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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

Prepared by Sandia National Laboratories, Albuquerque, New Mexico 87185 and Livermore, California 94550 for the United States Department of Energy under Contract 91-46488.

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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

Prepared for Sandia National Laboratories under Contract No. 91-4648B

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.

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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°C in low-temperature troughs to over 1500°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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- C. Design Requirements
- D. Economic Assessment Supporting Data
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APPENDIX A

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MATERIAL SELECTION

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 $1150^{\circ}C$ ($2100^{\circ}F$). The alternate operating method provides a portion of the energy input to the regeneration process from fossil fuel and energy input to the production in the maximum salt temperature to $954^{\circ}C$ ($1750^{\circ}F$). For both the baseline and the alternate chemical processes, a variety of ceramic and metal materials were evaluated, including:

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

The criteria considered in the material selection process included:

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

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

- o B&W Lynchburg Research Center
- o B&W Alliance Research Center
- o Olin Chemical
- o Black & Veatch
- o Sandia National Laboratories
- o Solar Energy Research Institute (SERI)
- o Rockwell International
- o 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 $1150^{\circ}C$ (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 $954^{\circ}C$ ($1750^{\circ}F$) 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 $900^{\circ}C$ (1652°F). It appears that silicon is oxidized by the carbonate salt and then absorbed into The exact mechanism and its associated kinetics have not the molten salt. The reported results were confirmed by the ceramic been determined. specialists at B&W's Lynchburg Research Center and by Olin. The corrosion rate of silicon carbide in the $900^{\circ}C$ (1652°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° C (1652° 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 $900^{\circ}C$ ($1652^{\circ}F$) 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 $900^{\circ}C$ ($1652^{\circ}F$) 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 $900^{\circ}C$ ($1652^{\circ}F$) 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 Thus, the two methods of data about 0.76 mm (0.030 in.) in 20 years. 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 is 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.

Material	900 ⁰ C Corrosion	Temperature Range ^O C/ ^O 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%)	<pre>.l um/day (good)</pre>	1150/2100	poor	thick wall only	good comp./ low tens.

TABLE 1.0 CERAMICS CONSIDERED FOR MOLTEN CARBONATE SALT SERVICE

TABLE 2.0ALLOYS CONSIDERED FOR MOLTEN CARBONATE SALT SERVICE

Material	900 ⁰ C Corrosion	Temperature Range ^o C/ ^o F	Thermal Shock	Tube Availability	Strength
Incoloy 800 H	10 um/day	980/1800	excellent	readily available	excellent
Cabot 214	ll 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	l um/day (good)	815/1500	excellent	readily available	good
Inconel 617	NA	980/1800	excellent	readily available	excellent

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

APPENDIX B EQUIPMENT SPECIFICATIONS

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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

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RAIL CAR DUMP HOPPER Manufacturer Number Type Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

Beaumont Birch Co. 1 Four-Outlet, Inverted Pyramidal Coal 200,000 1b Carbon steel; A.R. liner Ambient 14.7 48'L x 14'W x 19.7'H

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

Beaumont Birch Co. 4 Belt Coal 30,000 to 400,000 lb/hr Rubber, Carbon steel Ambient 14.7 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
Туре	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
Туре	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 R Number 1 Type E Process Material C Capacity 1 Primary Equipment Material C Design Temperature, F Design Pressure, PSIA 1 Remarks

Ramsey Engineering Co. 1 Electronic Coal 1,200,000 lb/hr Carbon steel Ambient 14.7

DIVERTER GATE

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

B-4

COAL STORAGE SILOS Manufacturer Beaumont Birch Co. 4 Number Cylindrical, single outlet Туре Process Material Coal Capacity 1.5 million 1b 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 Number Type Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

i.

Carter-Day 1 Fabric filter baghouse Coal dust

Carbon steel Ambient 14.2 Air Flow Rate: 18,000 cfm Fabric Area: 2,572 ft² minimum Air-to-Cloth Ratio: 7:1 Media Type: Polyester

FAN	
Manufacturer	Twin City Fan
Number	1
Туре	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
Туре	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 Number Type Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks Beaumont Birch Co. 1 Belt Coal 14,911.7 lb/hr Rubber, carbon steel 77 14.7 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
Туре	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

ManufacturerLightning MixersNumber1TypeMounted on acid mixerProcess Material-Capacity-Primary Equipment Material-Design Temperature, F176Design Pressure, PSIAAtmosphericRemarks-

HE-101 HEATER

Manufacturer	
Number	1
Туре	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	

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CP-101 SLURRY PUMP

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

VT-102 ACID TANK

Manufacturer	Arrow Tank
Number	1
Туре	Vertical
Process Material	5% H3PO4 solution
Capacity	
Primary Equipment Material	FRP lined carbon steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

AG-102 AGITATOR

ManufacturerLightning MixersNumber1TypeMounted on acid tankProcess Material5 % H3P04CapacityFrimary Equipment MaterialDesign Temperature, FAmbientDesign Pressure, PSIARemarks
CP-102 ACID PUMP

1

Manufacturer	BIF
Number	1
Туре	Metering
Process Material	5 % H3PO4
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
Туре	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
Туре	Vertical cylindrical
Process Material	Coal slurry
Capacity	27,950 lb/hr
Primary Equipment Material	316 stainless steel
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

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SC-103 ACID SOLUTION DEWATERER

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

1 Model K36-96W-3 Coal slurry with phosphoric acid 68,341.7 lb/hr 316 Stainless steel 176

AC-103 AGITATOR

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

Derrick-Linatex

CP-103 SLURRY PUMP

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

SC-105 DEWATERER

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

HE-102 DRYER

Manufacturer		
Number	1	
Туре	Thermoscrew	
Process Material	Wet coal	
Capacity	15,293.8 1b/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
Туре	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 Number Type Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks Beaumont Birch Co. 1 Belt type bucket elevator 14,911.7 lb/hr Rubber, carbon steel 77

14.7

Height, Inlet to Outlet: Approx 29 ft Size of Conveyed Material: 1 x 0 in.

CR-102 GRINDER

Manufacturer	Gundlach
Number	1
Туре	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
Туре	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

CN-104 BUCKET ELEVATOR

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ManufacturerBNumber1TypeBProcess MaterialCCapacity9Primary Equipment MaterialCDesign Temperature, F8Design Pressure, PSIA1RemarksS
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Beaumont Birch Co.

1

Belt type bucket elevator

Coal

9,941.1 lb/hr

Carbon steel

80

14.7

Size of Conveyed Material, Mesh: Plus 8

Height, Inlet to Outlet: Approx 18 ft

Recycle back to grinder
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Angle of Decline: 20 degrees 40% recycled back to grinder

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CN-105 SCREW CONVEYOR

Manufacturer	Martin Conveying Machinery
Number	1
Туре	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 Number Type Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

Martin Conveying Machinery
1
Screw
Coal
14,911.7 1b/hr
Carbon steel
80
14.7
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
Туре	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
Туре	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
Туре	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

FN-101 FAN Manufacturer Number Туре Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

Twin City Fan 1 SWSI, centrifugal Carbon steel

Media Type: Polyester

Ambient 14.2 Air Flow Rate: 10,000 cfm

VT-104 PITCH HOPPER

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

Height: 8 ft Diameter: 4.5 ft One hour residence time

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

Beaumont Birch Co. 1 Cylindrical Pitch 300,000 lb Carbon steel Ambient 14.7 Diameter: 16 ft Silo Height: 55 ft

FE-104 PITCH SILO FEEDER

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

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

PITCH CONVEYOR AIRLOCK

Carter-Day 1 Fabric filter baghouse Pitch

Carbon steel Ambient

Air-to-Cloth Ratio: 3:1

ManufacturerMeyerNumber1TypeRotary airlockProcess MaterialPitchCapacityPrimary Equipment MaterialCarbon steelDesign Temperature, FAmbientDesign Pressure, PSIARemarks

PNEUMATIC CONVEYING BLOWER Manufacturer M-D Pneumatics Number l 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
Туре	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
Туре	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 Design Pressure, PSIA Remarks 9.5% Pitch, 4.5% moisture 21,263.6 lb/hr Carbon steel 210 14.7 Air Flow Rate: 7,000 to 10,000 cfm

FN-102 FAN

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

VT-107 DEAERATION BIN

Remarks

Manufacturer Number Type

Process Material

Capacity

Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

Heigh

FE-105 COMPACTOR FEEDER

Manufacturer Number Type Process Material

Capacity

Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

1

Bepex

Inverted, conical 85.6% Coal, 0.4% Activated Carbon, 9.5% Pitch, 4.5% Moisture 7,088 lb Carbon steel

14.7 Diameter: 9 ft Height: 13 ft

Bepex

1
Variable rate screw feeder
85.6% Coal, 0.4% Activated Carbon,
9.5% Pitch, 4.5% Moisture
21,263.6 lb/hr maximum
Carbon steel

14.7

CR-104 COMPACTOR

Manufacturer	Bepex
Number	1
Туре	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

Gundlach Manufacturer 1 Number Double roll Туре 85.6% Coal, 0.4% Activated Carbon, Process Material 9.5% Pitch, 4.5% Moisture 21,263.6 lb/hr Capacity Primary Equipment Material

Design Temperature, F Design Pressure, PSIA Remarks

Carbon steel 200 14.7 Feed Size: 1/2 by 1/2 in. pellets Product Size: 6 x 20 mesh granules

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SC-107 SCREEN

Manufacturer Number Type Process Material

Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

CN-112 BUCKET ELEVATOR

Manufacturer Number Type Process Material

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

Beaumont Birch Co. 1 Continuous bucket elevator 85.6% Coal, 0.4% Activated Carbon, 9.5% Pitch, 4.5% Moisture 9,112.4 lb/hr Carbon steel 200 14.7 Height, Inlet to Outlet: Approx 14 ft Size of Conveyed Material, Mesh: Plus 6 Recycle back to grinder

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CN-113 SCREW CONVEYOR
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Manufacturer	Martin Conveying Machinery
Number	1
Туре	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
Туре	Screw Conveyor
Process Material	85.6% Coal, 0.4% Activated Carbon,
	9.5% Pitch, 4.5% Moisture
Capacity	6.075 lb/hr

Capacity

Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

6,075 lb/hr Carbon steel 200 14.7 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
Туре	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 Number Type Process Material

Capacity

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

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CN-117 WEIGH FEEDER

Manufacturer	Merrick
Number	1
Туре	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
Туре	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

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FR-201 CARBONIZATION FURNACE

Manufacturer	Olin	
Number	1	
Туре	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
Туре	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

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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
Туре	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
Туре	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
Туре	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
Туре	Tank mounted
Process Material	
Capacity	
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	

Remarks

HE-202 PRODUCT HEATER

Manufacturer	
Number	1
Туре	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
Туре	
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
Туре	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
Туре	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
Туре	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
Туре	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
Туре	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
Туре	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
Туре	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
Туре	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 pair 600 F

397 lb/hr steam supply to heating coils at 75 psig, 600 FMoisture separated from coal: 506.1 lb/hr

HE-204 FINAL PRODUCT COOLER Manufacturer Bepex Number 1 Type Thermo Process Material Active Capacity 3,309 Primary Equipment Material Carbon Design Temperature, F 212-10 Design Pressure, PSIA Remarks 0.7 mm

Bepex 1 Thermoscrew Activated carbon 3,309.8 1b/hr Carbon steel 212-100

0.7 mm Btu/hr duty Cooling water supplied at 75 F CN-201 CONVEYOR

Manufacturer	Cleveland Vibrator Company
Number	1
Туре	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 Number Type Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

```
Beaumont Birch Co.
2
Continuous, chain, bucket elevator
99.3 Char, 0.7 Activated Carbon
8,684 lb/hr
316 stainless steel
1,112
14.7
Height, Inlet to Outlet: Approx 57 ft
Size of Conveyed Material, Mesh: 6 x 20
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CN-203 CONVEYOR
     Manufacturer
                                     Cleveland Vibrator Company
     Number
                                     1
     Туре
                                    Vibrating trough
     Process Material
                                     99.3% Char, 0.7% Activated Carbon
     Capacity
                                     8.684 lb/hr
                                     316 stainless steel
     Primary Equipment Material
     Design Temperature, F
                                     1,112
     Design Pressure, PSIA
                                     14.7
     Remarks
```

CN-204 CONVEYOR

Cleveland Vibrator Company
1
Vibrating trough
Activated carbon
3,308.5 lb/hr
Incoloy 800 H
1,472
14.7
Size of Conveyed Material, Mesh: 6 x 20

CN-205 CONVEYOR

Manufacturer	Coastal Conveyor	
Number	1	
Туре	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
Туре	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
Туре	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 Туре Continuous bucket elevator Process Material 98% Activated Carbon, 2% Moisture 3,250 lb/hr Capacity Primary Equipment Material Carbon steel Design Temperature, F 100 14.7 Design Pressure, PSIA 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
Туре	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
Туре	
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 Process Equipment Builders Manufacturer 2 Number Telescoping Туре Activated carbon Process Material Capacity Carbon steel, fabric Primary Equipment Material Design Temperature, F Ambient 14.7 Design Pressure, PSIA Remarks

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

DC-401 DUST COLLECTOR

Manufacturer	Flex-Kleen
Number	1
Туре	Cyclone
Process Material	j.
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
Туре	Rotary airlock, machined tips
Process Material	Dust
Capacity	
Primary Equipment Material	310 stainless steel
Design Temperature, F	1,472
Design Pressure, PSIA	35
Remarks	

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SYSTEM: OFF-GAS COOLING AND COMPRESSION

FN-401 EXHAUST FAN Robinson Industries Manufacturer 1 Number SWSI, centrifugal Туре Process Material 28,140.4 1b/hr Capacity Primary Equipment Material 242 Design Temperature, F Design Pressure, PSIA 30 Remarks

HE-401 EVAPORATOR

Manufacturer	Struthers Wells
Number	1
Туре	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
Туре	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	

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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
Туре	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
Туре	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	

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GC-401 COMPRESSOR

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

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SYSTEM: SPENT CARBON RECENERATION

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VT-60	3 CRUDE WATER STORAGE TANK	
	Manufacturer	Arrow Tank
	Number	1
	Туре	
	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	

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CP-601 CRUDE WATER PUMP

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

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CP-602 WATER PUMP

Manufacturer	Warman
Number	1
Туре	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
Туре	
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	

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CP-603 PRODUCT WATER PUMP

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

FL-602 PRODUCT WATER FILTER

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

HE-601 PRODUCT WATER COOLER

Manufacturer	
Number	1
Туре	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

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HE-602 OFF-GAS HEATER	
Manufacturer	
Number	1
Туре	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

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FR-602 OFF-GAS INCINERATOR

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

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FL-603 SCRUBBER WATER FILTER

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

HE-603 SCRUBBER WATER COOLER

Manufacturer	
Number	1
Туре	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 Reverse foil Type Process Material Flue gas 14,000 cfm Capacity Primary Equipment Material 304 stainless steel Design Temperature, F 175 Design Pressure, PSIA 15 in H₂O Remarks

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Scrubber waste water

ST-601 STACK

Manufacturer	
Number	1
Туре	
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
Туре	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 l Type Process Material Spent carbon Capacity Primary Equipment Material Design Temperature, F Ambient Design Pressure, PSIA Remarks VT-601 SPENT CARBON STORAGE TANK

Manufacturer	A-S-H
Number	2
Туре	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 ft³

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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
Туре	
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	

VT-602 FEED TANK WITH AGITATOR

Manufacturer	A-S-H
Number	1
Туре	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
х . В	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

Continental Screw Conveyor
1
Inclined dewatering screw conveyor
Spent carbon
6,394 lb/hr
Carbon steel
70
14.7

FE-604 REGENERATION FURNACE FEEDER

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

VT-605 RECENERATED CARBON STORAGE TANK WITH AGITATOR

Manufacturer	A-S-H
Number	1
Туре	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
Туре	
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
Туре	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

CN-602 CONVEYOR

Remarks

Manufacturer	Beaumont Birch Co.
Number	1
Туре	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 Number Type Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

Beaumont Birch Co. 1 Single blade diverter Regenerated carbon

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Carbon steel Ambient 14.7

REGENERATED CARBON LOADING SILOS

Manufacturer Beaumont Birch Company Number 2 Туре Regenerated carbon Process Material Capacity Primary Equipment Material Ambient Design Temperature, F 14.7 Design Pressure, PSIA Remarks

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Cylindrical, elevated
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Carbon steel, 316 stainless steel lined Volume: $1,500 \text{ ft}^3$ each Diameter: 10 ft Height: 50 ft

TRUCK LOADOUT GATE Manufacturer Number Туре Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

Process Equipment Builders 2 Water collecting Regenerated carbon

Carbon steel, stainless steel lined Ambient 14.7

DC-601 DUST COLLECTOR

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

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FE-601 DUST FEEDER

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

SYSTEM: TAR RECOVERY AND AMMONIA REMOVAL

VT-301 COLLECTOR MAIN QUENCH TANK

Manufacturer	Olin
Number	1
Туре	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
Туре	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
Туре	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 B

FN-301 EXHAUSTER

Manufacturer	Raymond Kaiser
Number	1
Туре	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
Туре	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
Туре	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

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

HE-302 FLUSHING LIQUOR COOLER

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Manufacturer	Raymond Kaiser
Number	1
Туре	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
Туре	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
Туре	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
Туре	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
Туре	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
Туре	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
Туре	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

ManufacturerRaymond KaiserNumber1TypeTube bundleProcess MaterialAmmoniaCapacity216 stainless steelDesign Temperature, FDesign Pressure, PSIA

Remarks

VT-308 WASTE LIQUOR SUMP Manufacturer Number Type Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

Raymond Kaiser 1 Waste liquor

Carbon steel

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TW-301 AMMONIA SCRUBBER

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Manufacturer	Raymond Kaiser
Number	1
Туре	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
Туре	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
Туре	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

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

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TW-303 LIQUOR COOLING TOWER

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

SYSTEM: H2S REMOVAL AND SULFUR RECOVERY

HE-501 ABSORBER FEED COOLER

Manufacturer	Ametek
Number	1
Туре	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 H2S ABSORBER

Manufacturer	Norton
Number	1
Туре	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
Туре	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
Туре	Turbine
Process Material	H ₂ S
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
Туре	Cylindrical, horizontal
Process Material	H ₂ S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	100
Remarks	

GC-501 RECYCLE COMPRESSOR

Manufacturer	Norton
Number	1
Туре	Reciprocating
Process Material	H ₂ S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	350
Remarks	

HE-503 RECYCLE COOLER

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Manufacturer	Ametek
Number	1
Туре	Shell and tube
Process Material	H ₂ S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	350
Remarks	

VT-502 LOW PRESSURE FLASH DRUM

Manufacturer	Norton
Number	1
Туре	Cylindrical, horizontal
Process Material	H ₂ S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	100
Remarks	

TW-502 H₂S STRIPPER

Manufacturer	Norton
Number	1
Туре	Cylindrical, free standing
Process Material	H ₂ S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	100
Remarks	

CP-502 H₂S RECYCLE PUMP

Manufacturer	Norton
Number	1
Туре	Centrifugal
Process Material	H ₂ S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	400
Remarks	

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HE-504 SOLVENT COOLER

Manufacturer	Ametek
Number	1
Туре	Shell and tube
Process Material	H ₂ S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	350
Remarks	

HE-505 STRIPPER CONDENSER

Manufacturer	Ametek
Number	1
Туре	Shell and tube
Process Material	H ₂ S
Capacity	
Primary Equipment Material	Carbon Steel
Design Temperature, F	95
Design Pressure, PSIA	60
Remarks	

VT-503 STRIPPER KNOCKOUT POT

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Manufacturer	Arrow Tank
Number	1
Туре	Cylindrical, vertical
Process Material	H ₂ S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	95
Design Pressure, PSIA	60
Remarks	

RC-501 THERMAL REACTOR

Manufacturer	NATCO
Number	1
Туре	Shell and tube
Process Material	H ₂ S
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	
Design Pressure, PSIA	60
Remarks	

FN-501 THERMAL REACTOR FAN

Manufacturer	NATCO
Number	1
Туре	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
Туре	Furnace
Process Material	H ₂ O
Capacity	
Primary Equipment Material	Carbon steel
Design Temperature, F	800
Design Pressure, PSIA	40
Remarks	

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HE-507 STEAM HEATER

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

RC-502 CATALYTIC REACTOR

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

HE-503 CONDENSER

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

HE-510 CONDENSER

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

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FR-501 INCINERATOR

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

SYSTEM: SOLAR COLLECTION

HELIOSTAT

Manufacturer

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

SYSTEM: ELECTRICAL POWER GENERATION

INTERMEDIATE HEAT EXCHANGER

Manufacturer	Babcock & Wilcox	
Number	1	
Туре	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	
	Outlet temp: 325 B	

SALT CIRCULATION PUMP Manufacturer Number Туре Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

Lawrence

2 Vertical cantilever Nitrate salt 558,000 lb/hr

Nitrate salt: 436,000 lb/hr

Inlet temp: 580 F Outlet temp: 948 F

1,200 F

EVAPORATOR

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Manufacturer	Babcock & Wilcox
Number	1
Туре	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
Туре	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 DRUMManufacturerBabcock & WilcoxNumberlTypeVater/steamProcess MaterialWater/steamCapacityPrimary Equipment MaterialDesign Temperature, FDesign Pressure, PSIARemarksVater/steam

BOILER WATER CIRCULATION PUMP

2

Water

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

TURBINE-GENERATOR	
Manufacturer	Ε
Number	1
Туре	S
Process Material	S
Capacity	3
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	Т

E	lliot		
1			
S	ingle	extraction,	condensing
S	team		
3	MW		

Throttle conditions: 720 F, 1,065 PSIA

STEAM CONDENSER
Manufacturer
Number
Туре
Process Material
Capacity
Primary Equipment Material
Design Temperature, F
Design Pressure, PSIA
Remarks

l Surface condenser Turbine exhaust steam

Carbon steel shell, stainless steel tubes

CONDENSATE PUMP	
Manufacturer	Goulds
Number	2
Туре	Vertical
Process Material	Condensate
Capacity	220 gpm each, @ 120 ft
Primary Equipment Material	
Design Temperature, F	·
Design Pressure, PSIA	
Remarks	Carbon steel head, bar

Carbon steel head, barrel, and bowls; stainless steel shaft and impellers

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DEAERATOR Manufacturer Number Type Process Material Capacity Primary Equipment Material

Design Temperature, F Design Pressure, PSIA Remarks

BOILER FEEDWATER PUMP Manufacturer Number Type Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks l Water/steam 106,000 lb/hr delivered capacity, @ 265 F

ASC Manufacturing Company

Carbon steel shell, stainless steel internals

Goulds 2 Multistage, horizontal split case Boiler feedwater 220 gpm each @ 3,050 ft

Forged carbon steel casing, stainles steel internals

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CONDENSER EXHAUSTER	
Manufacturer	Nash Engineering
Number	1
Туре	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
Туре	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	

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DEMINERALIZED WATER STORAGE TANK

Manufacturer	CBI Na-Con, Inc.
Number	1
Туре	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 Centrifugal, frame mounted end suction Туре Demineralized water Process Material 50 gpm @ 20 ft tdh Capacity Stainless steel casing and internals Primary Equipment Material 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 com

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.

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DEMINERALIZATION SUBSYSTEM

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Manufacturer	Infilco Degremont, Inc.
Number	1
Туре	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	
Туре	Sample	rack
Process Material		
Capacity		
Primary Equipment Material		
Design Temperature, F		
Design Pressure, PSIA		
Remarks		

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

B-76

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

Remarks

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AIR RECEIVER

Manufacturer	Arrow Tank
Number	2
Туре	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
Туре	
Process Material	Oil filled
Capacity	10 MVA
Primary Equipment Material	
Design Temperature, F	
Design Temperature, PSIA	
Remarks	

HIGH VOLTAGE SWITCHING EQUI	PMENT
Manufacturer	General Electric
Number	1
Туре	
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
Туре	Metal clad, vacuum 5 kV
Process Material	· · · ·
Capacity	1,200 amp
Primary Equipment Material	
Design Temperature, F	
Design Temperature, PSIA	
Remarks	

SECONDARY TRANSFORMERManufacturerGeneral ElectricNumber4TypeOil filledProcess MaterialJ,500 kVA, 480-4160 VPrimary Equipment MaterialJesign Temperature, FDesign Temperature, PSIARemarks

SECONDARY SUBSTATION	
Manufacturer	General Electric
Number	4
Туре	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

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COLD SALT STORAGE TANK
Manufacturer
Number
Type
Process Material
Capacity
Primary Equipment Material
Design Temperature, F
Design Pressure, PSIA
Remarks
```

1

Carbonate salt

304 stainless steel 957

10,600 ft³ 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

,,,,,

304 stainless steel shell, Inconel 600 annulus

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

800 B&W l Balanced draft, multi-fuel

NumberlTypeBalanced draftProcess MaterialCarbonate saltCapacityPrimary Equipment MaterialDesign Temperature, FDesign Pressure, PSIARemarksKemarks

STANDBY SALT HEATER

Manufacturer

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

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SALT SUMP PUMP Manufacturer Lawrence Number 1 Туре 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
Туре	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 1 Number Tube bundle Туре Process Material Carbonate salt Capacity Primary Equipment Material 316 stainless steel Design Temperature, F 600 Design Pressure, PSIA 75 Remarks

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

CIRCULATING WATER PUMP Manufacturer Number 3 Type Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks Carbon steel head, stainless steel shafts,

```
Goulds
Vertical turbine
Circulating water
4,000 gpm each @ 35 ft tdh
```

```
ACID STORAGE TANK
Manufacturer
                                Arrow Tank
                                1
Process Material
                                5,000 gallons
```

bronze impellers

```
Primary Equipment Material
                               Carbon steel, coated
Design Temperature, F
                               Ambient
Design Pressure, PSIA
                               Atmospheric
```

Number

Capacity

Remarks

Туре

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

Milton Roy

1

INHIBITOR FEED SUBSYSTEM Manufacturer Number 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
Туре	Gas solution
Process Material	Chlorine gas
Capacity	2,000 pound per day
Primary Equipment Material	
Design Temperature, F	
Design Pressure, PSIA	
Remarks	

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

PROCESS WATER PUMP	
Manufacturer	Goulds
Number	2
Туре	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
Туре	
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

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

Goulds

2

Centrifugal, frame mounted end suction Treated process water 150 gpm each @ 25 ft tdh

Cast iron casing with stainless steel internals

RECYCLED WATER STORAGE TANK

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

OFF-GAS STORAGE TANK	
Manufacturer	CBI Na-Con, Inc.
Number	2
Туре	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	

```
FIREWATER STORAGE TANK
Manufacturer
Number
Type
Process Material
Capacity
Primary Equipment Material
Design Temperature, F
Design Pressure, PSIA
Remarks
```

```
CBI Na-Con, Inc.

1

Vertical cylindrical

Water

300,000 gallons

Carbon steel

Ambient

14.7
```

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

Fairbanks-Morse 1 Horizontal split case Water

```
Cast iron casing, bronze impellers, carbon steel shaft
```

DIESEL DRIVEN FIRE PUMP Manufacturer Number Type Process Material Capacity Primary Equipment Material Design Temperature, F Design Pressure, PSIA Remarks

```
Fairbanks-Morse
1
Horizontal split case
Water
```

Cast iron casing, bronze impellers, carbon steel shaft

B-88

CARBON FILTERS	
Manufacturer	Infilco Degremont, Inc.
Number	2
Туре	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
Туре	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	

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SEWAGE TREATMENT PLANT Manufacturer Environmental Conditioners, Inc. Number 1 Туре 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

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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 Location Insolation Rating Thermal Rating (Absorbed) Heat Transfer Fluid

Molten Salt Inlet Temperature Molten Salt Outlet Temperature Configuration Type

Operating Range Design Point Efficiency Heat Transfer Tubes

Receiver Tower Elevation Dry Weight

Fossil Fired Salt Heater: Fuel Thermal Rating (Absorbed) Molten Salt Inlet Temperature Molten Salt Outlet Temperature Type Heating Sections: High convective

Radiative

Low convective Design Point Efficiency Solar Noon, Day 355 Barstow, CA 950 W/m^2 41.8 MW (142.6 MM Btu/Hr) Molten Carbonate Salt; 32.2% Li₂CO₃, 33.3% Na₂CO₃, 34.5% K2CO3 by Weight $514^{\circ}C$ ($957^{\circ}F$) $954^{\circ}C$ (1750°F) C-cavity, North Facing Forced Circulation, Once Through, Two Control Zones. 30-100% 78% $236 \text{ m}^2 (2545 \text{ Ft}^2)$ 600/617 Coextruded Tubes 85m (280 Ft) 312,530 Kg (689,000 Lbs)

Reaction Furnace Off-Gas 35.0 MW (119.3 MM Btu/Hr) 514^oC (957^oF) 954^oC (1750^oF) Forced Circulation, Once Through

725m² (7801 ft²) 600/617 Coextruded Tubes 50m² (539 ft²) 600/617 Coextruded Tubes 548m² (5900 ft²) 304 SS 83%

Steam Generation:

Design Code Thermal Rating Carbonate Salt Composition

Nitrate Salt Composition

1. Intermediate Heat Exchanger Thermal Rating Carbonate Salt FLow Tin Tout Nitrate Salt Flow Tin Tout Configuration Design Pressure Tube-side Design Pressure Shell-side Design Temperature Heat Transfer Surface Material Dry Weight

2.Superheater Thermal Rating Nitrate Salt Flow Rate Tin ^{T}out Steam Flow (Steam By-Pass) Tin Tout, Pout Configuration Design Pressure Tube-side Design Pressure Shell-side Design Temperature Heat Transfer Surface Material Dry Weight

Section VIII, Division 1, ASME 17.1 MW (58.3 MM Btu/Hr) 32.2% Li₂CO₃, 33.3% Na₂CO₃, 34.4% K₂CO₃ by Weight 60% NaNO₃, 40% KNO₃ by Weight

```
17.1 MW (58.3 MM Btu/Hr)
62.8 Kg/sec (498,760 lb/hr)
649°C (1200°F)
496°C (925°F)
54.9 Kg/sec (436,000 lb/hr)
304°C (580°F)
509°C (948°F)
U-Tube, U-Shell
1.72 MPa (250 psig)
1.72.MPa (250 psig)
677°C (1250°F)
42.7m<sup>2</sup> (460 Ft<sup>2</sup>)
Incoloy 800
3140 Kg (6900 lb)
```

2.4 MW (8.0 MM Btu/Hr) 54.9 Kg/sec (436,000 lb/hr) 509°C (948°F) 481°C (898°F) 6.08 Kg/sec (48,290 lb/hr) 0.60 Kg/sec (4760 lb/hr) 297°C (567°F) 399°C,7.93 MPa (750°F, 1150 psia) U-Tube, U-Shell 8.96 MPa (1300 psig) 1.72 MPa (250 psig) 538°C (1000°F) 10.1m² (109 Ft²) 304 SS 1040 Kg (2300 lb) 3. Evaporator Thermal Rating Nitrate Salt Flow Tin Tout Total Water/Steam Side Flow Tin Tout Steam Flow, Tout

Configuration Design Pressure Tube-side Design Pressure Shell-side Design Temperature Heat Transfer Surface Material Dry Weight

 Steam Drum Steam Flow
 Feedwater Temperature Operating Temperature Design Pressure
 Design Temperature
 Material
 Dry Weight

Cold Salt Storage Tank: Design Code Design Pressure Design Temperature Cold Salt Temperature Maximum Capacity Material: Containment Vessel External Insulation Exterior Base

Dry Weight

14.7 Mw (50.3 MM Btu/hr) 70.3 Kg/sec (558,000 lb/hr) 443°C (829°F) 304^oC (580^oF) 26.7 Kg/sec (212,200 lb/hr) 260^oc (500^oF) 297°C (567°F) 6.68 Kg/sec, 297^oC $(53,050 \text{ lb/hr}, 567^{\circ}\text{F})$ U-Tube, U-Shell 9.65 MPa (1400 psig) 1.72 MPa (250 psig) 482°C (900°F) $156m^2$ (1680 ft²) 2-1/4 CR - 1 MO 13,290 Kg (29,300 lb)

6.68 Kg/sec (53,050 lb/hr) 129°C (265°F) 297°C (567°F) 9.65 MPa (1400 psig) 316°C (600°F) Carbon Steel 7,700 Kg (17,000 lb)

Section VIII, Division 1, ASME 0.12 MPa (18 psig) 538°C (1000°F) 514°C (957°F) 521,500 Kg (1,150,000 lb) salt

304 SS Block Aluminum Jacket Insulating Firebrick, Concrete Foundation 47,600 Kg (105,000 lbs)

Hot Salt Storage Tank: Section VIII, Division 1, ASME Design Code 0.12 MPa (18 psig) Design Pressure 538^oC (1000^oF) Containment Vessel Design Temp. 954^OC (1750^OF) Hot Salt Temperature 521,500 Kg (1,150,000 lb) salt Maximum Capacity Material: Inconel 600 Inner Liner 25mm (1") Alumina Spheres Internal Insulation Outer Liner 304 SS Cold Salt Cooling Tubes 304 SS 304 SS Containment Vessel External Insulation Block Exterior Aluminum Jacket Insulating Firebrick, Concrete Foundation Base Dry Weight 512,000 Kg (1,129,000 lb) HELIOSTAT FIELD 797 Number of Heliostats 76,113 m² Total Mirror Area 98.4 m^2 Single Mirror; Gross Area Single Mirror; Net Area 95.5 m^2 Average Reflectivity 91% CARBONATE SALT PROPERTIES Composition (Li, Na, K)₂ CO₃ Ternary Eutectic 32.2%, 33.3%, 34.5% Weight Percent $397^{\circ}C$ (747°F) Melting Point 1.9 $W/m^{-0}C$ Thermal Conductivity $(1.1 \text{ Btu/hr-ft-}^{\circ}F)$ 2252-0.474T kg/m³, T in $^{\circ}C$ Density (141.1-0.01643 T lbm/ft³, T in^oF) $T \leq 1200^{\circ}F$: 3.328x10⁹ T^{-4} Pa-sec, T in^oF (8.05x10¹² T^{-4} lbm/ft-hr, T in ^oF) Viscosity T > 1200°F: 0.187 $T^{-.67}$ Pa-sec, T in °F (452 $T^{-.67}$ lbm/ft-hr, T in °F) Specific Heat $1377 + 0.6904T J/Kg^{-0}C$, T in ^oC $(0.326 + 0.919 \times 10^{-4} \text{ T Btu/lbm-}^{\circ}\text{F,T in }^{\circ}\text{F})$

NITRATE SALT PROPERTIES	
Composition	(Na, K) NO ₃
Weight Percent	60%, 40%
Melting Point	245°C (473°F)
Thermal Conductivity	0.441+1.95x10 ⁻⁴ T W/m- $^{\circ}$ C, T in $^{\circ}$ C (0.253+6.27x10 ⁻⁵ T Btu/hr-ft- $^{\circ}$ F, T in $^{\circ}$ 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+2.2 (54.916-0.2903T+5.516x	81x10 ⁻⁷ T ² -1.474x10 ⁻¹⁰ T ³ Pa-sec, T in ^o C 10 ⁻⁴ T ² -3.556x10 ⁻⁷ T ³ 1bm/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/1bm- ^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 ₂ S Removal and Sulfur Recovery
Table 6	Regeneration

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EV. 1		SOLAR FLELS AND OFENILS	ALS SYSTEM DESI	VOLUDY		ACTIVATED CARBON PRODUCTION
11-21-84	5	OFFICE	SSECOND			PRETREATHENT
		EQUIPRENT L	IST BY FLOW			PAGE 1 CF 2
NUMBER NUMBER	EDUIPHENT	MATERIALS OF CONSTRUCTION	FLON (LB/HR)	TEMPERATURE (F)	PRESSURE (PSIR)	DESCRIPTION
	CORL CONFERENCE	CARBON STEEL	14911.7	7	14.7	FROM CORL STORAGE, 1°-5° SIZE, 10-15% MOISTURE
CR-101	I CONL CRUSHER	I RE TOOL STEEL OR MORT. CR-HO WHITE IRONI	14911.7	- 1	14.7	I RAM COOL CRUSHED TO 1" SIZE MAXIMUM
	I CORL BUCKET ELEVATOR	I CARBON STEEL	14911.7		14.7	I TO ELEVATION OF GRINDER
- CR-162	I COM GRINDER	- A2 TOOL STEEL OR MART, CR-HO WHITE IRONI	24852.8	8	14.7	1 1. SIZE GROUPD TO 8 X 38 NESH GRONULES
SC-162	I COML SCREEN	L CARBON STEEL	24652.8	8	14.7	I 444K RECYCLED BACK TO GRINDER
10-10	I COM. BUDKET ELEVATOR	· CARBON STEEL	24852.8	- 88	14.7	I TO ELEVATION OF GRINDER
24-162	I CORL CONVEYOR	CARBON STEEL	1.1465	 88	14.7	REETACLE BACK TO GRINDER
CH-186	I CORL CONVEYOR	I CARBON STEEL	14911.7	 88	14.7	I FROM SCREEN TO ACID MIXER
1 FE-183	FEEDER/AT ALOCK	I CARBON STEEL	11641	88	14.7	H FEED TO ACID MIXER
E-181	H DUST FEEDER	I CARBON STEEL	N.	4	14.7	BOTTOM OF BUST COLLECTOR
181-DC	I DUST COLLECTOR	+ CARBON STEEL	•			I CYCLORE, BABACKE OR COMBINATION
101-161	NGS TRUCK	I CARBON STEEL	•		•	DEPENDS ON AREAS CONTAINED
: VT-101	I ACID MIXER	I 316 STRINESS STEEL	43186.7	1 9/1		I DIE HOUR RESIDENCE TINE-304 COR, 764 ACID SOUN
181-9 0	H PEITATOR			_		HOUNTED ON ACID MIXER
101- 3 1	I HEATER	LCRRPENTER 20		_		1 764 LB/HR STEON, INNERSED COIL IN ACID MIXER
CP-101	HILL STIRRY STAR	· CDANCU INPELLER	43186.7	176 1	•	I CORL SLURRY FROM ACID NIXER TO DEMATERER
77-102	I ACID TANK	I FRO OR FRO LINED CARBON STEEL	146.3			NOILITIOS NOACH SSL I
961-6e	: REITATOR	- CFBM	-			I MOUNTED ON ACID TANK
% 	I ACID PUMP	1 316 STAIMLESS STEEL	146.3		٠	I FROM ACID TANK TO MIXER
SC-183	: ACID SOLN DEMATERER	I JIE STRIMESS STEEL	43186.7	176		I SEE FLOW DIRGROW FOR WATER ADDITION/SEPARATION
SC-184	I ACID SOLN DEMATERER	316 STRIMLESS STEEL	29422.3	541		- DOMN TO 15% MOISTURE
VT-103	E CORL MOSER	1 316 STRIMLESS STEEL	15293.3	-		+ 27959 LB/HR WATER ADDED, ONE HOUR RES TIME
101-90	I AGITATOP	I CDMICD	-	-		I MOUNTED ON COOL LINGHER
CP-183	SLURRY PIMO	CLANCU IMPELLER, CASING	43243.9	82.	•	I FROM CORL MISHER TO DEMATERER
-						
	** -					
				ENT ADDED DER	TSUM MUM	

TABLE 1

1-21-85		SULTRA FUEL OF THE	0 CHENICALS		TUDIS NO		HUITAHIED CHARLEN PRODUCTION
		ς,	DENICAL PRO	DESS			PRETREATMENT
		EQUI	I DHENT LIST	BY FLOW			PAGE 2 OF 2
	EQUIPMENT	MOTERIALS OF CONSTRUCTION		FLOU LP/HR)	TENDERATURE	(U)Sd) BUCSSON	DESCRIPTION
C-166 - DEH	DTERER	- CARBON STEEL	-	4 2243.9	78		1 SEE FON DIAGRAM FOR SEMARATION
C-106 DEM	IA TERER	I CARBON STEEL	-	2479.6	F		I SEE FLOW D'AGROW FOR SEPARATION
E-182 DRV	ER	- CORBON STEEL		15293.8	7-212	14.7	DOWN TO SK HOLSTURE, 2000 LB/HR STEAM
T-184 I PIT	ch hopper	I CAPBON STEEL	-	144.3	8 21	14.7	(ONE HOUR RESIDENCE
E-104 : FEE	DER/AIRLOCK	I CARBON STEEL	-	5.444:	138	.4.7	I FEED PITCH TO PALVERIZER
R-183 PUL	VERIZING HILL	CARBON STEEL	-	21263.6			1994 LESS 200 NESH CA 60-654 LESS 325 NESH
C-182 DIS	IT COLLECTOR	CARBON STEEL		21262.2			1 CVCLONE/BAGHOUSE
N-162 - EXH	INUEL FON	E CARBON STEEL	-	•	-	•	DEPENDS ON PHYSICOL LAYOUT
E-102 1 DUS	IT FEEDER	P CORBON STEEL	- .	21262.2			· ROTTOM OF RUST COLLECTOR
T-107 1 DEA	ERATION RIN	I CARBON STEEL	•	21262.2			EETHEEN DUST COLLECTOR AND COMPACTOR
E-106 : FEE	JER	- CARPON STEEL		21252.2			I BUTTOM OF DEREMATION RIN
R-104 - COM	IPACTOR	· CARBON STEEL	÷	1362.2	- 1	40-50,000	- CONPACT TO PELLETS 1/2" DIA X 1/2" LONG
119 1 201-1	NDER	CARBON STEEL	•••	21262.2			I GRIND TO 6 X 20 MESH GRONDLES
C-107 SCR	EEN	CARBON STEEL		38374.5		.	1 30% RECYCLED BACK TO GRINDER
N-112 - BUC	XET ELEVATOR	CORBON STEEL		21262.2			1 TO ELEVATION OF GRINDER
N-113 1 COM	MEYOR	TEELS NORWOOD I		3112.4	8	7.4E	· RECYCLE EACK TO GPINDER
N-11- 100	NEYOR	Canadon STEEL		:5:96.6		1.41	SCREEN TO PULVERIZING MILL
X-115 + BUC	XET ELEVATOR	I CAPBON STEEL		:5196.6		14.7	A TO ELEVATION OF STORAGE BIN
T-1A5 1 570	RAGE EIN	E CARBON STEEL	1.04	-	-		: 24 HOLD HOLDING CAPACITY
E-186 FEE	ter	P CARBON STEEL		:5195.6	Ē;	· 14.7	ROTTOM OF STORAGE BIN
3-112 - HED	BH CONVEYOR	CARBON STEEL	-	15186.E	E	14.7	FEED TO MUCKET ELEVATOR
N-116 BUC	XET ELEVATOR	L CARPON STEEL	-	:5186.6	R	14.7	- Com. To Carbonization Furnace
•• •··-							
		•••					
							
					is depend on Pr Ent 20060 PER	NSICAL PLANT	LAYOUT

TABLE 1 (CDNT.)

		saar flels and cheri	icars system desi	Vanns Hei		ACTIVATED CARBON PRODUCTION
11-21-85		CHENICA	L PROCESS			CARBONIZATION, ACTIVATION, PRODUCT CLASSIFICATION
		EQUIPACITY STATEMENT	LIST BY FLOW			POGE 1 CF 1
LTEN NUMBER	EQUIPMENT	MATERIALS OF CONSTRUCTION	FLON (LB/HR)	TENERROTUNE (F)	PRESSURE (PSIA)	DESCRIPTION
FR-201	i carbonization fi <i>m</i> ance		15188.6	~ ~	14.7	H 1112 F, OXYGEN FREE, 2 HOUR RES TIME
	I CONVEYOR	I 316 STRIMESS STEEL	8664.	1 1112 1	14.7	1 BUTTON OF CARBONIZATION FURANCE TO BUCKET ELEVATOR
CH-585	I BUDKET ELEVATOR	1 316 STRIMESS STEEL	8684.	1 1112 1	14.7	I ELEVATE TO ACTIVATION FURNICE
CN-283	e conveyor	1 316 STRIMESS STEEL	B584.	1 1112 1	14.7	I FEED ACTIVATION FURMACE
EB-200	: ACTIVATION FURNACE	-	9684.			1 1472 F, 21567 LB/HR STEOM ADDED, 4 HOUR RES TIME
FE-201	I FEDER	HIDDLDY BOOK	3386.5	1 1472 1	14.7	I BUTTOM OF ACTIVATION FURNACE
ある	i conveyor	HIGH ADDRESS ADDRE	3309.5	1472	14.7	I TO PREDUCT COOLER
162-34	PRODUCT COOLER	I 384 STRINLESS STEEL	3308.5	1 1472-180	14.7	I WATER COOLED CONVEYOR, 1.1 NR BITU/HR
10-10 10-10	HATER PUMP			_		I TEMPERED WATER TO DRYER
24-292	I CONFIDE	CARBON STEEL	3208.5	88	14.7	FRODUCT COOLER TO ACID MIXER
262-33	: FEEDER/AIRLOCK	I CARBON STEEL	3388.5	138	14.7	FEED ACID MIXER
VT-201	: ACID MIXER	I HAST, C-276 LINED OR ACID BRICK LINED I	5494.2	198		I DNE HOUR RESIDENCE TIME
102-50	REITATOR	I CHLORINET 3				I HOUNTED ON ACID MIXER
₩-286	t HEATER	- KBI-10				1 62 LB/HR STEAN, IMERSED COIL IN ACID MIXER
VT-282	: ACID DILUTION TANK	- FRP	530.7			1 15% HOL SOUTTON
CP-501	: ACID PUND	TEPLON LINED	658.7	- F:		I FROM ACID DILUTION TO ACID MIXER
CP-5 8 C	divíd Albants :	E DURICHLOR	6494.2	1 62 ;	•	I FROM ACID MIXER TO DEWATERER
1 9 2-36	i acto soun delaterer	HAST.C-276	6494.2	1 38		1 SEE FLOW DIAGRAM FOR WATER ADDITION/SEPARATION
VT-203	PRODUCT LIASHER	i 316 STRINLESS STEEL	3815.9	I 8∠ I		1 2000 LB/HR WRITER ADDED
16-203	; AGITATOR	I CDANCU	_	-		I MOUNTED ON PRODUCT LASHER
CP-283	dial yang	I CDANCU INPETTER	7865.9	1 78 1	•	i product inscher to dolaterer
31-36	E DEMOTERER	i 316 STRINLESS STEEL	7865.9	1 78 1		i down to 15% moisture, see flow diagoom
HE-203	I PRODUCT DRYER	I DARBON STEEL	3815.9	1 78212		i down to 2% moisture, 397 lb/hr steam
HE-50M	I FINGL PRODUCT COOLER	I CARBON STEEL	3389.8	1 212100 1		1 WATER COOLER, 0.7 MM BTU/HR
SC-203	I SCREEN	CARRON STEEL	3399.8	88		I SCREEN TO 6 X 20 NESH GRONALES, RECYCLE TO PRETREATHENT
54-20B	: CONVEYOR	R CARBON STEEL	3250.		14.7	1 TO PRODUCT STORAGE
			+ - NUREI	REAL ACCED ON OH	YSICAL PLANT REV. 1	LAVOUT
		-	-	-		

TABLE 2

C artavi	Solur Flets and devices system design study Devices production	EQUIPMENT LIST BY FLOW	INTERIALS OF FLOW FOREBATURE PRESSURE DESCRIPTION (LB/HR) FS13	LINED STEEL - 26942.5 1 1472 - 25 1 CMLONE	SS STEEL	DNZE LIGECS'C2 SHEFT I S7365'2 1 HER-128 I COOT 10 528 E	NA TUBES, 316 SS SHELL I 25942.5 [472400 ' PROULE 75 PFIG STEON			3, 316 55 SHELL 2 20140.4 1 242-55 30 1 401EP 2001ED, 13.6 MM PUI/HP	35 STEEL - 3944.4 - 25 - 4 - 4 - 26 - 4 - 4 - 26 - 1 - 4 - 20 - 20 - 20 - 20 - 20 - 20 - 20	9-586 ADTOR (150 KSI TS) 1 (5449,5 1 25 30-354 MM TTORE CTORE			
	SOLAR FLELS AND	6001	T MARERIALS OF CONSTRUCTION	REFRACTORY LINED STEEL	1 310 STATIMESS STEEL	: Allmann Bronze Tubes, cs Sfell	I SANDVIK 253 NA TUBES, 316 SS SHELL	-	: Spadvik 253 ing	1 316 SS TUBES, 316 SS SHELL	1 315 STAIMLESS STEEL)R	1 316 SS TUBES, 316 SS SFELL	1 316 STAIN ESS STEEL	
	1 11-21-85		ITEN EQUIPMENT NUMBER KONE	DC-401 I DIEL COTTECLOR	FE-401 FEEDER	: HE-402 - 1 BFN HEATER	i HE-401 i EVARORATOR	I VT-483 I STEAM DRUM	I FN-401 I EXHOUST FAN	HE-403 DIFFERS COOLER	- UT-401 - KNOCKOUT DRUM	1055340401 Streets 1044-38	HE-484 I INTERCOOLEPS	I JT-442 KNOCKOUT DRUM	

TABLE 3

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The Equipment Skinh on this page is approximate. The tran recovery manding reducts is available as a complete subprocess from several enember from. Actual equipment and design information should be obtained from the salected engineering firm as a result of cost inquiriles. (Refer to process flow discrements for mecessary inlet conditions) TAR REDOVERY/RANDNIA RENOVAL ACTIVATED CARBON PRODUCTION I 18-12 IN HE SUCTION, SP-55 IN HE DISCHARGE PREE 1 OF 1 DESCRIPTION TAR TO STORAGE AREA I 520 LB/HR STEAM ESCOLLO/HR STERM MINDERS DEFEND ON PHYSICAL PLANT LAYOUT
 EQUIPMENT 420ED PER REV. 1 PRESSURE (PSIA) 14.7 I TENPERATURE I 18 18 2 SOLAR FLELS AND CHENICALS SYSTEM DESIGN STUDY cale. EQUIPMENT LIST BY FLOW LOW (B/HG) CHENICAL PROCESS NATERIALS OF CONSTRUCTION I FLUSHING LIQUOR COOLER CP-366 / SCRUBBER RECYCLE PUMP · FLUSHING LIQUOR TANK I FLUSHING LIQUOR PUMP CRUDE LIQUOR STORAGE HE-302 + AMONIA LIGUER STILL TH-303 I LIQUOR COOLING TONER CRUDE LIQUOR STILL I CRUDE LIGUOR PUMP HE-306 I PORTIAL CONDENSER I PARTIAL CONDISER I HASTE LIQUOR SUMP EQUIPRENT NONE I TAR PRECIPITATOR TH-362 I AMONIA SCRUBBER NAT BUILDH RAT I I AMONIA SCRUBBER I PRIMARY COOLER SCRUBBER PUMP TAR DUUD I CAUSTIC LEB - DECANT PUND I QUENCH TANK DOMODIER I EXHAUSTER TAR PUMP I DECANTER NOTE: 11-51-65 137-00 <u>ال</u>ور. الور 105-10 NUCCESSION N VT-362 198-17 186-3H 瀬山 162-30 VT-383 59-385 HE-380 **Dec-1**0 V1-366 16-38 1 H-38 VT-300 1987-d) 505-1A VT-387 105-11

TABLE 4

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the equipment show on this page is approximate. The kes removal solution recovery system is available as a complete subprocess from several engineering fight. Actual equipment and design information should be optained from the selected engineering fight as a result of cost induiries. • Refer to process from ending for necessary filler (conditions) HES REDOVAL AND SILFUR REDOVERY ACTIVATED CARBON PRODUCTION PAGE | OF | DESCRIPTION I 22-36 F EXIT TEMPERATURE MURGER DEPEND ON PHYSICAL FLANT LAYOUT
 EQUIDMENT FORED DES REV. 1 (UISd) TENDERATURE | SOLAR FLELS AND CHEMICOLLS SYSTEM DESIGN STUDY R TABLE 5 Equipment List by Flow FLOU (IB/HR) CHENICAL PROCESS NATERIALS OF CONSTPLICTION I STRIPPER KNOCK OUT POT HUND HEALF RESS FLASH DRUM FLOW PRESS FLASH DRUM RELYCLE COMPRESSOR I STRIPPER CONDENSER I HYDRAULIC TURBINE I WASTE HEAT BOILER I CATALYTIC REACTOR EGUIPHENT · THERMAL REACTOR I REDYCLE COOLER SOLVENT COOLER I HEAT EXCHANGER I SULFUR STORAGE 1 4NOCK OUT POT RELYCLE PUMP HER STRIPPER I HES ARSORBER INCINERATOR CONDENSER - CONDENSER SOLER : HEATER HERTER Ë 11-21-85 HE-582 1. 1 195-11 1**95-1**0 HE-563 54 26 26 Æ-565 1-1-2 NUMBER 60-501 VI-562 71-562 197-191 197-191 VI-583 RC-561 985-94 2**8**5-26 HE-508 665-¥ HE-518 V1-585 FR-501 105-10 HE-587 HE-501

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			TOPT	5		
EV. 1		SOLAR FLEIS AND CHEN	iicals system den	sign study		SPENT ACTIVATED CARBON RESERVATION
11-21-65			DR. PROCESS			REIZINE RATION
		UGH4INI3	r list by Flow			PAGE 1 DF 2
LIEN NUMBER	EQUIPHENT	INDITERIALS OF CONSTRUCTION	FLOH (LB/HR)	TENCENATURE (F)	PRESSURE (PSIA)	DESCRIPTION
1VT-6019, B	II SPENT CARBON STURNEE	I CARBON STEEL	1 7674.		14.7	i tudi taaks de different size
IFE-6829, B	II FEEDER	I CARBON STEEL	1 7674.	1 70	14.7	i spent activated cafgon from storage
ED-6014.8	II EDUCTOR	i DURINET 20	1 26679.	-	84	A MOVE SPENT CARBON TO FEED TANK USING WATER
VT-682	I FEED TANK	I 316 STAINLESS STEEL	26678.	2		I FEED TONK FUR REGENERATION FURNICE
1 06-682	i AGITATOR	I 316 STRIMESS STEEL	1 26670.	. 70		I AGITATOR FOR FEED TRACK
11-683 11-683	T FEEDER	: 316 STAINLESS STEEL	: 25678.	1 28 1	_	I TO DEMATERING SCREW
20-£01	: DEMATERING SCREW	CARBON STEEL	1 2657 8.	8 4		REDUCE TO ARE MOISTURE
UT-683	: Crude water storage	I 316 STRIMLESS STEEL OR ACID BRICK	- 30206.	67	14.7	· RECIRCULATION TANK
leg-co	· CRUDE WATER PUMP	I CAST LEON	30286.	8 2	8	RECIRCULATE TO EDUCTOR
FE-634	- FEDER	I CARBON STEEL	1 65 34.	6	_	I FEED REGENERATION FURNACE
FR-601	REGENERATION FURNACE	-	5394.	_		1 DRVING (258-308 F) BOKING (908-1408 F) FEBEN (1888 F)
11-684	ALENCH TRAK	316 STAINESS STEEL	17004	-		. ROTTOM OF RESERVEDIN FURNICE
11-685	I FEEDER	I 216 STAINLESS STEEL				I BOTTOM OF GLENCH TANK
89 61	PRODUCT EDUCTOR	PURIME 20	24235	-	_	" MOVE PEGENERATED CARBON TO STURAGE
11-685	REGEN CARBON STURAGE	316 STATINESS STEEL LINED	1 24295.	97 1	14.7	: SAME SIZE AS LANGEST SPENT CARBON TANK
19 0 6 61	: 4617 ATOR	_	-	-		; MOUNTED ON REGENERATED CARBON STORAGE THAK
90 9-31 -	FEEDER	-	-		_	TO DEMATERING SCREW
20-64C	I DEMATERING SCREW	CARBON STEEL	- 24295.	_		I REDUCE TO 40-50% MOISTURE
5 - 63 - 63 - 63 - 63 - 63 - 63 - 63 - 63	· LATER PIMP	I CDANCU INPETLER	13607.	161 .:	: 14.7	· RECIRCULATE TO PRODUCT EDUCTOR
FL-682	I PRODUCT WATER FILTER		1 21691.	1	8	I FILTER RECIPCULATION WATER
VI-68	ERODUCT HATER STORAGE	1 216 STAINLESS STEEL OR FAP LINED	1 E1691.	153	14.7	RECIPCULATION TANK
CD-603	I PRODUCT LIGTER PLAN	I CAST IRON	1 21631.	1	8	RECIRCULATE TO PRODUCT EDUCTOR
HE 601	. PRODUCT WATER COOLER	! 94-18 CU/NI TUBES, 316 SS SHELL	1 21691.	16 -23:	8	: COOL PECIRCULATION MATER, J.9 MM BTU/HR
CN+CN+CN	COMEYOR	: CAPBON STEEL	- S208.	8 1 1	14.7	RECENERATED CARBON TO SHIPPING
			u - 1991 1 97 1 971 1 971 1 97		<u>.</u>	
-	•·· •• ••		• • • • •			
				iers depend on pr (erent added der	HYSICAL PLANT PEV. 1	ד נאיסטיד
	-		_	-		

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REV. 1		solar fuels and chem	itcals system des	IGN STUDY		SPEAT ACTIVATED CARBON REGENERATION
11-21-62		CHENC	XIL PROCESS			REGENERATION
		EQUIPHENT	LIST BY FLOW			PAGE 2 CF 2
LIEN MUREN	EGUI PRENT NOTE	HOTERICAL OF CONSTRUCTION	(18//8)	TEMPERATURE	(1) 20 DRESSNEE	DESCRIPTION
DC-681	NULL COLLECTION	CARBON STEEL	1 12506.	98 98 95	ĸ	CVCLOREREEDERATION FURNICE OFFERS
1 65 11	I DUST FEEDER	CARBON STEEL	-	_		r bottom of nust collector
16-682	I OFF G4S HEATER	I INCOMEL 600 TUBES, 204 55 SHELL	12566.	- 200-1500	ស	I USE MOLTEN SOLT TO PREPEAT MASTE GAS TO INCINERATOR
58-965	I OFFGAS INCINERATOR	I REFRACTORY LINED	1 12503.	1 12001200	8	I DISPOSE OF MOSTE GAS
109-HL	I SCRUPBER	I 316 STAIMLESS STEEL	1 4144A.	1200	R	I SCRUB INCINERATOR FLUE BAS
199 10	i scribber njap	÷ (5-8		-		I RECTROULATE SCRUBBER MATER
1-683	I WOTER FILTER	•		-		I FILTER RECIRCULATION WATER
HE-683	SCRUBBER COOLER	TIERS SS 912 "SERIL IN/DD 01-06 i	. .			1 COOL SCRUBBER HATER
199	DRAFT FON	· 304 STRINLESS STEEL	50545	- E		I EXHAUST GAS FROM SCRUBBER TO STROK
5T-681	E STROK	1 204 SS LINED OR ACID BRIDK	1 50245.		14.7	I DISCHARGE TO ATMOSPHERE
				HENT 200ED PER 1	PEV. 1	14301

TABLE 6 (CONTD)

APPENDIX D

ECONOMIC ASSESSMENT

SUPPORTING DATA

APPENDIX D - ECONOMIC ASSESSMENT

SUPPORTING DATA

<u>Table</u>	Title
D-1	Plant Capital Cost Summary
D-2	Capacity Summary: Worldwide
D-3	Supply/Demand Summary: Western Europe
D-4	Supply/Demand Summary: Japan
D-5	U.S. Producers of Activated Carbon
D-6	Western European Producers of Activated Carbon
D-7	Asian Producers of Activated Carbon
D-8	Financial Analysis for Baseline Solar Plant With 0%
	Escalation Rate.
D-9	Financial Analysis for Baseline Solar Plant With 3%
	Escalation Rate.
D-10	Financial Analysis for Natural Gas Plant With 0% Escalation
	Rate.
D-11	Financial Analysis for Natural Gas Plant With 3% Escalation
	Rate.
D-12	Component Costs for Comparison to Five Year Research and
	Development Plan 1986-1990.

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

TABLE D-1

PLANT CAPITAL COST SUMMARY

D-2

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	Ō
	2.4.2.8 Foundation (Hot Salt Tank)	50.000	Ő
	2.4.2.5000 Process Equipment	185.150	Ő
	2.4.2.5000.5 Tanks	185.150	Õ

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	n

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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	Ō
5.3.1 Process Waste Water Treatment	180.000	0
5.3.2 Sanitary Waste Water Treatment	135,000	Ō

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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

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TABLE D-2

CAPACITY SUMMARY: WORLDWIDE

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

* Estimated capacity as of January, 1985.

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

TABLE D-3

SUPPLY/DEMAND SUMMARY: WESTERN EUROPE

ALL ACTIVATED CARBON - 1983 (Millions of Pounds)

0	Capacity*	223
0	Production	170
ο	Imports	15.5
ο	Exports	35
0	Consumption	150

o Capacity Utilization = 76%

	GRANULAR	ACTIVATED CARBON (GAC) - 198	3
		GAC Estimated	GAC Estimated
		Annual Capacity*	Market Share
	Producer Country	(Millions of Pounds)	(Percent)
0	Belgium	20	18
o	France	22	20
0	West Germany	21	19
0	Netherlands	40	37
0	United Kingdom	_26	6
TOT	AL ESTIMATED GAC CAPACITY	109	100%

* Also estimated capacity as of January, 1985.

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*
SUPPLY/DEMAND SUMMARY: JAPAN

<u>ALL ACTIVATED CARBON - 1983</u> (Millions of Pounds)

0	Capacity*	143
ο	Production	123
0	Imports	10
0	Exports	5
ο	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.

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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	S.	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	٢	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

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TABLE D-5 (Cont'd)

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U. S. PRODUCERS OF ACTIVATED CARBON

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

	Company and Plant Location	Annual Capacity as of January 1985 (millions of pounds	Raw Material	<u>Trade Name</u>	Type	Primary End Uses
In	tco Chemical Corporation organic Specialties Div. Fostoria, OH ⁸ Petrolia, PA	ν ν	Petroleum base residues, coconut shells, coal	Colombia Witcarb	Granular, extruded	Gas-phase applica- tions, catalysts, industrial liquid and water purifica-
	TOTALħ	348		•		tion, solvent recovery
69	Two companies are not producer: Jacksonville, Florida, supplie: Columbus, Ohio imports from Fri	s, but supply activ s powdered and gran ance and Mexico.	ated carbon to the ular grades from th	U.S. market; Aπ e Netherlands;	kerican Norit North America	Co., Inc., of n Carbon, Inc., of
þ.	Plant is primarily for reactiv	ating carbon.				
ن. د	Purchased activated carbon pla	it from Kennecott C	corporation in 1982.			
ч .	U. S. production of activated overseas.	carbon is limited;	most activated carb	on products are	e purchased as	finished products from
e.	American Norit Co., Inc. has a facilities, in June 1985.	l agreement to buy	ICI's activated car	bon department,	including th	e manufacturing
4	Purchased from Merck by Calgon	group of employees	: by spring, 1985; n	ew name to be C	algon Carbon	Corporation.
\$	Purchased this plant from Unio	n Carbide in 1981.				
Ъ.	One industry source estimated	total U.S. capacity	for activated carb	on in 1985 to b	e 283 millior	l pounds instead of 348

TABLE D-5 (Cont'd)

U. S. PRODUCERS OF ACTIVATED CARBON

D-12

million pounds.

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	CARBON
	ACTIVATED
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TABLE D-6	PRODUCERS
	EUROPEAN
	WESTERN

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company and Plant Location	Annual Capacity as of January 1985 (thousands of metric tons)	Raw Material	Type	Remarks
NELGIUM Maltimore Aircoil- themviron sa Owned 63% by Calgon Orporation, USA and 7% by Baltimore Aircoil Co., ISA (owned by Merck & Co. inc., USA)				
Feluy	10	Coal	Mostly granular	
RANCE ECA SA owned 99.97% by Compagnie inanciere de Paris et des				
'ays-bas SA - <i>P</i> AKIBAS) Parentis-en-Born	12	Wood, coal coconut shells	Powdered, granular	
ociete Pica S A Vierzon	ω		Coconut shells eranilar	Powdered,
ERMANY, FEDERAL REPUBLIC OF				
Leverkusen	10	Lignite/peat	Powdered, eranular	
ergwerkaverband GmbH owned 100% by Bergbau-Forschu	gu			
moh <i>)</i> ssen	٣	Coal	Powdered, granular	

2 thousand metric tons regeneration unit of Mainly regeneration. Essentially a Currently not producing. capacity. Remarks Both Powdered Type Peat na na 1 WESTERN EUROPEAN PRODUCERS OF ACTIVATED CARBON Raw Material Wood, coal Mood only 1 TABLE D-6 (Cont'd) Coal Annual Capacity 36 na metric tons 9 ო January 1985 (thousands of Coconut shells as of GERMANY, FEDERAL REPUBLIC OF (Continued) 2 (owned over 25% by GfC Gesellachaft (owned 100% by NCB (Coal Products) (owned 100% by CECA SA (France)) Company and Plant Location Ing. A. Bonaccorsi & C.Srl 1 fuer Chemiewerte mbH) Thomas Ness Ltd. Chemviron, Ltd. Anticromos SpA UNITED KINGDOM Klazienaveen Brilon-Wald NETHERLANDS Zaanstad a Legnano Coedely Norlt NV Ferrara Degussa Grays Ltd.) ITALY

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BON	Remarks		ed Expansion to 10 thousand metric tons per year by 1982. Process is chemical activation with phosphoric acid.		
2 ATED CAR	Type		Powder	s/ na	
ABLE D-6 (Cont'd)	Raw Material		Wood	Coconut shell: coal	
I MESTERN EUROPEAN PE	Annual Capacity as of January 1985 (thousands of <u>metric tons</u>		10	υ	105
	Company and Plant Location	UNITED KINGDOM (Continued) Norit-Clydesdale Co. Ltd. (owned 100% by Norit NV (Netherlands))	Glasgow	Sutcliffe Speakman Leigh	Total

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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 ACTIVAT	TED 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	1
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	1
Futamura Chemical Industry Co., Ltd. Minokamo, Gifu Prefecture	Powdered 13,000	Coconut shell		Production is about 70%
	Granular 2,400	Coal	TAIKO	and 85% for PAC.
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
	Granular 2,000	Coconut shell, coal		or fact froutcion of GAC is greater than 75% of capacity.
Hokutan Chemical Industry Co. 144				
Toda, Saitama Prefecture	Granular 1,000	Coal, coconut per year. shell	STARCOAL	Production is 600 tons
• • •	× * *			

		TABI ASTAN PRODUCI	LE D-7 (Continued ERS OF ACTIVATED) CARBON - 1984	
<u>Company and Plant Location</u>		Annual Capacif by Type <u>(metric tons)</u>	ty <u>Raw Material</u>	Trade <u>Name</u>	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
Sankyo Sangyo Ltd. Amagasaki, Hyogo Prefecture	Granular	1,200	Coconut Shell	DIASORB	Production is 960 tons per year

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	ASIAN	Table PRODUCERS	<pre>p-7 (Continued) OF ACTIVATED CARB</pre>	<u> 1984 - 1984</u>	
	Annual Cap by Typ	acity e	Dour Motonial	Trade	Damostra
company and Flant Location	(metric t	01157	TRIJATEL MRY	Nallie	Velial XS
<u>JAPAN</u> (Continued) Shinagawa Carbon Co., Ltd. Shogawa, Toyama Prefecture	Powdered Granular	360 120	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	
U Takeda Chemical Industries, © 144					
Shimizu, Shizuoka Prefecture	Granualar	6,000	Coconut shell	SHIKASAGI	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 (mostly)	5,400	Coconut shell, coal, charcoal	TSUORUMICOAL	
Total	Granular 3 Powdered 2	19,540 14,840			
Total Japan	9	4,380			

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	Remarks	Υ.	Steam process for PAC. Some	exports to Japan.	About 90% of production exported to Japan.	Exported to Japan.
<u> 30N - 1984</u>	Trade Name	na	e C		na	na
<u>e D-7 (Continued)</u> s OF ACTIVATED CARE	Raw Material		Sawdust		Coconut shell	Coconut shell
Tabl ASIAN PRODUCERS	Annual Capacity by Type (metric tons)	មួយ	Powdered 2,000		Granular 5,000	Granular 2,500
	Company and Plant Location	<u>KOREA, REPUBLIC OF</u> Yoolin Chemical Industrial Co., Ltd. Kimpo	<u>MALAYSIA</u> 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	6 6 6 7 7 7 7 7 7 7 7 7 7 7 7 7	Hendue, Cebu	Davao Central Chemical Corporation (joint venture of Takdea Chemical Ind. (Japan), Mitsubishi Corporation (Japan, and local capital in the Philippines)) Davao

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	ASIAN	Table PRODUCERS	D-7 (Continued) OF ACTIVATED CARB	ON - 1984	
Company and Plant Location	Annual Ca by Ty (metric	pacity pe 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	в Ц	
Phillippine-Japan Active Carbon Company (joint venturi of Futamura Chemical Industry Co., (Japan) and Kowa Co. (Japan)) Mindanao	Granular	3,000	Coconut shell	ង	
Total Phillippines	Powdered Granular	0 11,700			
<u>SINGAPORE</u> Singapore Activated Carbon Company Singapore	Powdered	600	na		
<u>SRI LANKA</u> Hayleys Lts. Colombo	Granular	1,000	Coconut shell	na	

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Company and Plant Location	Annual Capacity by Type (metric tons)	Raw Material **	e e
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 <u>1,200</u> 6,000		
Total Asian	21,300		

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

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

c. Data include annual capacity for regenerated carbon.

Taihei Chemical Industry Co. (Japan) and Kowa Company (Japan) have withdrawn from the joint venture. SOURCE: CEH estimates. Ģ.

<u>Table D-7 (Continued)</u> ASIAN PRODUCERS OF ACTIVATED CARBON - 1984 Remarks

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ANALYSIS FOR BASELINE SOLAR PLANT WITH 0% ESCALATION

ECONOMIC MALIYSIS FOR SOLAR FUELS AND	CHENICALS	SVSTENS 1	NESIGN STU	٩V																			
:	241	2661	1661	5441	9661	1991	8661	6661	2000	2001	2002	2003	2004	29 02	5006	007	500	00 20	10 201	11 201	2013	201	
Capital Espenditures Land	272	•	•																				
Plant and Equipment						• •																	
	1221		1221	1128	1120	1128	1128	1128	112	1128	1129	1128	1128	1120	1128	128 1	128 11	28 11	211 82	8 112	1 1126	112	
	11001	12001	10021			121		N i	N a		1	1	134		1.24	51 5	1		= : 5 :			=	
Total Conventional	1110	14340	11340	2012	2012	2012	2045	2045	SADS	2012	2045	2045	2045	2065	2045	1065	731 045 21	20 IV	42 30 37	12 201	206	202	_
Total Plant and Equipment	14897	16972	16842	2615	2142	2415	2412	2415	3192	2415	2615	2615	2615	2615	2192	192 3	12 24	52 31	21	2 319	2 319	316	
Levenues																							
Activated Carbon				23213	21213	23213	23213	1213 2	3213	21213	23213	22213 2	23213 2	3213 2	3213 2	1213 23	213 23	213 232	13 232	13 2321	3 2321	1222 2321	
Regenerated Carbon Sultar				7000 9	200 9	2000 0	200	7000	900	992 900	7000 7000	200 200	8 °	90 200	992 °	8°	× 8	2 90	8 8	8	0 200	8 <u>6</u>	
Electricity				• 6	• 6	° 9	° 8	• 6	• 8	• 8	° (1	° 8	• 9	• 6	• 9	° 6	• 63	• 00	9 9 9	• 0	• • •		_
Tars and Dils				-294	1967	1967	196	196	696	111	696	176	196	192	947	196	615	967 9	19	- 5	36	8	
Systhetic Eas Total Aeronus (+)				31716	31716	1116 I	1714 L	11716 J	• 111	31716	31716	31716 J	81716 J	61716 J	1716 3	1716 JI	0 II 110 II	0 716 317	0 16 317	0 16 3171	6 3171 (317	_
failes, femeral and																							
Adesaistrative Expense (~)				70 m	1007	1997	70 BY	1907	a a	1995	1085	1001	200	1087	1987	1081	FF 908	7	75 75	38	9	380	
berraciation Espense (-) Solar Partion of Plant Conventional Partion of Plant				3612	18081 11081	8549 10180	1856 59/8	9022 9444	1128 7507	87126 8711	1120	1128 7048	1128 5942	1128	1128	92 IS	128 1	51 I 51 I 51 I 51 I 51 I 51 I 51 I 51 I	12 12 12	2 E 2 E	6914 817	5 228 616 80	_
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TABLE D-8 (CONT.)

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ANKIAL DPERATION AND MAINTENANCE EXPENSES (costs in thousands of dollars)

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Veriable Cests Fuel	Fired Costs Operating Labor (16 I 535,000) Maintenance Labor (10 I 535,000)	Naintemance Materials and Contracts Naterials Contracts	Derating Consumbles Salt Routement (32/yr) Hiscellaneous Supplies Total Fired Costs	Tatal Power Plant Oak Coats	- Chenical Plant	Activated Carbon Production Variable Costs Variable Costs Cost	coal Tar Pitch Bhoshoric Arid (733)	Bydrachloric Acid (301) Total Variable Costs	Fined Costs Accession (13) accounted)	Fringe Benefits (201 of labor)	Maintenance Labor (3% of capital costs)	Maintemance Naterials and Contracts Docestics Constina (192) of Ameratina Jahor)	Plant Overhead (80% of all labor)	Total Fixed Costs Total Praduction Costs - Activated Carbon	Regeneration of Spent Carbon Operating Labor 15 personnel)	Fringe Benefits (201 of operating labor) Total Production Costs - Regenerated Carbon	Tetal Chenical Plant OHM Costs
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FINANCIAL ANALYSIS FOR BASELINE SOLAR PLANT

WITH 3% ESCALATION RATE

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NEMECIATION SCHEDULE																							
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Total Depreciation Exponse for Balar Purtien of Plant	fal e			295	877	61 <u>6</u> 1	59/8	2206	1128	1128	1120	9211	1128	1120	1128	1128	1128	1120	120 1	241 1	-	547	a.
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Tetal Depreciation Expense for Communicational Pertion of Plant	Converti	1		3612	11001	10190	1956	Ŧ	(154	2775	818	7048	2945	2045	2065	2156	2165	2210	Į	9/0	2	10	1

TABLE D-9 (CONT.)

TABLE D-9 (CONT.)

AMMUN. ØFERATION AND MAINTENANCE EIPENSES (conts in thousands of doilars)

- 16. 1.4	Marinhle Costs Fuel	Fired Casts Operating Labor (16 1 435,000) Reintenance Labor (10 1 435,000)	Haintenade Materials and Contracts Naturials Contracts	Operations built Represents (SUyr) Ancellandous Supplies Total Fired Casts	Tatal Power Plant BM Costs	- Desical Mat	Activated Extens Production Variable Conta Variable Conta Contactuals	Caul Tar Pitch Poopharic Acid (752) Hedracharic Acid (302)	Total Variable Costs	Fired Casts Operating Labor (33 personnel)	Fringe Banefits (201 of Labor) Maintenance Labor (31 of canital costs)	Maintenance Materials and Contracts	Operating Supplier (102 of operating Jabor) Plast Emerand (BOT of all labor)	Total Franktim Costs - Activited Carbon Total Pranktim Costs - Activited Carbon	Regeneration ef Spent Carbon Dearstag Labor (5 personal) Frage Bueneits (2016 operating labor) Tatal Prakerins (2014 - Boonsarins Carbon	Justal Chanical Plant Old Conts
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	394	35 0	511 14	59 1134	1220		01.71	59 99 N	1492	1184	222	8511	61 Q	2065	12 P (2	13654
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TABLE D-9 (CONT.)

Aunt Monistian and IEVE	SHOTLIGHU SH	ir creates in the	in the share	14.0																			
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Activated Carbon (Ibs) - Praduction - Price - Annaua	1.13	2147000 24 24.4 21212	A. 14	12 March 24	1.02 1.02 2545	1.05 1.05 26126	1.01 1.01 1.02	24946000 24 11.1 27717	1.14 1.14 28549	11-18 29465	1.21 1.21 30287	1.25 1.25 31194	1.29 1.29 2132 1	0000 2494 1. 33 1 3094 34	000 24940 -17 -1- -28 - 15	1966 26960 -7- 17	.45 1	01612 000 1 61.		10 3 4 F	872	
Ingenerated Carbon (1)	ki - Prakolin - Price - Breen	5.1	2000000 X 87.4 7000	0.14 0.14 7210	0.57 0.17 7426	000000 20 9.28 7649	00000 20 6.31 7879	00000 14.0 1113	20000000 20 0.42 8358	1.43 1.43 1.43	000000 200 0.44 0.44	00000 200 0.44 9.111	0000 200 0.47 9467	0000 2000 8.45 9.45	0000 2000K	000 20000 1.51 0 280 10	606 20600 1.53 0 588 10	000 2000 1.55 6 904 11	000 20000 1.51 0 233 11	00 20000 156 0	00 2000 .40 .11	99 19:52	
Systactic for (Mtu)	- Prakctien - Price - Broom	77	• 3 •	• * •	• 3 •	• ;; •	6 3.71 0	• 11 •	• 1 •	• 4 •	• • •	4°21 •	° 17 °	4°21	• • •	• 25 •	• ÷ •	• • •	4 9 4 2	- 1 -	• 4 •	• F •	
Extricity (so)	- Production - Price - Revenue	0.94314	1500000	1500000 1.06503 1.12	1 100001 1 1 1110-0	- 192 - 192	50000 10110	60006 62176 254	6.07539	1.0745 0	50000 K -07996 A	00000 EC		00000 BSA 06740 0.1	0000 E50 1002 E.0	000 8500 7777 0.09	600 E50 1350 1.01 112	000 1500 1170 0.11	000 8500 122 0.14 141	000 E500	000 8500 749 0.11	860 17	
by-yradiuct Tars Itans	- Production - Price - Bernaun	8	1145 19.00 19.0	754 5714 5714	4745 105.05 1026	8745 11.001 1066	100 11.111 1111	876 11.11 111	9212 12.011 12.011	9745 121.76 1189	9765 125.41 1225	9765 29.17 261	9745 133.05 1279	11 10 10 11 10 10 11 10	8745 11.15 11.11	1420 149 1420 149	212 G	1/12 1/24 1/24			27 3	1997 1997 1997	
Product Salling Price and Cost Esculation Facto	fruit/Fandatack Fuel/Fandatack F		1.800 J. 800	1.836	1.030	1.039	1.636	1.03 0 1.030	1.039	1.026	1.039	1.036	1.056	1.030	1.020 1		1 929	1 020.	98		- 950	920	
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Caul Tar Pitch (tam		a X Š		242 242 290	2 2 2 <u>5</u>	595 595	5955 5255 7257	198 198 198	5962 5962	5965 5965	99 ²⁴ 25	29 ES 45	55 \$₹ \$₹		a e a	2545 489 712	5 5 5 E		n n Naz	5 55 55 55 55 55	12 CR 12	20 1 1	
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FINANCIAL ANALYSIS FOR NATURAL GAS PLANT

1	ECONOMIC ANALYSIS FOR SOLAR FUELS AND CHEN	ICALS SYNCI	TENS AESI	AMLS 1101			IM	D HT	% ES	CALA	IION	RATE													
		2441	1661	16	544.]	1994	1997	8661	5661	2000	2001	2002	2003	2004	2005	2004	2007	2008	2009	2010	2011	2012	2013	\$01 4	
	Capital Espenditures Land Plant and Equipment	147	Inti	•	2012	2012	2012	2012	2012	2013	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	2012	
	Revenues Activited Carbon Regenerated Carbon Galfer Tera and Oils	•			25215 7000 9 11100	23213 7000 947	23213 7000 6 147	23213 7000 967 967	23213 7000 947 947	23213 7006 967 967	23215 7800 947	23213 7000 967 711.000	23213 7000 947	23215 7000 947	23215 7000 9 0	23213 7000 967 1120	23213 7000 947	23215 7000 947	23213 7000 947	23215 7000 947	23213 7600 747	7000 7000	7000 967	7000 947	
	inci promov (*) Sales, Seneral and Mainistrative Espanse (-)				2045	2142	342	2142	3742	3142	3142	3742	3742	2742	21/2	3742	2142	2142	2)42	3142		2) (C	2142 a	2742	
	bepre ciation Exponse (-)	9	•	•	1179	5/07	512	4908	2109	5310	5995	5270	15MS	2172	2012	2012	2102	2108	2202	2403	2105	1114	3999	0104	
	Bperating Costs				16211	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	11794	1 14/1	1911	
	lacom before Tax				5721	1756	10133	10734	10535	10224	10555	10374	\$6101		1772	13433	13542	1351	13443	1341	12940	12470	11646	1276	
	laee . Bisto, 01. Foderal, 461 Dither Tauen, 11 Lavestamet Tau Crudit, 101 Tatal Taues (-)	111	ы	IHI	102 102 104	40 10 10 10 10 10 10 10 10 10 10 10 10 10	110 2012 2012 2013 2014	556 201 2205	843 7 201 201	627 4576 7 201 5005	944 7 201 201	810 4387 7 201 5023	815 4310 7 201 4932	801 7 201 201 201 201	1091 5744 7 201 201	1091 5746 7 201 201	1083 5728 7 201 4417	1083 5725 7 201 8414	1075 5685 7 201 8567	1059 5466 7 201 5464	1035 5475 7 201 201	998 5274 7 201	2264 2264 2010	771 7 201 4451	
	Net Jacone Fros Operations				9629	1691	1622	1755	1116	I	ĨĦS	1925	2261	1/15	9169	0/67	5241	2269	\$189	5//1	9799	7372	2883	4983	
	Hep reciation Expense (+)	٠	•	•	111	5015	2112	8061	2109	9110	5005	5270	5451	27.92	2012	2012	2102	2108	2202	2405	20105	3174	3666	0109	
	Het Cash Flow From Operations				9470	11026	10743	10439	10540	1041	10530	10421	10712	10803	1848	1868	9027	9030	9077	8/16	9330	9544	1866	2660	
	Marting Cupital Requirements				2742	3742	3742	3742	3742	3742	3742	3742	3742	2)42	2142	2742	3742	3742	3742	2342	3742	2142	2142	2)42	-4
	lacromental Norting Capital	-14157	01141-	19251-	1091-	•	•	•	•	•	•	•	•	•	9	٠	¢	•	9	•	•	•	9	•	245
	Tetai Net Cash Flows	11/21-	-12049	-13948	2982	9014	12/8	8427	6258	0248	8219	8410	10/8	2618	0264	6470	7015	7018	7044	1417	1319	2257	9797	B982 3	242
	Met Present Value for Discount Late	- 55 - 12 - 12 - 12 - 12 - 12 - 12 - 12 - 12		201510 20151																					
	isterail fate of Setura 14 20.073																								

ENECTATION EXCLATION EXCLANTION	Tstal bepaciation Espena Pertian of Plant enconnecteonoconnecteonoc	Amuk, PCANINE AD NAINTENNEE EFFE - Demical Plant Activated Carlus Production Veriable Carlus Call Call Call Plant Progenic Acts (781) Negenic Acts (781) Nege
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2011 2012 2013 2014 2017 2017 2017 2017 2017 2017 2017 2017	3	214 214 215 215 215 215 215 215 215 215 215 215
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	2108	1134 1134 1134 1134 1134 1134 1134 1134
	2902	21% 1916 151 151 152 153 153 153 153 153 153 153 153 153 153
	2443	2194 1946 151 151 152 153 119 1527 1289 119 1280 1280 1280 1280 1280 1280 1280 1280
	2765	211 212 213 213 214 215 215 215 215 215 215 215 215 215 215
	3174	219 1946 1946 11946 1194 1194 1194 1194 1
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181 251 251 251 251 255 265 265 265 261 201 201 201 201 201 201 201 201 201 20	e 191	21 12 12 12 12 12 12 12 12 12 12 12 12 1

TABLE D-10 (CONT.)

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TABLE D-10 (CONT.)

PLANT PRODUCTION AND REVENUE	PROJECTI ONS	trevenue in th	ausands of dal	lars)										•								
	-	hit cost																				
Activated Carbon (lbs)	- Production - Price - Bevenue	6,93	24946006 21 0.93 23213	1940000 24 0.93 21215	96000 241 0.93 23213	940000 24 0.93 23213	960000 241 0.93 23213	940000 0.93 23215	24940000 2 0.45 0.45	1966000 21 0.93 23213	1940000 241 0.43 23213	140000 241 0.93 23213	0.93 0.93 23213	60000 249 0.93 23213	0.95 0.95 15213 2	6006 249/ 0.93 13213 2	0000 2494 0.93 3213 2	0000 2496 0.93 (3213 2	0000 2496 0.93 0.93 1 3213 2	0000 2496 0.93 3213 2	0000 2494 0.93 3213 2	0000 0.93 3213
Reyenerated Carbon (15s)	- Praduction - Price - Revenue	e. 15	2000000 2 0.35 7000	000000 20 0.15 7000	000000 201 0.35 7000	000000 20 0.35 7000	000000 20 0.35 7000	000000 0.35 7006	20000000 2(0.35 7900	000000 26 0.35 7000	000000 20(0.15 7000	00000 200 0.35 7000	00000 200 0.35 7000	00000 2001 0.35 7000	0000 2000 0.35 7000	0000 2000 0.35 7000	0000 2000 0.35 7000	0000 20000 0.35 7000	000 2000 0.33 7000	0000 2000 0.35 7000	000 2000 0.35 7000	0000 0.35 7000
Synthetic Gas (NBtu)	- Production - Price - Revenue	1.30	e 9. i 9	9 9 9 9 1	• 9î •	• 9 • 11	0 9 9 Fi	• 97 •	30 ° 9	3. Jo 9	• 9 • 1	• 9 , •	3,30	° 9, ° ''	, i 1 1 1 1 1 1 1	1. Yo	• 3 • 	• 9 •	• 9 •	• 9 •	• • • •	• • • •
By-preduct Tars (tans)	- Production - Price - Revenue	3.8	5979 80.99 748	2916 5916	2719 29.89 23.8	196 90°64 5764	5764 90°64	296 5979 296	9745 967 967	5745 64.00 749	97.65 99.09 947	9765 997.00 749	176 5979 5979	9745 99.00 947	9745 94.00 967	9745 94.00 947	9745 99.00 967	9765 9.00 967	7 53 7 60 7 61 7 61	9165 90.00 139	9745 94.00 94.7	7745 90.69 967
Product Selling Price and Fu Cast Escalation Factor	at foodstack		1.000	1.000	1.000	1.006	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	000	000	1 000	1 000.	1 000.	1 000-	1 000.	
ANY NATERIALS AND FIEL	ltotal costs in ti	of te sheered	ller)																			
Coal (tons)	Quantity Unit Cost Total Can		19126 11%	44 214 214	9612 97	49920 44 2194	9412 97	4928 44 2194	49920 44 2196	9612 7196	49920 44 2194	49920 44 2196	49920 44 2194	49926 44 2196	1920 44 2194	1920 11 2194	19720 44 2196	9920 4 44 2196	19920 44 2196	19920 44 2196	9920 44 2194	19920 44 2194
Easl Tar Pitch (tans)	Buantity Unit Cost Total Cos			222 223 294	55 E 14			SH N	2552 211 1141	5555 223 1946	5155 5155	2552 212 448	555 555	5545 111 1846	5555 212 1046	545 21 194	5955 511 1941	2545 211 1846	55 E 10	5955 514 1819	222 ES 19	53 FF #
Magharic Acid (tass)	buentity Unit Cost Total Cost	-	338	338	338	395	335	395	59 99 6X	338	398	299 6E	59 99 62 59 99 62	33 83 62	S9 9 61	31 99 ES	39 9 E	595 6004	59 9 65 59 9 65	335	595 596 609	545 600 119
Nydrachiaric Acid (ta	asi Buantity Unit Cast Total Cas	**	75. 75. 75.	1227 1221	1254 126	951 951	1256 151	72 8 E	120	921 921	122	128	921 921	151 151	128	128 129	128	1256 120 151	1254 120	128 129 12	1221 121 121	12 23 51 12 23 51
Hatural Gas (Mbtu)	Recently Unit Cont Total Con	. 	28986 3.36 95	28900 3. 30 75	28900 31.36	28900 3.30 95	28900 3. 34 29	28900 3.30 95	28900 3.50 8	28900 J. JO	28900 3.36	28900 3.30 95	28900 3.36	28900 3.36	28900 3.30	3.30	28900 3.30 95	00680 3.30 27	28400 3.50	28900 3.30	0068 97.00 92.1	9968 97.5
Electricity (MM)	Quantity Unit Cost Tetal Co	ž	1921.0000 008500 848	10210000 1 0.00500 1 040	0210000 11 0.08500 4	0210000 1 1.08500 1 848	0.08500 1 0.08500 1	0210000 0.00500 0.0	10210000 6.66500 848	1 0000 1 0.05500 848	0210000 1(0.08500 0 848	210000 1(08500 - 0 848	210000 10 - 08500 0. 848	210000 10. .08560 0.	10000 102 08500 0.02 848	10000 102 08500 0.1	10000 102 08500 0.(848	10000 102 08500 0.6	10000 102 08500 0.(10000 102 08500 0.(848	10000 102 8500 0.4	10000 10000 110000

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FINANCIAL ANALYSIS FOR NATURAL GAS PLANT

WITH 3% ESCALATION RATE

D MAN STERN AND STATE FOR STUAR FIELD	ENICALS SYS	TENG NEBU	ANUS II																				
	2441	2661	ł		N	141	Ĩ	Ē	9947	2001	2002	2065	2004	500	70	67	ž	4 201			201	Ŕ	_
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COSTS FOR COMPARISON TO FIVE YEAR R&D PLAN 1986-1990

Plant Rating - 35,000 kWt Heliostat Field - 76,000 M² 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 5.1.2.3 5.2.2.3 5.4.2.3	\$ 400,000 \$ 191,900 \$1,147,800 \$ <u>319,700</u> \$2,059,400	\$ 59/kW _t
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System	0 9 + Total Direct	\$3,735,200 \$ <u>5,767,000</u>	
Total System (Costs	\$38,340,000	\$1095/kW+

APPENDIX E

USES AND APPLICATIONS FOR ACTIVATED CARBON

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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.

<u>Cane and Beet Sugar</u> - 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

<u>Taste and Odor Control</u> - 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.

<u>Organic Compounds</u> - 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.

<u>Municipal Wastewater</u> - 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.

<u>Industrial Wastewater</u> - 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 service basis, where the responsibility for а 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 Such manufacturing operations as petroleum refineries and these. chemical plants use specially designed activated carbon grades for this Nonindustrial applications involving purpose. 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.

<u>Industrial Gas Purification</u> - 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.

<u>Miscellaneous</u> - 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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