon cartridges can be added to supplement cleaning.

Demand for activated carbon is expected to exhibit little growth due to the increasing popularity of wash-and-wear fabrics. Consumption of activated carbon for dry solvent purification in 1983 is estimated to have been 4 million pounds. Little change is expected by 1988.

Electroplating

Activated carbon is used to remove organic contaminants from electroplating baths (typically nickel-plating baths) that would detract from the visual surface quality of the plate. Demand for activated carbon in electrobath reconditioning is estimated to have been 3 million pounds in 1980, unchanged from 1976. Little change is expected by 1988.

Household Uses

Activated carbon is used for home water taps in drinking water purification, for home oven hoods, and for aquariums. The total consumption for all household uses is estimated to have been 5 million pounds in 1983; relatively slow growth is anticipated for this application.

Miscellaneous

Miscellaneous liquid-phase applications for activated carbon include shoe innersole deodorizers; platicizer decolorizers; decoloration and purification of phosphoric acids and various organic acids, alum, and dyestuffs; blood detoxification, and others. Demand for activated carbon in miscellaneous applications is estimated to have been 15 million pounds in 1983. By 1988, demand is expected to grow slightly, totaling 16 million pounds.

B. GAS PHASE APPLICATIONS

Gas phase applications require grades of mostly granular activated carbon with small pores to maximize adsorptive capacity.

Automotive Evaporation Control Systems

Beginning in 1970, all new U.S. produced automobiles were equipped with an evaporation control system (ECS), which includes a cartridge of activated carbon. The system is designed to prevent air pollution from evaporation of gasoline from automobile engines and fuel tanks while the engines are not being operated. Gasoline vapors are conducted from the carburetor and the fuel tank to the activated carbon filter whenever the engine is turned off. They are largely adsorbed by the carbon there. When the engine is started, the hot gases from the engine are used to desorb and burn the gasoline from the carbon filter.

Such systems are still used, although the decrease in average car size and (until very recently) the stagnation in the number of autos produced in the United States have limited activated carbon consumption in recent years. In 1983, estimated sales of carbon for the ECS market were 8 million pounds; this volume is forecast to increase to 9 million pounds in 1988.

Cigarettes

The use of activated carbon as a filtering medium in cigarettes is declining steadily. Used at 40-100 milligrams per cigarette, activated carbon functions principally to filter the gaseous products of the cigarette, rather than the tars or nicotine.

As the sales of the charcoal-filtered brands continue to shrink, the volume of activated carbon in cigarettes is expected to decline from approximately 2 million pounds in 1983 to one million pounds in 1988.

Solvent Vapor Recovery

Continued pressures to reduce organic solvent emissions in to the atmosphere and large increases in organic solvent costs have combined to generate substantial use of activated carbon columns in solvent-using industries. These industries include solvent coaters, solvent manufacturers, chemical manufacturers, printing firms, paint and coatings manufacturers and users, the computer industry, the automotive industry, and numerous others. Organic solvents such as alcohols, chlorinated hydrocarbons, esters, ethers, ketones, hydrocarbons, and aromatics are all recovered with activated carbon columns.

While techniques such as condensing or scrubbing are sometimes less expensive than carbon adsorption, they frequently cannot reduce the level of solvent vapors in the effluent air stream to acceptably low levels.

Incineration of solvent fumes is effective in this respect, but the recovery value of the solvent is lost, with the exception of its heat value, which may or may not be usable in the plant situation involved.

Carbon adsorption of industrial solvent vapors is accomplished most commonly with a combination of at least two beds or columns. One bed remains online while the other is being regenerated. The solvent-laden gas flow may be downward or upward through a carbon column to minimize the entrainment of carbon particles in the purified exhaust air. The regeneration of such beds consists of sweeping the loaded bed with steam or an absorbent gas, such as nitrogen or carbon dioxide. The removed solvent vapor is then condensed and separated from the water or adsorbing fluid by distillation or decantation.

Annual U.S. consumption of activated carbon for solvent recovery is estimated to have been 9 million pounds in 1983. Virtually all of this material was pelleted, granular, beaded, or fibrous in form. Continued environmental pressure, including lowered emission levels for many solvents, is expected to increase this market for activated carbon to 18 million pounds per year by 1988, an annual growth of approximately 15%. Several industry sources, however, feel that this growth will be slower, since a surge of regulations has been passed and petroleum prices are much lower now than in the mid-and late 1970s.

Air Purification

Air purification applications require pore sizes of activated carbon with diameters less than 25 Angstroms and a high available surface area. Reportedly, cocunut-based activated carbon is especially suited for these applications.

The total consumption of activated carbon for all air purification applications is estimated at 10 million pounds. A growth rate of 8% annually is forecast for all air purifications uses of activated carbon for the years 1983 through 1988.

Effluent Gas Purification - A large variety of industrially produced effluents are adsorbed in the vapor state by activated carbon columns or cartridges. Off-gases such as hydrogen sulfide, sulfur dioxide, mercaptans, and other compounds of sulfur are particularly common among these. Such manufacturing operations as petroleum refineries and chemical plants use specially designed activated carbon grades for this purpose. Nonindustrial applications involving hydrogen sulfide adsorption include sewage treatment plants and geothermal generating plants.

Regeneration systems for these units are generally of the steam-in-place type, although removal of the loaded carbon to off-site thermal regeneration units also is used, particularly if the adsorbed materials are difficult to desorb with steam or are highly toxic.

Activated carbon specially coated with elemental sulfur is used to adsorb fugitive mercury vapors in plants handling mercury. The mercury reacts with the sulfur to form mercuric sulfide on the carbon. Another application of activated carbon for industrial vapor control is the removal of vinyl chloride monomer (VCM) from plants that manufacture or process this material. Current regulatory guidelines limit VCM vapor level to five parts per million in effluent air streams; activated carbon adsorbers are considered to be the most effective method of meeting this standard. The process also permits recovery of the adsorbed VCM material, thus providing return of the equipment investment.

In addition to adsorption of effluent gas in activated carbon beds or columns, a few applications exist wherein the carbon is suspended in a slurry, usually aqueous, and the effluent gas is bubbled through the slurry vessel. The adsorption system thus is a combination of a solid, a liquid, and a gas. High adsorption efficiencies characterize these systems. It is estimated that approximately 7 million pounds of activated carbon were used in general industrial off-gas treatment in 1983.

Industrial Gas Purification - Mixtures of some gases can be separated into desired components by preferential adsorption in activated carbon beds. Nitrogen can be extracted from atmospheric air, for example, by preferential adsorption of oxygen in activated carbon. The principle of separating various gases in this way is known as pressure swing adsorption. In addition to small-scale nitrogen generation, activated carbon is used to remove impurities from hydrogen streams for industrial processing. This market is estimated to have consumed about 2 million pounds of activated carbon in 1983.

Miscellaneous - Other categories for air purification include the use of granular carbon in air conditioning systems, "white rooms" in high technology plants, and in food storage plants. An estimated one million pounds of activated carbon were consumed in these miscellaneous applications.

Others

It is believed that the first application that brought widespread attention to the capabilities of activated carbon to adsorb gases effectively was its use in gas mask canisters during World War I. This application, now principally for industrial gas masks, but also for some military use, is stable at an estimated level of one million pounds per year.

Activated carbon has variety of uses in the catalyst field. As a support for catalytic metals such as vanadium, activated carbon-based systems are used in the production of isocyanates, phosgene, and chlorinated solvents. The total volume of carbon in this market was 5 million pounds in 1983.

Adsorption of radioactive gases provides another small market for activated carbon. It is used both in masks and in stationary adsorption units for filtering processing gases in nuclear power plants. Impregnated carbon is used for the removal of inorganic vapor-phase radioactive iodine species. The activated carbon is impregnated with triethylene-diamine, which is an excellent chemical for reaction of methyl iodide. It is estimated that about 2 million pounds of activated carbon were consumed in 1983 for radioactive gas adsorption.

Additional miscellaneous uses, such as removing trace sulfur compounds from natural gas streams that might poison certain catalysts (for example, nickel reforming catalysts used in ammonia and methanol production), are estimated to have consumed 4 million pounds in 1983. A growth of about 3% annually is anticipated for activated carbon in miscellaneous gas-phase uses from 1983 through 1988.

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