345
9/21/84 JS (1)

DA-0418-9

DOE/MC/19045-1626
(DE84011992)

OPERATING COSTS AND PLANT OPTIONS ANALYSIS FOR THE SHAMOKIN FLUIDIZED BED BOILER

By
**M. G. Klett
T. E. Dowdy
R. Litman**

March 1984

Work Performed Under Contract No.: DE-AM21-82MC19045

For
**U. S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia**

By
**Gilbert Associates, Inc.
Reading, Pennsylvania**

**TECHNICAL INFORMATION CENTER
OFFICE OF SCIENTIFIC AND TECHNICAL INFORMATION
UNITED STATES DEPARTMENT OF ENERGY**

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A05
Microfiche A01

Codes are used for pricing all publications. The code is determined by the number of pages in the publication. Information pertaining to the pricing codes can be found in the current issues of the following publications, which are generally available in most libraries: *Energy Research Abstracts (ERA)*; *Government Reports Announcements and Index (GRA and I)*; *Scientific and Technical Abstract Reports (STAR)*; and publication NTIS-PR-360 available from NTIS at the above address.

OPERATING COSTS AND PLANT OPTIONS ANALYSIS FOR THE SHAMOKIN FLUIDIZED BED BOILER

By
**M. G. Klett
T. E. Dowdy
R. Litman**

March 1984

Work Performed Under Contract No.: DE-AM21-82MC19045

For
**U. S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P. O. Box 880
Morgantown, West Virginia 26505**

By
**Gilbert Associates, Inc.
Reading, Pennsylvania 19603**

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
1.0	<u>SUMMARY</u>	1
2.0	<u>INTRODUCTION</u>	3
3.0	<u>DATA COLLECTION AND ANALYSIS</u>	8
4.0	<u>OPERATING COST PROJECTIONS - HISTORICAL OPERATIONS</u>	20
4.1	OPERATING COST ESTIMATE	20
4.2	COMPARISONS WITH PROJECTED COSTS AND REVENUES	23
5.0	<u>OPERATING COST PROJECTIONS - FUTURE OPERATIONS</u>	29
5.1	OPERATING COST ESTIMATE - PRESENT CONFIGURATION	29
5.2	SENSITIVITY ANALYSIS - PRESENT CONFIGURATION	33
5.3	OPERATING COST ESTIMATES - RECONFIGURED PLANT	42
5.4	SENSITIVITY ANALYSIS - RECONFIGURED PLANT	46
5.5	OPTIONS TO IMPROVE PLANT ECONOMICS	49
5.5.1	<u>Increase Steam Sales and/or Price</u>	49
5.5.2	<u>Replacement of Electric Drives with Steam Turbine</u>	52
	<u>Drives</u>	
5.5.3	<u>Reducing or Eliminating Limestone Feed</u>	53
5.5.4	<u>Operating Labor</u>	54
6.0	<u>CONCLUSIONS</u>	57
7.0	<u>REFERENCES</u>	58
Appendix A	Landfill Regulatory Requirements for Disposal of Ash	59
Appendix B	Sample Calculations	73
Appendix C-1	Shamokin Operating Cost Summary	80
Appendix C-2	Shamokin Operating Cost Summary Gross Sales Options	88
Appendix D	Definition of Terms	92

TABLES

<u>Table</u>		<u>Page</u>
1	Fluidized Bed Boiler Design Parameters	5
2	Shamokin Anthracite Culm-Fired Boiler Operating Summary	9
3	Ultimate Analysis of Shamokin Anthracite Culm	11
4	Typical Limestone Analysis	13
5	Electric Power Costs	16
6	Water Costs	16
7	Other Variable Costs	18
8	Fixed Costs	18
9	Shamokin Anthracite Culm Boiler Extended Test Plant Availability	19
10	Base Case Parameters - Historical	22
11	Historical Base Case - Cost Breakdown	24
12	Projected Operations and Maintenance Costs	26
13	Budgeted Versus Actual Cost - Extended Test Period	27
14	Base Case Parameters - Full Commercial Operation	31
15	Commercial Operation Base Case - Cost Breakdown	32
16	Sensitivity Summaries - Commercial Operation	37
17	Reconfigured Plant Base Case - Cost Breakdown	45
18	Sensitivity Summaries - Reconfigured Plant	47
19	Steam Cost from Oil or Gas Fired Boiler	51
20	Effect of Operating Labor Requirement on Operating Cost	56

FIGURES

<u>Figures</u>		<u>Page</u>
1	Feed Preparation and Storage	4
2	Boiler System	4
3	Potential Revenues Versus Average Steam Flow	34
4	Breakeven Price Versus Steam Production	35
5	Operating Cost Versus Steam Production Factor - Restart Case (\$ per hour)	40
6	Operating Cost Versus Steam Production Factor - Restart Case (\$ per 100 lb steam)	41

SUMMARY

This report presents the results of a study that examined the operating costs and options to improve the Shamokin Atmospheric Fluidized Bed Combustion Demonstration Plant located near Shamokin, Pennsylvania. The purpose of this study was to perform an operating cost analysis and compare the results with projected operating costs. An analysis was also made to identify possible cost savings options. Two base case scenarios were developed for this study:

- o The first scenario assumed that the plant operated in a manner similar to operations during the extended test program.
- o The second scenario was concerned with two options. One option assumed upgrading the plant to achieve continuous full load operation, restarting, and used revised costs and revenues. The second assumed reconfiguring the plant for cogeneration.

A sensitivity analysis was performed using parameters such as steam production factor (load factor times availability), anthracite culm cost, limestone cost, combustion efficiency, Ca/S ratio, waste disposal costs, and operating labor requirements.

Based on the plant performance data, the operating cost estimates, and the cost sensitivity analysis, the following conclusions are made:

- a. The Shamokin facility has demonstrated the technical ability to generate steam from anthracite culm with both a high reliability and reasonable operating cost. However, the current steam selling price is too low to recover full operating costs even at full steam flow. A steam selling price of approximately \$6 per 1000 lb of steam would allow the unit

to break-even on an operating and maintenance basis at steam sales rates of 11,500 lbs/hr. This price should be very competitive if customers can be found.

- b. Projected and actual operating costs show substantial agreement.
- c. The largest contributors to operating costs are labor and electricity which each make up about 30 percent of operating costs. No other item makes up more than 10 percent of operating costs.
- d. None of the cogeneration options could allow operation at "break-even," much less pay back the relatively large investments required for cogeneration. Essentially, the boiler is too small in capacity and the design steam temperature and pressure is too low for the unit to be a cost effective power generator. No other system changes could be recommended which would reduce operating costs substantially.

INTRODUCTION

In the Fall of 1978, the U.S. Department of Energy awarded a contract to the Shamokin Area Industrial Corporation (SAIC) of Shamokin, Pennsylvania to design, construct, and operate a fluidized bed boiler fueled with anthracite culm, waste product from anthracite coal preparation. The project team supporting SAIC, an industrial- development oriented agency seeking to bring new jobs and industry to the Shamokin area, included Dorr Oliver and E. Keeler Company who, together, designed and built the fluidized bed boiler. Stone and Webster Engineering Corporation was responsible for the fuel preparation and water treatment systems as well as the overall plant integration. Curtiss-Wright Corporation was the overall program manager with management and procurement responsibilities, and was additionally responsible for the automatic control system and instrumentation.

The boiler plant was designed to produce 20,000 lb/hr of 200-psig saturated steam, to be sold to a nearby paper manufacturer or other customers on a variable-demand basis 24 hours a day, 7 days a week. Figures 1 and 2 show the demonstration plant equipment and flow diagram. Table 1 gives the design boiler data.

The plant began initial operation in August 1981. After startup and shakedown tests, 17 parametric tests were conducted between October 1981 and June 1982. Continuous plant operation resumed on August 9, 1982, after completion of the parametric testing and a scheduled annual maintenance period. The plant ran continuously from August 9, 1982 to April 30, 1983, when it was shut down due to completion of the DOE-supported program. Cellu Products Corporation, the only commercial customer for the steam, purchased an average of only 3000 lb/hr during this period. The plant, while operating continuously, was only at about 40 percent load. Excess steam above the 3000 lb/hr utilized by the customer (approximately 5000 lb/hr) was vented to the atmosphere.

Figure 1
Feed Preparation and Storage

Figure 2
Boiler System

TABLE 1
FLUIDIZED BED BOILER DESIGN PARAMETERS

Steam Flow, net	20,000 lb/hr
Steam Flow, gross*	23,400 lb/hr
Steam Condition	200 psig saturated
Bed Dimensions	10 x 10 ft
Bed Height	4 - 6 ft
Fluidizing Velocity	3.5 - 6 ft/s
Bed Temperature	1450 - 1650° F
Sulfur Capture	88%
Turndown (steam)	2.5 - 1
Convection Area	2966 ft ²
Furnace Area	1360 ft ²
Freeboard Height	16 ft
Furnace Volume	2100 ft ³

* 3400 lb/hr used internally by deaerator

This study was conducted in two phases.

The objectives of the first phase were to:

- o Document the historical operating costs, and, thereby, the steam production cost and revenue requirements (excluding capital charges) for the AFBC Demonstration Plant,
- o Perform a sensitivity analysis to identify those parameters which have the greatest effect on the operating cost, and
- o Define cost saving recommendations that might make future operation of the plant economically viable.

After a review of the first phase assumptions by SAIC and Curtiss-Wright, the second phase of the study began. The objectives of the second phase were to:

- o Compare actual to projected cost and revenues.
- o Based on operating cost saving recommendations of Phase I, assess the options that could reduce operating costs or increase revenues.

This report presents the results of both phases.

The study contains an estimate of the operating costs for the plant based primarily on historical operating and maintenance costs from the extended run period of August 9, 1982, to April 30, 1983. During this period of operation, culm was supplied free of charge, solid wastes were stored temporarily on-site, and steam was sold at an attractive price to the consumer. It was also found that, because of some minor bottlenecks, the plant could not operate

continuously at full load. Thus, two base case scenarios were developed for this study:

- o The first scenario assumed that the plant operated in a manner similar to operations during the extended test program, (i.e., the historical base case).
- o The second scenario was concerned with two options. Option A assumed upgrading the plant to achieve full load continuously, restarting, and assuming revised costs and revenues (i.e., the full commercial operation base case). Option B assumed reconfiguring the plant for cogeneration (i.e., the reconfigured plant base case).

A sensitivity analysis was performed using parameters such as steam production factor (load factor times availability), culm cost, limestone cost, combustion efficiency, Ca/S ratio, waste disposal costs, and operating labor requirements.

It should be noted that the operating costs established in this report are for a site specific first-of-a-kind demonstration plant. In general, these costs should not be used for generic fluidized bed boiler operating costs or for comparison with alternative methods and fuels for steam production.

Reliable consumption rates and unit costs for raw materials, utilities, waste disposal, and labor were required to estimate operating costs. Such data were obtained by discussions with Curtiss-Wright and Shamokin Area Industrial Corporation personnel as well as from published sources. Historical data from the nine month extended test were obtained from Curtiss-Wright and are summarized in Table 2.

Fuel Cost: The fuel used is anthracite culm. The Shamokin area contains mountains of anthracite culm that have accumulated over the years. This culm presents an eye sore to the community as well as an environmental problem because of acid water runoff. Several processors are now in the business of reclaiming and upgrading the raw culm; however, their operations only scratch the surface of the available material. Basically, the culm represents more of a liability than an asset at the present time. The Pennsylvania Department of Environmental Resources (PaDER) periodically attempts to require the owners to limit acid water runoff into streams and groundwater by building lined ponds.

Through the operational period to date, the fuel has been provided at no charge from a local anthracite processing operation. This operation purchases run-of-mine anthracite and upgrades it to high quality anthracite, producing culm as a waste byproduct. The culm is then trucked several miles to a location for disposal. The plant has provided this material to the Shamokin FBC site at no charge because it is considerably closer than the normal disposal site and thus, their cost of culm disposal has been reduced. SAIC believes that culm could still be obtained from this source at no cost or at a very nominal charge for future operation. However, this source could only provide 50 to 75 percent of the culm required for continuous operation if the FBC boiler is operated at full load for an extended period of time.

TABLE 2

SHAMOKIN ANTHRACITE CULM-FIRED BOILER OPERATING SUMMARY

CATEGORY	1982					1983			
	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APRIL
SAIC Labor	\$17,466	\$17,997	\$19,061	\$18,154	\$17,687	\$19,195	\$17,419	\$18,844	\$17,306
Electricity	13,269	16,382	15,352	16,498	12,018	15,904	16,184	14,587	11,403
Water	1,368	1,761	1,638	1,613	1,210	1,897	1,600	1,686	1,743
Start-Up Oil	1,430			1,567	1,544		505	1,451	
Insurance	4,369				9,924	813	813	813	813
Loader Fuel & Lube	519	39		98	57	39			579
Maintenance									
General Maint.	2,335	760	4,350	1,110	3,850	6,565	6,030	5,385	2,040
Computer & Tape Rec.			790	620	620	620	170	170	
Gas Analyser		1,223						1,402	
Sample Analysis	764	764	764		1,852		616		1,395
Subtotal	41,520	38,926	41,955	39,660	48,762	45,033	43,337	44,233	35,279
Limestone Cost	296	633	792	666	275	517	484		
Steam Revenues @ 2.595	3,367	5,545	5,419	5,861	3,591	5,150	6,160	6,050	3,724

The above discussion provides an indication of why it is difficult to obtain a "fair market value" for anthracite culm. Basically there is no market for raw culm. Upgraded culm (i.e., culm which has been processed to improve heating value by removing ash and/or moisture) can be priced, but this material would exceed the Shamokin FBC boiler requirements. The upgrading adds considerably to the cost, with a non-linear relationship existing between heating value and cost; i.e., cost goes up more rapidly than does heating value.

At the present time, SAIC receives anthracite culm free of charge delivered to the site. Discussions with SAIC personnel indicate that SAIC could obtain all the raw culm that the FBC unit could fire at a cost of \$2.00 per ton delivered to the site. They have seen prices of \$2.60 per ton for culm that has been crushed by the vendor, but not upgraded in heating value. They stress that such prices must be negotiated. As there is no market, owners do not know what is a reasonable charge and a wide range of quotes will be obtained. Potentially, anthracite culm represents a significant energy resource in the local geographical area. However, more of a market must develop before prices will firm up. Based on SAIC's estimate, a full commercial operation "base case" cost of \$2.00 per ton for anthracite culm was utilized.

The anthracite culm fired at the plant has varied considerably in composition and heating value. Table 3 lists the design fuel analysis with the actual range of analyses encountered during parametric testing.⁽¹⁾ Additionally, the table shows the midpoint values which were used in this report.

Limestone: Limestone was provided from a local source. This limestone represented a low-grade material for which the supplier had no other use. Most of the \$5.50 per ton cost was associated with the requirement that the material be crushed and sized by the

TABLE 3
ULTIMATE ANALYSIS OF SHAMOKIN ANTHRACITE CULM⁽¹⁾

	<u>Design</u>	<u>Actual</u>	<u>Average</u>
Carbon %	27.02	24.15 - 26.59	25.37
Hydrogen %	1.42	0.89 - 1.04	0.965
Nitrogen %	0.66	0.47 - 0.56	0.515
Oxygen %	3.48	3.06 - 5.33	4.195
Sulfur %	0.57	0.73 - 0.94	0.835
Ash %	66.85	67.3 - 69.3	68.12
HHV, Btu/lb	4198	3918 - 4164	4041

supplier and delivered via a pneumatic truck. SAIC believes that this price is reasonable for future operations as well. Table 4 gives a typical analysis of the limestone.

Ash Disposal: The historical base case shows no cost for ash disposal, since through the present time, ash has been temporarily stored at the site. If the unit is restarted for extended operation, the waste material would have to be permanently disposed. Several options have been identified.

Option A, the +50 mesh material has been approved by the Pennsylvania Department of Transportation as an anti-skid material. This potential market for 30 to 40 percent of the material produced (most of the bottom ash) could be sold at a price of \$2.00 to \$4.00 per ton. Some additional classification of the bottom ash might be needed to remove excess fines.

Option B, both the FBC flyash and bottom ash could potentially be utilized as extenders in cement and other limestone related products. The major criterion for this application is that the carbon content must be less than two percent. Thus, the total ash generated or the flyash not sold as anti-skid material could be utilized. It is anticipated that no charge could be made for such an extender and the user would haul the material away at no charge to the FBC boiler.

Option C, it has been brought to PaDER's attention that FBC ash is basic, not acidic, and that heavy metals do not leach as from conventional fly ash. PaDER is considering changing the classification of FBC ash material to allow the material to be "returned to the hole" from which it was removed. This would apparently be implemented as a part of the reclamation plan for the mining operation, and would help neutralize acid water runoff from

TABLE 4
TYPICAL LIMESTONE ANALYSIS

Total CaO, %	37.15
Available CaO, %	0.095
MgO, %	1.92
Na, ppm	248
K, ppm	242
Fe, %	1.37
Al ₂ O ₃ , %	2.31
SiO ₂ , %	15.86
Acid Insolubles, %	22.55
Cl, ppm	200
Acid Evolution CO ₂ , %	31.73
LOI @ 1000° C, %	32.22

these operations. Such a disposal method would not involve landfill tipping fees, as discussed below, but would require hauling of the ash to the disposal site and placing it as directed by the mining operator. A charge of \$2.00 per ton would cover hauling for a one-way distance of 20 miles or less for this method of disposal.

Option D, the material could be disposed of at an approved landfill as is normally accomplished with conventional flyash. Under normal circumstances obtaining an ash disposal cost by this method would not present a problem. Disposal charges, or tipping fees, would be obtained from approved landfills in the area, with trucking charges added to obtain an ash disposal cost. As of July 1, 1983, all of the landfills in the immediate Shamokin area were closed as they were not in compliance with PaDER regulations. In the future either these landfills will be brought into compliance and reopened or new landfills will be constructed. The future charges will be higher than any historical charges.

Requirements for landfill disposal are mandated by PaDER regulations (see Appendix A). Any approved landfill must meet these requirements. As there are currently no approved landfills in the Shamokin area, representative costs were obtained for landfill disposal from other sources. Fluidyne Engineering Corporation provided their projected cost of landfill disposal for the FBC boiler currently under construction at East Stroudsburg State University. Their cost will be \$3.27 per cubic yard (approximately one ton/cubic yard) for disposal plus \$3.00 per ton to truck a distance of approximately 30 miles. This total cost of approximately \$6.27 per ton seems reasonable for landfill disposal. Fluidyne is also considering the options of use as an anti-skid material and/or as an extender.

In calculations for full commercial operation of the FBC boiler, the Option C cost of \$2.00 per ton was applied. This cost represents a compromise between the extremes of selling the material and landfill

disposal. The effect of varying the cost of ash disposal is discussed in the sensitivity analysis.

Electrical Power Cost: The historical average electrical charges and usage along with the estimated full load charge and usage are given in Table 5. The historical and estimated full load electrical charges were used to establish a linear relationship between the steam flow and electrical cost.

The average steam flow for the most recent nine months of operation was 8730 pph. The full design boiler flow rate is 23,400 pph with 3400 pph being used internally by the deaerator, yielding a net steam flow of 20,000 pph. Thus, the power charges were fit with the linear equation relating power cost to steam flow rates. The equation used is given in Table 5.

Water Cost: The average and estimated full load water cost is given in Table 6. The water usage is actually about twice that required for boiler feedwater, with the balance being used for sanitary and miscellaneous items. The water consumption was also fit with a linear equation, since additional usage will probably vary fairly linearly with load. The equation generated is included in Table 6.

Other Variable Costs: The additional cost factors of general maintenance, computer supplies/service, and front end loader operation/maintenance will also vary approximately with average boiler load. These items were lumped together to yield an "other variable" linear equation as shown in Table 7.

Fixed Cost: Such items as operating labor, startup fuel oil, insurance, sample analyses, and gas analyzer system maintenance are essentially independent of operating load. These fixed cost items are summarized in Table 8. As seen, the operating labor is the largest factor in the fixed cost.

TABLE 5
ELECTRIC POWER COSTS

	<u>Historical Average</u>	<u>Estimate For Full Load</u>
Electrical, \$/mo	14,622	20,000
Net Steam Flow, pph	8,730	20,000

Equations:

$$$/mo \text{ Total} = 0.4772 \times \text{Steam Flow (pph)} + 10456$$

$$$/hr = 0.0006537 \times \text{Steam Flow (pph)} + 14.32$$

TABLE 6
WATER COSTS

	<u>Historical Average</u>	<u>Estimate For Full Load</u>
Water, \$/mo	1,613	3,200
Net Steam Flow, pph	8,730	20,000

Equations:

$$$/mo \text{ Total} = 0.1408 \times \text{Steam Flow (pph)} + 383.70$$

$$$/hr = 0.0001929 \times \text{Steam Flow (pph)} + 0.5256$$

TABLE 7
OTHER VARIABLE COSTS

	<u>Historical Average</u>	<u>Estimate For Full Load</u>
Gen. Maint, \$/mo	3,603	6,300
Loader, \$/Mo	148	400
Computer, \$/Mo	<u>332</u>	<u>1,000</u>
Total \$/Mo	4,083	7,400
Net Steam Flow, pph	8,730	20,000

$\$/\text{mo Total} = 0.2943 \times \text{Steam Flow (pph)} + 1513$

$\$/\text{hr} = .0004032 \times \text{Steam Flow (pph)} + 2.073$

TABLE 8
FIXED COSTS

SAIC Labor, \$/mo	18,125
Startup oil, \$/mo	725
Insurance, \$/mo	1,765
Sample Analyzer, \$/mo	300
Gas Analyses, \$/mo	<u>300</u>
Total, \$/mo	21,215

$\$/\text{hr} = \$21,215 / 730 \text{ hrs} = \29.06

Note: Additional cost by Curtiss-Wright or others for engineering support of testing is estimated at \$8,000 (minimum) to \$16,000 (moderate) per month.

Steam Revenues: The current single customer for the steam generated by the plant has a negotiated charge rate of \$3.48 per thousand pounds of steam purchased. Additionally, the customer was allowed a 25 percent credit because he was required to maintain his own backup boiler and it was anticipated that the availability of the demonstration boiler might prove to be low. This brought his net rate to \$2.595 per 1000 lb steam. An additional factor that should be considered is that the customer's actual usage has been considerably lower than originally planned, averaging only approximately 3000 pph. This has kept actual revenues lower than anticipated for the plant.

Assuming that a customer could be found who could utilize a larger quantity of the steam produced, a key factor would be the determination of the fair market value of the steam.

Gilbert/Commonwealth's data indicate that industrial customers in the eastern Pennsylvania area are paying \$5 to \$6 per million Btu's for natural gas. Thus, a steam charge in the range of \$5 to \$6 per 1000 lb steam would seem reasonable. This is discussed further in the following sections.

Plant Availability: The plant availability experienced during the extended test was provided by Curtiss-Wright and is shown in Table 9. The cumulative availability experienced during the nine months was 92.5 percent, which was used in this study.

Boiler Efficiency: The parametric test data are still being analyzed by Dorr Oliver and Curtiss-Wright and boiler performance data have not been published. However, preliminary data indicated full load efficiency was in the 70 percent range. For this study, the design efficiency of 73.5 percent was used.

TABLE 9
SHAMOKIN ANTHRACITE CULM BOILER
EXTENDED TEST PLANT AVAILABILITY

<u>Period</u>	<u>Hours Run (Fluidized)</u>	<u>Hours Available</u>	<u>Percent Availability</u>
Aug. 9 - Aug. 31, 1982	540	540	100.
Sept. 1 - Sept. 30	718	720	100.
Oct. 1 - Oct. 31 *(Water & Elect. Service Interrupted to Plant)	736.5*	744	99.
Nov. 1 - Nov. 30	720	720	100.
Dec. 1 - Dec. 31, 1982 Planned shutdown for Refractory Installation & Maintenance	368	558 ⁽¹⁾	66.
Jan. 1 - Jan. 31, 1983 Replaced Baghouse bags & Seals	679	744	91.
Feb. 1 - Feb. 28	672	672	100.
Mar. 1 - Mar. 31 Installed Cyclone Recycle Pipe Extension	668.5	744	90.
April 1 - April 30, 1983 Evaluated Bituminous Waste & Low Temp. Start on Culm	528.5	648 ⁽²⁾	82.
Cumulative	5630.5	6090	92.5

(1) Excludes planned shutdown for refractory installation

(2) Excludes planned investigation of low temperature ignition of culm

4.0

OPERATING COST PROJECTIONS - HISTORICAL OPERATIONS

In this section estimates are provided of the operating costs for the Shamokin Fluidized Bed Combustion demonstration facility, using assumptions based upon conditions similar to conditions achieved during the recent nine-month demonstration operation.

4.1

OPERATING COST ESTIMATE

The design capacity of the Shamokin fluidized bed boiler is 23,400 pph of saturated steam at 200 psig. Of this steam, 3400 pph is used internally by the deaerator, leaving a net amount available for export of 20,000 pph.

During recent operation, the Shamokin unit was only able to sell an average of 3000 pph of steam. Additionally, the negotiated selling price of the steam was low, basically to reflect an uncertainty as to the reliability of the demonstration boiler. This has resulted in net revenues from steam sales which were significantly below the theoretical revenues of the unit.

A factor to consider is there are a few bottlenecks still remaining at the plant that prohibit long-term, continuous operation at full load. Notable among these considerations is that the baghouse operation is not acceptable at full load, this limiting operation to 75 percent of full load at the present time. An increase in baghouse size to decrease the air-to-cloth ratio would be required to allow full load operation of the baghouse. A combination of limited funds and a lack of demand for full steam production has prohibited modifications necessary to achieve full load operation.

The culm being fired at the facility was delivered to the site at no charge. This might continue in the future, depending upon what arrangements could be negotiated with the culm suppliers, at least for a portion of the culm. It is more likely that some charge would

be made for the culm for a long-term production operation. It should be noted that in order to deliver 3000 pph of steam it was necessary to operate the boiler at a higher load, since this load was below the minimum turndown of the facility. This has adversely affected the operating cost of the unit as compared to the actual revenues. However, the effect was not as great as it would have been if the culm had not been provided free.

During operation to date, the ash generated from the system (i.e., fly ash and bottom ash) has been stored in a temporary storage area located at the site.

The 88 percent SO₂ removal quoted in the unit operational permit and which was achieved is considerably higher than required for operation of similar capacity boilers in this area. Also, the facility has conducted a number of parametric tests since startup. Therefore, the historical Ca/S has been fairly high, averaging about 4.

The historical base case is based upon conditions similar to conditions achieved during the recent nine-month demonstration operation including those described above. The assumption is made that customers could be found for a higher flow rate of steam. Also, it is assumed that no modifications would be made to the system so that maximum capacity would still be limited to the current maximum of approximately 15,000 pph net or 75 percent load factor. Other conditions for the historical case are given in Table 10. This case is representative of conditions that would be encountered if the unit is restarted in its current configuration. It should be noted that before the plant can be restarted some overhaul work, primarily to the I.D. fan and ash removal system, would be necessary. Curtiss-Wright⁽²⁾ estimated that the cost of these items would be \$75,000.

TABLE 10
BASE CASE PARAMETERS
Historical

Load Factor = 0.750	Limestone Cost = \$5.50/ton
Availability = 0.925	Culm Cost = 0.00
Steam Production Factor = 0.694	Ash Disposal Cost = 0.00
Internal Steam Use = 2,550 lb/hr	
Export Steam = 15,000 lb/hr	
Boiler Efficiency = 0.735	
Ca/S Ratio = 4.0	
HHV Culm = 4041 Btu/lb	

A breakdown of the components of the operating cost is given in Table 11 for the historical base case. The largest components of the cost are labor and electricity. All other items are relatively small. To significantly reduce the operating cost, either the labor or electrical costs, or both, must be reduced.

4.2 COMPARISONS WITH PROJECTED COSTS AND REVENUES

Operating costs were projected for the Shamokin plant for two purposes. One was to assess the economic feasibility of the concept and the other was for budget planning purposes for operations. In this section, both types of projected costs are compared to the actual costs and the major discrepancies are discussed.

In August 1979, a study was completed which compared the capital and operating costs of steam for a 20,000, 50,000, and 100,000 lb/hr FBC boiler using anthracite culm as a fuel source.⁽³⁾ The capital cost of the 20,000 lb/hr boiler was arrived at from the actual equipment cost and estimated engineering and installation costs at Shamokin. The operating costs for the FBC boiler included all raw material such as culm, limestone, chemicals, and water, and all other elements of cost such as electricity, labor, and maintenance. The projected unit costs used are listed as follows:

<u>Item</u>	<u>Unit</u>	<u>Dollar</u>
Culm	Ton	1.00
Limestone	Ton	4.50
Chemical	Per 1000 lbs H ₂ O	0.20
Water	1000 gal. H ₂ O	1.20
Electricity	Kwh	0.03
*Labor	Hour	8.00

*This is average labor cost including 70 percent overhead.

TABLE 11
HISTORICAL BASE CASE - COST BREAKDOWN

Fixed Cost

	<u>\$/year</u>	<u>%</u>
SAIC Labor	217,500	37.77
Startup Oil	8,700	1.55
Insurance	21,180	3.68
Sample Analysis	3,600	0.63
Gas Analyzer	<u>3,600</u>	<u>0.63</u>
 Total Fixed Cost	 254,580	 44.21

Variable Cost

Culm Cost	0	0
Ash Disposal	0	0
Limestone Cost	21,135	3.67
Electricity	204,900	35.58
Water	28,050	4.87
Loader	3,170	0.55
General Maintenance	56,380	9.79
Computer	<u>7,660</u>	<u>1.33</u>
 Total Variable Cost	 321,295	 55.79
Total Annual Cost	575,875	100.00

Potential Steam Revenue	
(@ \$6.00 per 1000 lb)	729,270
 Net Revenue	 153,395

Table 12 compares the yearly operation and maintenance costs projected from this study to projected costs for commercial operation. It assumes that the unit would be modified as needed to achieve full-load continuous operation and that the full quantity of steam produced could be sold.

A major difference in the two cost estimates was the unit costs used for culm, ash disposal, and electricity. The 1979 study used \$1 per ton for culm and ash disposal and 3¢ per kwh for electricity; this study used \$2 per ton for culm and ash disposal and 5¢ per kwh for electricity. The rationales for the culm and ash disposal costs were discussed previously. The cost for electricity was based on SAIC's actual cost during the extended test period. The other major difference was in maintenance costs, this study's estimate being based on the actual costs during the extended test period. Since the extended test lasted only nine months, some deferrable maintenance may not have appeared, making this estimate slightly low. The differences resulted in this study's estimate of operations and maintenance cost for continuous full load operation being approximately 12.5 percent higher than in the previous study. Basically, projected operations costs from the 1979 study are not significantly different from this study based on actual costs.

The second comparison shows the budgeted versus actual amounts spent during the nine month extended test period. The budgeted numbers were obtained from an internal DOE report. Eighteen months of extended testing had been planned from mid-March 1982 to mid-September 1983. However, only nine months were actually run, from August 1982 to April 1983. Table 13 compares the budget versus actual amounts for the nine months of extended testing.

Budgeted items that were significantly higher included insurance, electricity, and water. Both electricity and water use were considerably higher than anticipated. Maintenance was lower than

TABLE 12
PROJECTED OPERATIONS AND MAINTENANCE COSTS
 (20,000 lb/hr net Culm Fired Boiler)

	<u>1979 Study</u>	<u>This Study</u>
Labor	\$218,781	\$217,500
Startup Oil	-	21,180
Culm	32,412	63,893
Ash Disposal	32,412	49,214
Limestone	17,827	17,632
Electricity	168,542	231,410
Water	29,171	35,865
Loader Fuel and Lube	-	4,400
Maintenance	<u>136,130</u>	<u>86,305</u>
Total	653,993	736,099
Cost, 1,000 lb steam	4.04	4.54

TABLE 13
BUDGETED VERSUS ACTUAL COST
EXTENDED TEST PERIOD
(August 1982 - April 1983)

	<u>Budget</u>	<u>Actual</u>
SAIC Labor	171,246	163,125
Insurance	6,990	15,885
Startup Oil	12,408	6,498
Startup Coal	1,000	0
Culm	*	0
Ash Disposal	*	0
Limestone	*	5,554
Electricity	108,973	131,598
Water	7,577	14,517
Loader Fuel & Lube	0	1,332
Maintenance		
General	51,075	26,533
Computer	3,566	2,988
Gas Analyzer	3,634	2,628
Chemicals	3,516	5,894
Sample Analysis	<u>9,374</u>	<u>6,156</u>
Total Cost	374,359	382,708
Steam Revenues	84,399	44,867
Net Cost	289,960	332,287

*Non-budgeted items, SAIC provided as cost sharing.

budgeted, reflecting, perhaps, deferrable maintenance which was not done. The actual total cost of operations and maintenance during the extended test period came to 2.2 percent over budget which is not a significant difference. The steam revenues were low, since the customer only took about 50 percent of the steam that had been anticipated. This resulted in a net cost 15 percent greater than budgeted.

5.0

OPERATING COST PROJECTIONS - FUTURE OPERATIONS

In this section estimates are provided of the operating costs for the Shamokin Fluidized Bed demonstration facility for two different options concerning future operations. The first option assumes continued operation in the current configuration with, however, a charge for culm and ash removal. The second option assumes that the plant is reconfigured so that excess steam can be used to generate power. Calculations are also provided of the required selling price of steam in order for the facility to break-even on an operational basis, and a sensitivity analysis of key factors is also presented.

5.1

OPERATING COST ESTIMATE - PRESENT CONFIGURATION

This option assumes that the unit would be modified as needed to achieve full-load continuous operation and that the full quantity of steam produced could be sold. This condition would be representative of full commercial operation of the facility.

There are several differences between this option and the historical operations discussed in Section 4.0. Previously, the culm being fired at the facility was delivered to the site at no charge. It is likely that some charge would be made for the culm for a long-term production operation. A \$2.00/ton charge for culm was assumed.

During prior operation, the ash generated from the system (i.e., fly ash and bottom ash) was stored in a temporary storage area located at the site. If the unit is to be restarted for commercial operation, some arrangement must be made for disposal of the ash generated. Thus, for restart conditions, an allowance should be made for ash disposal. It is possible that a buyer might be found for the bottom ash which is less fine than the fly ash. This is dependent upon the ability to locate such a buyer.

In the event that a commercial restart is made, it may be possible to modify the operational permit and/or operate at as low a Ca/S as possible to minimize cost. Based upon data plotted in Reference 1, a Ca/S of 2.5 appears reasonable for a restart condition.

There are a few bottlenecks still remaining at the plant that would prohibit long-term, continuous operation at full load. Notable among these considerations is that the baghouse operation is not acceptable at full load. An increase in baghouse size to decrease the air-to-cloth ratio would be required to allow full load operation of the baghouse. A combination of limited funds and a lack of demand for full steam production has prohibited making the modifications necessary to achieve full load operation.

Curtiss-Wright⁽³⁾ estimated that the cost of these items would be:

	<u>Required to Run Full Load</u>
ID Fan Overhaul	\$ 25,000
Ash Removal Dust Suppression & Misc.	50,000
Increased Baghouse Capacity	105,000
Prepared Culm Storage Shed & Handling	65,000
Improved Material for Ash Conveyor System	15,000
Contingency (10%)	<u>26,000</u>
	\$286,000

Base case parameters used for the full commercial operation option are summarized in Table 14.

A breakdown of the components of the operating cost is given in Table 15 for the commercial operation base case. As with the historical base case, the largest components of the cost would be labor and electricity. All other items would be relatively small. To significantly reduce the operating cost, either the labor or electrical costs, or both, would have to be reduced.

TABLE 14
BASE CASE PARAMETERS
Full Commercial Operation

Load Factor = 1.000	Limestone Cost = \$5.50/ton
Availability = 0.925	Culm Cost = 2.00/ton
Steam Production Factor = 0.925	Ash Disposal Cost = 2.00/ton
Internal Steam Use = 3,400 lb/hr	
Export Steam = 20,000 lb/hr	
Boiler Efficiency = 0.735	
Ca/S Ratio = 2.5	
HHV Culm = 4041 Btu/lb	

TABLE 15
COMMERCIAL OPERATION BASE CASE - COST BREAKDOWN

Fixed Cost

	<u>\$/year</u>	<u>%</u>
SAIC Labor	217,500	29.55
Startup Oil	8,700	1.18
Insurance	21,180	2.88
Sample Analysis	3,600	0.49
Gas Analyzer	<u>3,600</u>	<u>0.49</u>
 Total Fixed Cost	 254,580	 34.58

Variable Cost

Culm Cost	63,893	8.68
Ash Disposal	49,214	6.69
Limestone Cost	17,632	2.40
Electricity	231,410	31.44
Water	35,865	4.87
Loader	4,400	0.60
General Maintenance	68,174	9.26
Computer	<u>10,931</u>	<u>1.48</u>
	481,519	65.42
 Total Cost	 736,099	 100.00
 Cost, 1000 lb steam	 4.54	
 Potential Steam Revenue (@ \$6.00 per 1000 lb)	 972,360	
 Net Revenue	 236,261	

Figure 3 shows a plot of annual operating cost versus potential revenues for various steam selling prices. Also plotted is the estimated annual operating cost for the commercial operation conditions. It is significant to note that the current steam selling price would be too low to recover full operating costs even at full steam flow. Selling prices of \$5 to \$6 per 1000 lb of steam would allow the unit to break even or generate a small profit (excluding capital charges) at high steam production factors.

Figure 4 shows the necessary selling price needed to break-even on an operations and maintenance basis at various steam production rates for both the historical and commercial operation base cases. The break-even point for the commercial operation case is higher since both culm and waste disposal costs are assumed. Also included for comparison are the predicted and budgeted operations cost for the Shamokin facility.⁽³⁾ This plot graphically illustrates the necessity to sell reasonably large quantities of steam to break-even. An average steam production of 11,500 lb/hr of steam would allow a break-even selling price of \$6.00 per 1000 lb of steam. This appears to be both a reasonable price and to be well within the generating capability of the unit.

5.2 SENSITIVITY ANALYSIS - PRESENT CONFIGURATION

The previous sections have presented estimates of the operating cost of the Shamokin FBC demonstration plant. In generating the figures a series of assumptions were made as itemized in Table 14, Base Case Parameters for the Full Commercial Operation case. In this section a sensitivity study is presented that shows the effect of changes in the Base Case Parameters upon the economics of the plant. A number of terms are used to represent the parameters considered in the sensitivity analysis. Definitions of these terms are included in Appendix D.

FIGURE 3
POTENTIAL REVENUES VERSUS AVERAGE
STEAM FLOW

FIGURE 4
BREAK EVEN PRICE VERSUS
STEAM PRODUCTION

The sensitivity analysis was performed to determine the effect upon the operating cost of variations in several key parameters. This analysis provides information as to areas that might be modified in order to lower operating costs or otherwise improve revenues.

Table 16 summarizes results of calculations of operating costs for the commercial operating case. Sample calculations are provided in Appendix B and complete printouts are shown in Appendix C. In these cases, the base load factor is 1.00, the Ca/S is 2.5 and culm cost and ash disposal cost are \$2.00 per ton of material for each. The load factor of 1.00 assumes that the plant has been modified to allow continuous full load operation.

Figure 5 shows a plot of operating cost in dollars per hour versus steam production factor (SPF). The operating cost would increase essentially linearly with increases in the steam production factor. Figure 6 shows a plot of operating cost in \$/1000 lb steam versus steam production factor. This figure shows the sensitivity of the required selling price of steam to the steam production factor. As seen from Figure 6 or Table 19, for steam production and sales of 18,000 pph or greater (i.e., $SPF = 0.9$), the break-even steam selling price could be as low as \$4.60 per 1000 lb steam.

A review of Table 16 shows the operating cost is not very sensitive to either boiler efficiency or calcium-to-sulfur ratio. Relatively large changes in these parameters cause only small changes in operating cost.

The operating cost is quite sensitive to both culm cost and ash disposal cost, however. Operating costs, expressed either in \$/time or \$/1000 lb steam, increase linearly and rapidly with increases in either culm or ash disposal cost.

TABLE 16
SENSITIVITY SUMMARIES -
COMMERICAL OPERATION

<u>Case No.*</u>	<u>Load Factor</u>	<u>Steam Cost, \$/1000 lb</u>	<u>Case No.*</u>	<u>Limestone Cost, \$/ton</u>	<u>Steam Cost, \$/1000 lb</u>
41	0.50	6.66	79	0.00	4.43
42	0.55	6.24	80	2.00	4.47
43	0.60	5.89	81	4.00	4.51
44	0.65	5.59	36	5.50	4.54
45	0.70	5.34	82	6.00	4.55
46	0.75	5.12	83	8.00	4.59
47	0.80	4.93	84	10.00	4.63
48	0.85	4.76	85	12.00	4.67
49	0.90	4.61	86	14.00	4.71
36	0.925	4.54	87	16.00	4.75
50	0.95	4.48	88	18.00	4.79
			89	20.00	4.83

<u>Case No.*</u>	<u>Boiler Eff</u>	<u>Steam Cost, \$/1000 lb</u>	<u>Case No.*</u>	<u>Ca/S</u>	<u>Steam Cost, \$/1000 lb</u>
51	0.60	4.72	56	0.0	4.41
52	0.65	4.65	57	1.0	4.46
53	0.70	4.58	58	2.0	4.52
36	0.735	4.54	36	2.5	4.54
54	0.75	4.53	59	3.0	4.57
55	0.80	4.48	60	4.0	4.62
			61	5.0	4.68

*Case No. 36 is the base case; for complete details see printout in Appendix C-1.

TABLE 16 (Cont'd)
SENSITIVITY SUMMARIES
COMMERCIAL OPERATION

<u>Case No.*</u>	<u>Culm Cost, \$/ton</u>	<u>Steam Cost, \$/1000 lb</u>
62	0.00	4.15
36	2.00	4.54
64	4.00	4.94
65	6.00	5.33
66	8.00	5.73
67	10.00	6.12
68	12.00	6.51
69	14.00	6.91
70	16.00	7.30
71	18.00	7.70
72	20.00	8.09

<u>Case No.*</u>	<u>Ash Disposal, \$/ton</u>	<u>Steam Cost, \$/1000 lb</u>
73	0.00	4.24
36	2.00	4.54
75	4.00	4.85
76	6.00	5.15
77	8.00	5.45
78	10.00	5.76

<u>Case No.*</u>	<u>Power Factor</u>	<u>Steam Cost, \$/1000 lb</u>
36	1.00	4.54
90	.75	4.13
91	.50	3.73
92	.25	3.33
93	0.00	2.93

TABLE 16 (Cont'd)
SENSITIVITY SUMMARIES
COMMERCIAL OPERATION

<u>Case No.*</u>	<u>Labor Factor</u>	<u>Steam Cost, \$/1000 lb</u>
36	1.00	4.54
94	.75	4.19
95	.50	3.86

FIGURE 5
OPERATING COST VS STEAM PRODUCTION FACTOR
RESTART CASE
(\$ PER HOUR)

FIGURE 6
OPERATING COST VS STEAM PRODUCTION FACTOR
RESTART CASE
(\$ PER 1000 LB. STEAM)

BOILER EFF	=	0.735
Ca/S	=	2.5
CULM	=	\$2.0
ASH DISPOSAL	=	\$2.0
LIMESTONE	=	\$5.50

The electrical power factor and the labor factor show strong effects upon the cost of steam as seen in the last two entries of Table 16. These factors represent fractions of current cost levels with reductions obtained by either lowering rates or reducing usage. As noted previously, power and labor represent major fractions of the total plant operating cost. Therefore, the strong sensitivity to these factors is understandable.

5.3 OPERATING COST ESTIMATES - RECONFIGURED PLANT

Since the sale of significantly more steam is not likely in the near future, an investigation was made into the feasibility and economics of reconfiguring the plant for cogeneration.

It must be pointed out that cogeneration was not an initial design goal of the system, rather, the objective was to verify the ability to fire anthracite culm in an FBC boiler. The size of the boiler and steam conditions were established to meet requirements of the smallest size required to verify operation and provide the appropriate steam conditions for customer needs. The unit is simply too small and steam conditions too moderate for good cogeneration. Since steam sales have, to date, proven to be too low to support continued operation, cogeneration has been examined as a possible alternate to keep the unit operating.

In considering cogeneration, a number of assumptions were made. For the base case, all applicable parameters (i.e., costs of limestone, culm, ash disposal, Ca/S, boiler efficiency, etc.) were considered to be the same as for full commercial operation (Table 14). Additionally, it was necessary to consider the selling price of steam, quantity of steam sold, purchase and selling price of power,

turbine generator efficiency, and steam and condenser conditions. The base case cogeneration conditions are listed below.

Selling Price of Steam	\$6.00 per 1000 lb
Quantity of Steam Sold	3000 lb/hr
Purchase Price of Power	\$0.05/kWh
Selling Price of Power	\$0.06/kWh
Turbine Generator Efficiency	0.70

Variations of the above parameters are considered in the sensitivity analysis, Section 5.4.

A special "sell back" rate would be available from the electric utility for power generated from culm. The utility would purchase power at \$.06 per kWhr from a cogeneration facility using culm for fuel. Therefore, an advantage could be realized if all the excess steam was used to generate electrical power, the power sold to the utility at \$.06 per kWhr, and the power required for plant operation purchased back from the utility at \$.05 per kWhr (present energy cost).

An investigation was made to find turbine-generator equipment on the secondary market, since purchasing new equipment from a manufacturer would be extremely expensive. The investigation discovered a suitable system, surplus equipment owned by an Elmira, New York, supplier. The supplier was able to quote on a "never used" G.E. turbine-generator suitable for use at the Shamokin facility. The supplier could furnish the turbine-generator, an air cooled condenser system, switchgear, and all turbine controls for \$455,000 (1983 price). The unit would generate a maximum of 1000 kW, utilizing 200 psig saturated steam at the throttle and condensing at atmospheric pressure with an air cooled condenser.

The budgetary capital cost for the installation of the turbine generator and air cooled condenser is estimated to be:

Turbine-Generator and Condenser	\$455,000
Foundations (Bldg. & Equipment)	25,000
Building (30' x 50' x 16' high)	36,000
Equipment Setting	10,000
Piping, Valves, and Condensate System	100,000
Electrical	<u>80,000</u>
Total	\$706,000

This is in addition to the \$286,000 estimated to be needed to bring the plant up to full load operation making the full cost \$992,000.

The steam generator would be capable of producing 23,400 lbs per hour of 200 psig saturated steam. A total of 3,000 lbs per hour could be sold to a local manufacturer. The balance of the steam could be used to generate electricity and to heat deaerator water. Assuming that 20,000 lbs per hour of condensate could be recovered (neglecting losses), 3000 lbs per hour of feedwater would have to be made-up to the system. This feedwater would have to be heated to deaerator temperature along with the condensate return. It would take approximately 825 lbs per hour of steam to effect this. Consequently, the net amount of steam available for electrical generation would be 19,575 lbs per hour. The turbine generator proposed could generate approximately 780 kW with this steam input. A 92.5 percent availability would drop the average hourly generation to 724 kW.

A breakdown of the components of the operating cost is given in Table 17 for the reconfigured plant base case. The analysis shows that the net revenue that could be received from plant operations would be \$230,500 less than operating costs. This approach, while reducing the operating deficit, is not economically feasible.

TABLE 17
RECONFIGURED PLANT BASE CASE - OPERATING COST BREAKDOWN

Fixed Cost

	<u>\$/year</u>	<u>%</u>
SAIC Labor	217,500	28.72
Startup Oil	8,700	1.15
Insurance	21,180	2.80
Sample Analysis	3,600	0.48
Gas Analyzer	<u>3,600</u>	<u>0.48</u>
 Total Fixed Cost	 254,580	 33.63

Variable Cost

Culm Cost	64,040	8.46
Ash Disposal	49,320	6.52
Limestone Cost	17,700	2.34
Electricity	244,940	32.36
Water	37,970	5.02
Loader	4,660	0.62
General Maintenance	72,170	9.53
Computer	<u>11,570</u>	<u>1.53</u>
	502,370	66.37
 Total Cost	 756,950	 100.00
 Steam Revenue	 145,850	
 Power Revenue	 380,620	
 Net Revenue	 (230,480)	

The air cooled condenser considered above presents the lowest capital cost option for cogeneration, but does not present the best thermodynamic cycle. Options were considered to improve the efficiency of the cycle by utilization of a water cooled condenser and adding superheat to the steam. These options would potentially decrease the deficit in operating costs but would require greater capital expenditures. In no case considered would sufficient revenues be generated to amortize the capital investment.

5.4 SENSITIVITY ANALYSIS - RECONFIGURED PLANT

In examining the sensitivity of cogeneration options, a new set of parameters was considered. The basic costs of culm, limestone, ash disposal, Ca/S, load factor, boiler efficiency, and availability remained as in the commercial operating cases examined. Additionally, however, it was necessary to consider the selling price of steam, quantity of steam sold, selling price of power, and turbine generator efficiency.

Table 18 summarizes calculated net revenues for a series of conditions including culm cost, ash disposal cost, power price, steam price, and the amount of steam sold. Sample calculations are found in Appendix B and complete printouts are shown in Appendix C. Base case conditions were taken as close as possible to the commercial operating conditions, i.e., load factor = 1.00, availability = 0.925, etc.

Additionally, the base case for cogeneration assumes that 3000 pph of steam (i.e., the historical demand) would be sold at \$6.00 per 1000 lb of steam. The balance of available steam would be sent to the turbine generator. Since the selling price of the steam would be significantly greater than the selling price of power that could be generated with the steam in all cases, this represents the most profitable case.

TABLE 18
SENSITIVITY SUMMARIES - RECONFIGURED PLANT

<u>Case No.*</u>	<u>Culm Cost, \$/ton</u>	<u>Net Revenues \$/hr</u>	<u>Case No.*</u>	<u>Steam Sold pph</u>	<u>Net Revenues \$/hr</u>
1	1.00	-22.66	2	3000	-26.31
2	2.00	-26.31	11	4000	-22.98
3	3.00	-29.97	12	5000	-19.65
4	4.00	-33.62	13	6000	-16.32
5	5.00	-37.27	14	7000	-12.99
6	6.00	-40.93	15	8000	- 9.66
7	7.00	-44.58	16	9000	- 6.33
			22	10,000	-3.00
			23	11,000	+0.33
			24	12,000	3.66
			25	13,000	6.99
			26	14,000	10.32
			27	15,000	13.65

<u>Case No.*</u>	<u>Ash Disposal \$/ton</u>	<u>Net Revenues \$/hr</u>	<u>Case No.*</u>	<u>Steam Price \$/1000 lb</u>	<u>Net Revenues \$/hr</u>
8	6.50	-38.98	17	4.00	-31.86
9	3.10	-29.41	2	6.00	-26.31
2	2.00	-26.31	18	8.00	-20.76
10	-.80	-18.43	19	10.00	-15.21
				12.00	-9.66
				14.00	-4.11
				16.00	1.44

*Case No. 2 is the base case; for complete details see printout in Appendix C-2.

TABLE 18 (Cont'd)
SENSITIVITY SUMMARIES - RECONFIGURED PLANT

<u>Case No.*</u>	<u>Power Price \$/kWh</u>	<u>Net Revenues \$/hr</u>
21	.04	-40.79
20	.05	-33.55
2	.06	-26.31

*Case No. 2 is the base case; for complete details see printout in Appendix C-2.

No combination of culm cost, ash disposal cost, and power price came close to breaking-even operationally. A steam price of approximately \$15 per 1000 lb would be necessary to break-even operationally. The amount of steam that would have to be sold to break-even would be reduced slightly in the cogeneration option from 12,000 to 11,000 lb per hour. Under no conditions considered could the unit generate sufficient revenue to pay for the capital charges of the turbine generator and associated equipment.

5.5 OPTIONS TO IMPROVE PLANT ECONOMICS

In addition to reconfiguring the plant for cogeneration, which was discussed in Section 5.4, several other options were identified from the preceeding analysis which were felt to have the potential to improve overall plant economics. By far the greatest effect upon plant profitability could be obtained by increasing steam sales at a higher steam selling price. This option is discussed in Section 5.5.1. It should be noted that in all of the following considerations, maximum profitability would always be obtained at the maximum steam sales rate, since steam is the maximum value product from the facility.

The use of steam turbine drives for reducing electric power costs is considered in Section 5.5.2, limestone usage reduction is considered in Section 5.5.3, and labor reductions in 5.5.4.

Other possibilities to reduce operating costs, such as by improving boiler efficiency, were not considered since there is no practical method to accomplish this.

5.5.1 Increase Steam Sales and/or Price

The Shamokin Area Industrial Corporation has the objective of bringing new businesses into the Shamokin area. One of the incentives which they have used is the availability of steam from

the Shamokin FBC demonstration boiler. Availability of this steam at an attractive price is one of the potential advantages for a business to locate in the Shamokin area.

The Shamokin area and, in general, the anthracite belt, have been economically depressed for a number of years. As a result, SAIC has not been successful in finding a new business to utilize the steam from this plant. The result is that only one customer is now available who can use the steam produced. This customer has only utilized an average of 3000 pph in recent operational periods. Although SAIC has been seeking, and will continue to seek, additional customers, it is not likely that they will be found in the near future.

A related question is, if customers could be found for a larger quantity of steam, what would be a "fair market price"? The current customer already owns a coal fired boiler which he maintains as a backup. It would be more common for a new business locating in the area to purchase an oil or gas fired package boiler to generate 20,000 pph of 200 psig steam, if the Shamokin FBC steam unit was not available. A coal fired boiler is an alternate; however, the capital cost and operating labor would be considerably higher, though the fuel cost would be lower.

Table 19 summarizes a budget estimate of the cost of steam generated from a 20,000 pph oil or gas fired package boiler. These figures indicate that it would cost a new business \$9.52 per 1000 lb steam for gas firing or \$11.64 per 1000 lb steam for oil firing to provide their own steam based upon the assumptions used in the calculations. A selling price below these figures should still be attractive to any new business.

SAIC has had some discussions with potential customers and has suggested a selling price of \$6.00 per 1000 lb of steam. Based upon the above comparison to oil or gas fired boilers, this seems to be a rate that would be attractive to a new business.

TABLE 19

STEAM COST FROM OIL OR GAS FIRED BOILER

	<u>\$/1000 lb Steam</u>	
	<u>Oil Fired</u>	<u>Gas Fired</u>
Capital charge ¹	0.34	0.31
Fuel cost ²	10.58	8.49
Operating Labor ³	<u>0.72</u>	<u>0.72</u>
Total Cost	11.64	9.52

¹ Capital charge based on budgetary estimate of \$249,500 for gas fired and \$272,400 for oil fired package boiler delivered and erected and 0.22 capitalization factor.

² Fuel cost based on \$5.50/million Btu for gas and \$0.95/gallon for oil. Boiler efficiency of 0.76 in both cases.

³ Based on a single boiler operator at \$14.42 per hour.

5.5.2 Replacement of Electric Drives with Steam Turbine Drives

One of the options investigated to improve the plant operating economics was the replacement of electric motors with steam turbines to provide power for the major energy users at the facility. One of the feedwater pumps, now utilized as a standby, is driven by a steam turbine. It has a horsepower rating of 19 and a water rate of 53.4 lbs per horsepower. However, the turbine driven pump is only rated at two-thirds of the capacity required for operating the facility at maximum steam output. Twenty-eight horsepower would be required to provide the feedwater required at plant full load. If the standby pump was replaced with a steam turbine driven pump for full load, and the turbine had the same water rate (a normal turbine efficiency for this size of turbine), the steam required to operate the pump would be 1495 lbs per hour. Translating this requirement into operating cost, the annual expenditure for operating the feedwater pump at full boiler capacity would be \$10,800.

The cost of electric power to operate the feedwater pump at full load operation is \$10,400 per year, which is less than the cost with a steam turbine drive. It is estimated that the cost of procuring and installing a new feedwater pump, steam turbine drive, controls, steam piping, valves, and foundation would be \$20,000.

By comparing the two results, and considering the amortization of capital costs involved in acquiring and installing a new feedwater pump and turbine, the driving of the feedwater pump with steam would increase the operating cost of the facility.

The two largest energy users in the system are the fluidizing blower and the induced draft fan. The fluidizing blower uses 280 bhp at full load and the induced draft fan uses 140 bhp at full load.

If steam turbines were added to power the two blowers (in addition to the electric drives), a significant portion of the facility

electrical consumption would be eliminated (60 percent). The water rate (i.e., efficiency) is better for the larger size steam turbines. A steam turbine having a water rate of 36 lb/bhp could be purchased for the fluidizing blower. Similarly, a turbine for the induced draft fan would require 36 lb/bhp. These values are based on using 200 psig steam and exhausting at near atmospheric pressure. Therefore, 10,080 lbs/hr of steam would be required for the fluidizing blower and 5,040 lbs/hr of steam would be required for the induced draft fan to operate the facility at full load. The annual cost for operating both blowers with steam would be \$108,800 per year. The cost of operating the blowers with the existing electric drives at full load would be \$156,400 per year.

There would be a net savings of \$47,600 per year if steam turbines were used to drive the fluidizing blower and induced draft fan. However, this would only allow a net of 4880 lbs/hr of steam to be sold (3400 lbs/hr required for deaerator heating). At \$6 per 1000 lbs of steam, total plant revenue would be \$237,300 per year which would not cover plant fixed costs (labor, etc.) per year, based on full load generation disregarding fuel, ash, and capitalization costs. Retrofitting steam turbines to the existing blowers would cost a minimum of \$55,000 (turbines, new fan rotor shafting and couplings, steam piping, controls, and foundation modifications). Therefore, conversion to steam turbines is not a viable option.

5.5.3 Reducing or Eliminating Limestone Feed

A major goal of the Shamokin culm fired plant was to demonstrate sulfur capture in the bed with limestone. Experimental data have shown that an 88 percent reduction in sulfur dioxide emissions was possible with a reasonable Ca/S ratio.⁽⁴⁾ When burning the design anthracite culm with 0.57 percent sulfur, the SO₂ emission rate would be 0.33 lb/SO₂ per million Btu with an 88 percent reduction in emissions. The plant is subject to state emission regulations which

allow an emission rate for this size plant of 4.0 lb/SO₂ per million Btu. Thus, in theory, no SO₂ control is necessary. However, since sulfur control was going to be demonstrated, an enforceable permit condition of 0.33 lb/SO₂ per million Btu was included in the operational permit. To reduce or eliminate limestone feed, a change in the permit would be necessary.

If limestone was eliminated, the plant's SO₂ emissions would be above the allowable emissions that presently exempt it from PSD and emission offset regulations. The plant then would be subject to: (a) an air quality review, (b) an impact analysis, and (c) a best available control technology review.

In addition, the elimination of limestone would probably make the disposal of the culm ash more difficult. The excess limestone makes the ash basic, and, thus, less susceptible to heavy metal leaching. The request to PaDER for a favorable ruling on the disposal of this ash is predicated on limestone being in the ash.

The potential savings from the elimination of limestone would be relatively small, 2.4 percent of the total operating costs. Because of the potential regulatory and waste disposal problems, elimination of the limestone would probably not be feasible. However, the historical Ca/S ratio has been fairly high, averaging about 4. In future operations, it may be possible to modify the operational permit and/or operate at lower Ca/S ratios to reduce limestone costs.

5.5.4 Operating Labor

The plant operation staff included 12 persons. During the day shift, six persons were at the plant: two were assigned to materials handling, three for operations and maintenance, plus the plant manager. The three other shifts required for continuous operation had two persons each for operations and maintenance. This

staffing would probably be adequate for boiler capacities up to the 50,000 to 100,000 lb/hr range. Above this capacity an additional material handling person would be needed per shift.

For the cogeneration case, no additional operating labor was assumed. If turbine operators are necessary, the labor requirements might increase to 16. Table 20 shows the effect of these operating labor assumptions on annual operating costs.

TABLE 20

EFFECT OF OPERATING LABOR REQUIREMENT ON OPERATING COST

(Continuous Operation Base Case)

<u>Operating Labor Required, men</u>	<u>Annual Operating Costs, dollars</u>	<u>Steam Cost \$/1000 lb</u>
9	681,720	4.21
12 (Base Case)	736,099	4.54
16	808,595	4.99

CONCLUSIONS

Based on the plant performance data, the operating cost estimates, and the cost sensitivity analysis, the following conclusions are made:

- a. The Shamokin facility has demonstrated the technical ability to generate steam from anthracite culm with both a high reliability and reasonable operating cost. However, the current steam selling price is too low to recover full operating costs even at full steam flow. A steam selling price of approximately \$6 per 1000 lb of steam would allow the unit to break-even on an operating and maintenance basis at steam sales rates of 11,500 lbs/hr. This price should be very competitive if customers can be found.
- b. Projected and actual operating costs show substantial agreement. The key factor that has resulted in less revenues for the facility is lower than expected steam revenues.
- c. The largest contributors to operating costs are labor and electricity which each make up about 30 percent of operating costs. No other item makes up more than 10 percent of operating costs.
- d. None of the cogeneration options could allow operation at "break-even," much less pay back the relatively large investments required for cogeneration. Essentially, the boiler is too small in capacity and design steam temperature and pressure is too low for the unit to be a cost effective power generator. No other system changes could be recommended which would reduce operating costs substantially.
- e. Conversion of the electric drives to steam drives is not cost effective.

REFERENCES

1. D. G. Chiplaanker, et al., "Performance of a Fluidized Bed Steam Generator Burning Anthracite Culm," presented at the 7th International Conference on Fluidized Bed Combustion, Philadelphia, Pa. October 25-27, 1982.
2. Personal communications from Fred Spindler, Curtiss-Wright to Mike Klett, Gilbert Associates.
3. "Design, Construction, Operation and Evaluation of a Prototype Culm Combustor Boiler/Heater Unit: Technical and Economic Evaluation of Prototype and Larger Size Facility," Dorr-Oliver Incorporated, Thermal Products Technology, Stanford, Connecticut, 06904, DOE Report FE-3269-14A, August 1979.
4. Leon, A. M., et al., "Combustion Studies Conducted in 12" Diameter Fluid Bed Facility," Dorr-Oliver Incorporated, Thermal Products Technology, Stanford, Connecticut, DOE Report FE-3269-9A, April 1979.

APPENDIX A

LANDFILL REGULATORY REQUIREMENTS FOR DISPOSAL OF ASH

APPENDIX A

LANDFILL REGULATORY REQUIREMENTS FOR DISPOSAL OF ASH

I. INTRODUCTION

The Shamokin Area Industrial Corporation (SAIC) is reviewing operating requirements for an atmospheric fluidized bed anthracite culm combuster located at the Shamokin Area Industrial Park. Landfill disposal is required for an average of 50 tons/day and a maximum of 77 tons/day of ash. Distribution of ash is estimated to be 60 percent fly ash and 40 percent bottom ash.

Ash disposal presents a problem in the Shamokin area. As of July 1, 1983, all local landfills were closed by the Pennsylvania Department of Environmental Resources (DER). Alternative sites must be located, or the existing local landfills must be brought into compliance. The purpose of this review is to identify the regulatory requirements which must be considered in disposing of the ash by landfill.

As with any solid waste disposal project, the initial approach to regulatory requirements for disposal of FBC ash consists of answering the following questions:

1. Are the wastes classified as hazardous or non-hazardous?
2. Is design and permitting of the facility governed by Federal regulations, state regulations, or a combination of both?
3. Are the wastes to be landfilled in an existing, permitted facility, or will design and licensing of a new facility be required.

II.

CLASSIFICATION AS HAZARDOUS OR NON-HAZARDOUS WASTE

Solid wastes are classified as hazardous wastes if they are listed hazardous wastes or if they exhibit the characteristics of hazardous wastes. Listed hazardous wastes and hazardous waste characteristics are presented by the EPA in 40 CFR 261 and by DER in 25 Pa. Code 75.261. Defined hazardous waste characteristics are ignitability, corrosivity, reactivity, and EP (Extraction Procedure) toxicity.

Bottom ash and fly ash from fluidized bed combustors are not listed hazardous wastes. Ash from the FBC unit at Shamokin has not been tested specifically for the characteristics defining hazardous waste. However, FBC solid wastes in general are not ignitable or reactive. Although basic, an aqueous solution of the material would not be expected to exceed the pH limit of 12.5 defining corrosivity. Because of the basic nature of the material, leachate heavy metals concentrations are normally well under the EP toxicity limits.

EPA and PaDER specifically exclude certain wastes from being classified as hazardous wastes, regardless of their characteristics. Specifically excluded wastes include "fly ash waste, bottom ash waste, slag waste, and flue gas emission control waste generated either from the combustion of coal or other fossil fuels." This exclusion appears to be broad enough to include solid wastes from a fluidized bed combustor.

Considering the general characteristics of FBC wastes, along with the probability of qualifying for a specific exclusion, it is reasonable to assume that the FBC wastes from the unit at Shamokin are not hazardous wastes. As a result, discussion of landfill permitting and design requirements will consider only non-hazardous wastes.

III. APPLICABILITY OF FEDERAL AND/OR STATE REGULATIONS

Permitting and design requirements for hazardous waste landfills derive primarily from Federal regulations developed under the Resource Conservation and Recovery Act (RCRA). RCRA allows EPA to grant authorization to states to administer hazardous waste management programs which are equivalent to the Federal program.

RCRA leaves management of non-hazardous solid wastes primarily to state and local agencies. The primary effect of RCRA is to require states to adopt minimum standards to eliminate "open dumps." The operative standards governing permitting and design of landfill disposal of the Shamokin FBC wastes are those adopted by the Pennsylvania DER.

Current regulations governing solid waste management in Pennsylvania are contained in 25 Pa. Code, Chapter 75. These regulations are primarily directed toward municipal solid waste, or "sanitary landfills." Subchapter 75.37 addresses standards for fly ash, bottom ash, or slag disposal areas, but not in a comprehensive manner.

In order to more adequately address non-municipal solid wastes, DER has issued for comment a set of draft guidelines for residual waste disposal. Residual waste is defined as "any garbage, refuse, other discarded material or other waste including solid, liquid, semisolid, or contained gaseous materials resulting from industrial, mining and agricultural operations and any sludge from an industrial, mining or agricultural water supply treatment facility, waste water treatment facility or air pollution control facility, provided that it is not hazardous." Both the current regulations and the draft guidelines are evaluated in the following sections.

IV. MINIMUM CRITERIA FOR RESIDUAL WASTES

Residual wastes must meet the following minimum criteria as provided by draft 25 Pa. Code, Chapter 283:

1. Residual waste shall be a minimum of twenty (20) percent solids by weight and non-fluid.
2. Residual waste shall have a pH of 5.0 to 11.0.
3. Residual waste shall not be subject to spontaneous combustion under ambient atmosphere and temperature.
4. Residual waste shall be compatible with other solid wastes disposed of at the facility.
5. Leachate resulting from the residual waste shall be compatible with the design of the disposal facility.

V. INDUSTRIAL WASTE DISPOSAL AT PERMITTED SITES

Disposal of industrial solid wastes at sites previously permitted by Pennsylvania DER requires submittal and approval of Module No. 1, a copy of which is attached. Completion of Module No. 1 requires the following information:

1. Description of the manufacturing process(es) generating the waste(s) and a list of the raw materials as well as intermediates and final products contained in each waste.
2. An analysis of the waste itself and a leachate analysis of the waste. For a residual waste which is the sole waste deposited in a facility, the sample shall be prepared according to ASTM-Method A leaching analysis. For a residual waste which is to be disposed of in any facility in which it will be mixed

with other residual wastes or with municipal wastes, the sample shall be prepared in accordance with the EP toxicity or ASTM-Method B leaching analysis procedures.

3. Information about the disposal site, including location, ownership, disposal method, and design specifications.
4. Environmental assessment of disposal.

In determining whether to permit the disposal of a residual waste, such as the Shamokin FBC ash, at a specified disposal facility DER will evaluate the physical and chemical analysis of the residual waste, as well as the following factors:

1. Chemical quality of the residual waste to be disposed of in relation to the constituents in the waste as compared to the quantity of that waste;
2. Capabilities of the approved leachate treatment facilities;
3. Ability of the soil to attenuate the residual waste constituents in a natural attenuation site;
4. Compatibility of the residual waste with the liner in a lined site;
5. Waste handling practices at the disposal facility;
6. Health and safety of the employees at the disposal facility;
7. Quality and quantity of other residual waste being managed at the facility;
8. The quality of ground water in the area of the disposal facility; and

9. Compliance of the disposal facility with DER rules and regulations.

The draft guidelines (25 Pa. Code, Chapter 283) establish the suitability of certain types of disposal facilities for certain residual waste streams. The guidelines establish maximum chemical concentrations allowable in each type of residual waste disposal facility. Facilities are classified as Types I, II, III, and IV. Type I facilities provide the least amount of protection to the environment and Type IV facilities provide the greatest amount of protection to the environment.

Typical leachate characteristics for FBC wastes indicate that the Shamokin FBC ash would be likely to be characterized as a Type II waste. Type II residual waste disposal facilities are those designed in accordance with either Subchapter E or Subchapter G of draft Chapter 284. Type II facilities designed in accordance with Subchapter G may only accept fly ash or bottom ash wastes. Type II facilities designed in accordance with Subchapter E may accept any wastes suitable for Type I or Type II facilities. Type II wastes may also be disposed of in Type III or Type IV facilities, but probably at significantly higher costs.

Type II, Subchapter E facilities manage leachate by natural soil attenuation utilizing a maximum 2:1 ratio of solid waste to attenuating soil. A minimum of eight feet of attenuating soil beneath the waste and above the seasonal high groundwater table is required.

Type II, Subchapter G facilities manage leachate by use of a soil drain and filter blanket system. This system is a network of pipes and drains which separately collect all perched water and leachate from the disposal facility and remove such waters to a central collection point for monitoring and for treatment, if necessary. Allowable depth of solid waste is limited only by stability and bearing capacity of underlying geologic foundation materials.

VI. INDUSTRIAL WASTE DISPOSAL AT NEW SITES

Design and permitting of new solid waste landfills is currently regulated by 25 Pa. Code, Chapter 75. Specific requirements for fly ash, bottom ash, or slag disposal areas are presented in Subchapter 75.37. These regulations will eventually be replaced by draft Chapters 283 and 284, as previously discussed. Permit application requirements, currently a two-stage process, will remain largely unchanged.

Phase I of the Pennsylvania DER Solid Waste Management Permit Application is primarily for site approval, without describing the proposed facility in detail. Major elements of the Phase I application are:

1. Site ownership, location, zoning, etc.
2. Narrative description of the proposed operation, including solid waste types and quantities.
3. Chemical analysis of the solid waste.
4. Leachate testing and analysis.
5. Detailed geological and groundwater description of the site, including logs of test borings and test pits.
6. Proposed groundwater monitoring system.

Following approval of the Phase I submittal, a Phase II application is prepared. Phase II includes detailed design information on the facility, including responses to any conditions attached to the Phase I approval. Major elements of the Phase II application are:

1. Detailed drawings and specifications for landfill construction.

2. Detailed operating plan.
3. Information on equipment, access roads, fire protection, vector control, water, communications, and employee facilities.
4. Soil Erosion and Sedimentation Control Plan.
5. Pollution Incident Prevention Plan.

Technical design requirements for a new site to accept FBC ash are essentially the same as those for an existing, permitted site able to accept the same material. Obtaining approval to landfill a new solid waste at an existing, permitted site is a much simpler process than obtaining a permit for a new site. Economics will vary depending upon the site, but will generally favor an existing site because of significant engineering and facilities construction costs for a new site.

INDUSTRIAL WASTE DISPOSAL AT PERMITTED SITES

MODULE NO. 1

1. Describe in detail on a separate sheet the manufacturing process(es) generating the waste(s) and list the raw materials as well as intermediates and final products contained in each waste.
2. Include an analysis of the waste itself and a leachate analyses of the waste. The analyses must contain but need not be limited to the following parameters unless the applicant has specific knowledge of the absence of any of these parameters:

Percent Solids	Arsenic
pH	Cadmium
Chemical Oxygen Demand	Copper
Total Organic Carbon	Chromium
Oil/Grease	Lead
Total Dissolved Solids	Mercury
Total Volatile Solids	Molybdenum
Specific Conductance	Nickel
Ammonia-Nitrogen	Selenium
Phenol	Silver
Cyanide	

If codisposal with municipal refuse is proposed, use ASTM Method B or EPA's extraction procedure for leaching the waste. Otherwise, use ASTM Method A. Use appropriate Standard Methods of Analysis or EPA's methods for the chemical analyses.

For the analysis of the waste itself, use a nitric acid digestion for extraction of the metals. An organic analysis may be required if the waste contains appreciable amounts of organics.

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
BUREAU OF SOLID WASTE MANAGEMENT

PERMIT NUMBER OF PROPOSED
DISPOSAL SITE

PREPARED

INDUSTRIAL WASTE DISPOSAL AT PERMITTED SITES
MODULE NO. 1

--	--	--	--	--	--

A. DISPOSAL SITE INFORMATION:

1. Facility Name: _____
2. Facility Location: _____

3. Facility Owner: _____
4. Facility Mailing Address: _____

5. Facility Manager: _____ Telephone No. _____
6. Facility Contact: _____ Telephone No. _____
(person responsible for providing data for this survey)
7. Does the facility discharge industrial wastes to a municipal sewer system? ____ Yes ____ No
If yes, name of system _____
8. Does the site have a leachate treatment facility? ____ Yes ____ No
If yes, attach discharge standards.
9. If the site is a landfill, attach last monitoring analysis. If last analysis is more than three (3) months prior, attach a current analysis to this module.

B. DESCRIPTION OF SPECIFIC WASTE:

1. Company origin of waste (name and address): _____

Company Contact: _____ Telephone No. _____
2. Treatment: Is waste conditioned prior to disposal? _____ How? _____

3. Disposal: Present Method _____

4. Provide and attach special characteristics of this waste which determine the method of disposal. Include chemical analysis, physical description, percent of water and leaching analysis relative to disposal proposal. Provide the date of all data submitted.
5. What difficulties do disposal of this waste presently present? _____

6. What difficulties are anticipated for the disposal of this waste in the future? _____

DATE PREPARED

INDUSTRIAL WASTE DISPOSAL AT PERMITTED SITES
MODULE NO. 1

--	--	--	--	--	--

7. What other processes can be used effectively? _____

8. Average Daily Volume _____
9. Annual Volume _____
10. What process generated this waste? (Describe) _____

TABLE A - WASTE DESCRIPTIONS

11. CHECK APPROPRIATE CATEGORY

- ☐ A-1 Concentrated sulfuric acid solutions with heavy metal
- ☐ A-2 Concentrated mixed acids with heavy metals
- ☐ A-3 Dilute acid solutions containing hexavalent chromium and/or other oxidants
- ☐ A-4 Dilute acid solutions containing heavy metals but no hexavalent chromium or ammonia
- ☐ A-5 Dilute acid solutions containing heavy metals and ammonium salts
- ☐ A-6 Acidic nitrate solutions containing heavy metals
- ☐ A-7 Acidic wastes with hazardous metals except Cr^{+6}
- ☐ B-1 Alkaline solutions containing cyanides
- ☐ B-2 Alkaline solutions containing sulfides
- ☐ B-3 Concentrated alkaline solutions containing no sulfide nor cyanide
- ☐ B-4 Miscellaneous alkaline solutions containing contaminants other than hazardous metals
- ☐ B-5 Alkaline solutions containing hazardous metals
- ☐ C-1 Combustible organic sludges, solids and liquids
- ☐ C-2 Sludges, slurries and solids containing cyanides
- ☐ C-3 Sludges, slurries and solids containing hexavalent chromium
- ☐ C-4 Inorganic sludges, slurries, solids containing no hexavalent chromium nor cyanide
- ☐ C-5 Wastewater contaminated with high concentrations of organic substances
- ☐ C-6 Organic contaminated solids
- ☐ C-7 Other (describe)

12. Physical State At Ambient Temperature:

- ☐ Solid and non-pumpable liquid - solid mixtures
- ☐ Liquid and pumpable liquid - solid mixtures

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
BUREAU OF SOLID WASTE MANAGEMENT

PERMIT NUMBER OF PROPOSED
DISPOSAL SITE

DATE PREPARED

INDUSTRIAL WASTE DISPOSAL AT PERMITTED SITES
MODULE NO. 1

--	--	--	--	--	--

13. *Primary Characteristic*

Inorganic

- ☐ Acid
- ☐ Alkaline
- ☐ Cyanide
- ☐ Filter Aids & Clays
- ☐ Heavy Metal
- ☐ *WWT Sludge
- ☐ Pesticides
- ☐ Catalyst
- ☐ Other, describe _____

Organic

- ☐ Oil & Oily Sludge
- ☐ Paint & Pigment Residue
- ☐ Plastic, Pasticizers, Resins, Elastomer Residues
- ☐ Solvent
- ☐ *WWT Sludge
- ☐ Pesticides
- ☐ Still Bottoms, Heavy Residue
- ☐ Pharmaceutical Waste
- ☐ Other, describe _____

Secondary Characteristic

- ☐ Heavy Metals
- ☐ Other Metals
- ☐ Sulfides
- ☐ Hexavalent Chromium
- ☐ Organic
- ☐ Halogenated
- ☐ Sulfonated
- ☐ Inorganic
- ☐ Other, describe _____

14. *Hazards*

☐ Toxic Substance	☐ Poison
☐ Skin Irritant	☐ Explosive
☐ Respiratory Irritant	☐ Carcinogen
☐ Corrosive to Steel	☐ Reactive, acid
☐ Corrosive to Concrete	☐ Reactive, water
☐ Corrosive, other	☐ Reactive, other
☐ Flammable	☐ Other, describe _____
☐ Cyanogen	

C. *DISPOSAL METHOD:* (describe applicable items)

Type of disposal (i.e., landfill, lagoon, pond, etc.). _____

DESIGN SPECIFICATIONS.

1. Liner type (i.e., concrete, asphalt, clay, etc.) and thickness. _____

2. Leachate collection and treatment capability at site for waste to be disposed of. (Describe) _____

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
BUREAU OF SOLID WASTE MANAGEMENT

PERMIT NUMBER OF PROPOSED
DISPOSAL SITE

DATE PREPARED

INDUSTRIAL WASTE DISPOSAL AT PERMITTED SITES
MODULE NO. 1

--	--	--	--	--	--

3. Methods of burial (i.e., mixing hazardous waste with other wastes, containerization, etc.)

4. Identify and describe method of transportation of the waste the site.

D. *ENVIRONMENTAL ASSESSMENT OF DISPOSAL*: State briefly the anticipated impact of disposal at the site and provide the data or substantiation for the stated conclusions.

E. *ENGINEER*:

1. Name _____

3. Registration Number _____

2. Address _____

4. Signature _____

Telephone Number & Area Code:

AC() _____

5. Seal of Registered Professional Engineer

SEAL

5 Seal of Registered Professional Engineer

APPENDIX B
SAMPLE CALCULATIONS

APPENDIX B

SAMPLE CALCULATIONS

Base Case Input:

Availability	=	0.925
Load Factor	=	1.00
Boiler Efficiency	=	0.735 percent
Ca/S	=	2.5
Culm Cost	=	\$2.00 per ton
Ash Disposal Cost	=	\$2.00 per ton
Limestone Cost	=	\$5.50 per ton

All flows are in lbs/hr

1. Steam Production Factor = (Availability) x (Load Factor)
= (.925) x (1.000)
= 0.925

2. Steam Production = (Steam Production Factor) x (20,000 lb/hr)
= (0.925) x (20,000)
= 18,500 lb/hr

3. Culm In = $\frac{(\text{Steam Production}) \times (\text{Enthalpy Rise in Steam})}{(\text{Boiler Efficiency}) \times (\text{HHV of Culm})}$ lb/hr

= $\frac{(18,500) \times (1171)}{(.735) \times (4041)} = 7294$ lb/hr

4. Limestone In = (Culm In) x (.04014)* x (Ca/S)
= (7294) x (.04014) x (2.5)
= 732 lb/hr

$$\begin{aligned}
 *.04014 &= \left(\frac{1 \text{ bs}}{1 \text{ b culm}} \right) \times \left(\frac{1 \text{ lb-mole S}}{32 \text{ lbs}} \right) \times \left(\frac{100 \text{ lb CaCO}_3}{1 \text{ lb-mole CaCO}_3} \right) \times \left(\frac{1 \text{ b limestone}}{1 \text{ b CaCO}_3} \right) \\
 &= (.00835) \times \left(\frac{1}{32} \right) \times (100) \times \left(\frac{1}{.65} \right) \frac{1 \text{ b limestone}}{1 \text{ b culm}}
 \end{aligned}$$

5. Ash Out = ((Culm In) + (Limestone In)) x 0.7** lb/hr
= (7294 + 732) x .7
= 5618 lb/hr

**0.7 is an approximate average ash content of culm plus limestone based upon historical data.

$$6. \quad \text{Fixed Cost} = \$29.06 \text{ per hour}$$

$$\begin{aligned} 7. \quad \text{Culm Cost} &= (\text{Culm In}) \times (\text{Culm Cost}) / (2000) \\ &= (\text{lbs/hr}) \times (\$/\text{ton}) / (\text{lbs/ton}) \\ &= (7294) \times (2.00) / (2000) \\ &= \$7.29 \text{ per hour} \end{aligned}$$

$$\begin{aligned} 8. \quad \text{Limestone Cost} &= (\text{Limestone In}) \times (\text{Limestone Cost}) / (2000) \\ &= (\text{lbs/hr}) \times (\$/\text{ton}) / (\text{lbs/ton}) \\ &= (732) \times (5.50) / (2000) \\ &= \$2.01 \text{ per hour} \end{aligned}$$

$$\begin{aligned} 9. \quad \text{Ash Cost} &= (\text{Ash Out}) \times (\text{Ash Disposal Cost}) / (2000) \\ &= (\text{lbs/hr}) \times (\$/\text{ton}) / (\text{lbs/ton}) \\ &= (5618) \times (2.00) / (2000) \\ &= \$5.62 \text{ per hour} \end{aligned}$$

$$\begin{aligned} 10. \quad \text{Variable Cost} &= (\text{Steam Production}) \times .00125 + 16.92 \\ &= (18500) \times .00125 + 16.92 \\ &= \$50.05 \text{ per hour} \end{aligned}$$

(See item 14)

$$\begin{aligned} 11. \quad \text{Total Hourly Cost} &= (\text{Fixed Cost}) + (\text{Culm Cost}) + (\text{Limestone Cost}) \\ &\quad + (\text{Ash Cost}) + (\text{Variable Cost}) \\ &= (29.06) + (7.29) + (2.01) + (5.62) + (40.05) \\ &= \$84.02 \text{ per hour} \end{aligned}$$

$$\begin{aligned} 12. \quad \text{Cost per 1000 lb Steam} &= \frac{(\text{Total Hourly Cost})}{(\text{Steam Production lbs/hr})} \times (1000) \\ &= \frac{(84.03) (1000)}{(18500)} \\ &= \$4.54/1000 \text{ lb steam} \end{aligned}$$

$$\begin{aligned} 13. \quad \text{Total Annual Cost} &= (\text{Total Hourly Cost}) \times (8760 \text{ hr/yr}) \\ &= (84.03) (8760) \\ &= \$736,100 \text{ per year} \end{aligned}$$

$$\begin{aligned} 14. \quad \text{Variable Cost Equation} &= (\text{Electrical Cost}) + (\text{Water Cost}) \\ &\quad + (\text{Other Variable Cost}) \\ &= (.0006537 + .0001929 + .0004032) \\ &\quad \times (\text{Steam Production}) + (14.32 + .5256 + 2.073) \\ &= .00125 \times (\text{Steam Production}) + 16.92 \end{aligned}$$

Sample Calculation - Cogeneration Case

Input:

Load Factor	=	1.00
Availability	=	0.925
Boiler Efficiency	=	0.735
Ca/S	=	2.5
Culm Cost	=	\$2.00 per ton
Ash Disposal Cost	=	\$2.00 per ton
Limestone Cost	=	\$5.50 per ton
Steam Sales	=	3000 lb/hr
Steam Selling Price	=	\$6.00 per 1000 lb steam
Power Selling Price	=	\$0.06 per kWh
Power Purchase Cost ¹	=	\$0.05 per kWh
Steam Turbine		
Generation Efficiency	=	0.70
Turbine Enthalpy ²	=	195 Btu/lb steam
Boiler Enthalpy ³	=	1003 Btu/lb steam
Deaerator Flow ⁴	=	825 lb/hr

All flows are in lbs/hr.

Notes:

- 1 Cases of both "net" and "gross" power sales were considered. In "net" sales, internal power usage was subtracted prior to selling net power at \$0.06 per kWh. In "gross" sales, total generator output is sold at \$0.06 per kWh and internal power is repurchased from utility at \$0.05 per kWh.
- 2 Turbine Enthalpy - theoretically available enthalpy difference of saturated or superheated steam entering turbine and enthalpy resulting from isentropic expansion to condenser operating pressure, Btu/lb.
- 3 Boiler Enthalpy - enthalpy increase of steam/water from saturated liquid exiting deaerator to saturated or superheated steam leaving boiler, Btu/lb.
- 4 Deaerator Flow - flow rate of saturated steam necessary to heat makeup water and condensate to deaerator exit conditions (approximately 5 psig, 228° F). Numbers used in calculations are correct for base case flow of 3000 pph steam sales, but are not corrected for other steam sales.

1. Steam Production = $(\text{lbs/hr} - \text{lbs/hr}) \times \text{Load Factor} \times \text{Availability}$
 $\text{Steam Flow} - (\text{Deaerator Flow}) \times (\text{Load Factor})$
 $\times (\text{Availability})$
 $= (23400 - 825) \times (1.00) \times (.925)$
 $= 20882$

2. Culm In =
$$\frac{(\text{Steam Flow}) \times (\text{Load Factor}) \times (\text{Availability}) \times (\text{Boiler Enthalpy})}{(\text{Boiler Efficiency}) \times (\text{Culm HHV})}$$

 $= (\text{lbs/hr})(\text{Btu/lb})/(\text{Btu/lb})$
 $= \frac{(23400) \times (1.00) \times (.925) \times (1003)}{(.735) \times (4041)}$
 $= 7309 \text{ lb/hr}$

3. Limestone In = $(\text{Culm In}) \times (.04014) \times (\text{Ca/S})$
 $= (\text{lbs/hr})(\text{lbs limestone/lb culm})$
 $= (7309) \times (.04014) \times (2.5)$
 $= 733 \text{ lbs/hr}$

4. Ash Out = $((\text{Culm In}) + (\text{Limestone In})) \times 0.7$
 $= ((7309) + (733)) \times 0.7$
 $= 5629 \text{ lbs/hr}$

5. Turbine Power = $((\text{Steam Production}) - (\text{Steam Sales}) \times (\text{Availability}) \times (\text{Load Factor})) \times (\text{Turbine Enthalpy}) \times (\text{Turbine Efficiency}) \div 3413$
 $= (\text{lbs/hr})(\text{Btu/lb})/(\text{Btu/kW-hr})$
 $= (20882 - (3000) (1) (.925) \times (195) (.7))/3413$
 $= 724 \text{ KW}$

6. Power Usage = $\text{Steam Production} \times 0.01866 + 212.4$
 $= (23400) \times (\text{Availability}) \times (\text{Load Factor}) \times 0.01866 + 212.4$
 $= 616 \text{ KW}$

7. Power Net = $(\text{Turbine Power}) - (\text{Power Usage})$
 $= 724 - 616$
 $= 108 \text{ KW}$

Note: For net sales this is multiplied by power sales rate. For gross sales the total turbine power is sold, and the power usage repurchased.

8. Fixed Cost = \$29.06 per hour
9. Culm Cost = (Culm In) x (Culm Price) / 2000
 = (lbs/hr) x (\$/ton)/(lbs/ton)
 = (7309) x (2.00) / 2000
 = \$7.31 per hour
10. Limestone Cost = (Limestone In) x (Limestone Price) / 2000
 = (lbs/hr) x (\$/ton)/(lbs/ton)
 = 733 x 5.50 / 2000
 = \$2.02 per hour
11. Ash Disposal Cost = (Ash Out) x (Disposal Price) / 2000
 = (lbs/hr) x (\$/ton)/(lbs/ton)
 = 5629 x 2.00 / 2000
 = \$5.63 per hour
12. Variable Cost = Steam Production x 0.000427 + 2.337
 = (Steam Flow) x (Load Factor) x (Availability)
 x .000427 + 2.337
 = (23400) x (1.00) x (.925) x .000427 + 2.337
 = \$11.58
13. Total Operating Cost = (Fixed Cost) + (Culm Cost) + (Limestone Cost)
 + (Ash Disposal Cost) + Variable Cost) +
 (KW Used) x .05 *
 = 29.06 + 7.31 + 2.02 + 11.26 + 11.58 + 616 x .05
 = \$86.40 per hour

*Gross Sales Case

14. Steam Revenue = (Steam Sales) x (Load Factor) x (Availability)
 x (Steam Price) / 1000
 = (3000) x (1.0) x (.925) x (6.00) / 1000
 = \$16.65 per hour
15. Power Revenue* = (KW Produced) x (Power Price)
 = 724 x .06
 = \$43.44 /hr

*Gross Power Sales Case

16. Total Revenue = (Steam Revenue) + (Power Revenue)
 = 16.65 + 43.44
 = \$60.09 per hour

$$\begin{aligned} 17. \text{ Net Revenue} &= (\text{Total Revenue}) - (\text{Total Cost}) \\ &= (60.09) - (86.40) \\ &= -\$26.31 \text{ per hour} \end{aligned}$$

$$\begin{aligned} 18. \text{ Annual Revenue} &= (\text{Net Revenue}) \times 8760 \\ &= -\$26.31 \times 8760 \\ &= -\$230,500 \end{aligned}$$

APPENDIX C-1

SHAMOKIN OPERATING COST SUMMARY

Summary Nomenclature

<u>Abbreviation</u>	<u>Nomenclature</u>
Load Fact	Load Factor
Availability	Availability
Efficien	Efficiency
Ash Disp	Ash Disposal
SPF	Steam Production Factor
STM Prod	Steam Production
Disp Cost	Disposal Cost
Varbl Cost	Variable Cost

Note: Column numbers refer to Case Numbers.

SHAMOKIN OPERATING COST SUMMARY

	1	2	3	4	5	6	7	8	9	10
LOAD FACT	0.925	0.400	0.450	0.500	0.700	0.600	0.650	0.700	0.750	0.800
AVAILABILITY	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750
EFFICIENCY	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735
CA/S	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
CULM COST	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH DISP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LIMESTONE	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500
SPF	0.694	0.300	0.338	0.375	0.525	0.450	0.488	0.525	0.563	0.600
STM PROD	13875.	6000.	6750.	7500.	10500.	9000.	9750.	10500.	11250.	12000.
CULM IN	5470.	2366.	2661.	2957.	4140.	3548.	3844.	4140.	4435.	4731.
STONE IN	878.	380.	427.	475.	665.	570.	617.	665.	712.	760.
ASH OUT	4444.	1922.	2162.	2402.	3363.	2883.	3123.	3363.	3603.	3844.
FIXED COST	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06
CULM COST	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STONE COST	2.42	1.04	1.18	1.31	1.83	1.57	1.70	1.83	1.96	2.09
DISP COST	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WARBL COST	34.26	24.42	25.36	26.30	30.05	28.17	29.11	30.05	30.98	31.92
\$/HR	65.74	54.52	55.59	56.66	60.93	58.80	59.86	60.93	62.00	63.07
\$/1000	4.738	3.987	4.236	4.555	5.803	6.533	6.140	5.803	5.511	5.256
\$/YR	575875	477635	486991	496347	533772	515059	524416	533772	543128	552484

SHAMOKIN OPERATING COST SUMMARY

	11	12	13	14	15	16	17	18	19	20
LOAD FACT	0.850	0.900	0.950	0.925	0.925	0.925	0.925	0.925	0.925	0.925
AVAILABILITY	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750
EFFICIENCY	0.735	0.735	0.735	0.600	0.650	0.700	0.750	0.800	0.735	0.735
CA/S	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	1.000
CULM COST	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH DISP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LIMESTONE	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500
SPF	0.638	0.675	0.713	0.694	0.694	0.694	0.694	0.694	0.694	0.694
STM PROD	12750.	13500.	14250.	13875.	13875.	13875.	13875.	13875.	13875.	13875.
CULM IN	5027.	5322.	5618.	6701.	6186.	5744.	5361.	5026.	5470.	5470.
STONE IN	807.	855.	902.	1076.	993.	922.	861.	807.	0.	220.
ASH OUT	4084.	4324.	4564.	5444.	5025.	4666.	4355.	4083.	3829.	3983.
FIXED COST	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06
CULM COST	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STONE COST	2.22	2.37	2.48	2.70	2.73	2.54	2.37	2.22	0.00	0.60
DISP COST	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WARBL COST	32.86	33.80	34.73	34.26	34.26	34.26	34.26	34.26	34.26	34.26
\$/HR	64.14	65.21	66.27	66.28	66.05	65.86	65.69	65.54	63.32	63.93
\$/1000	5.030	4.830	4.651	4.777	4.761	4.747	4.734	4.724	4.564	4.607
\$/YR	561840	571197	580553	580635	578642	576933	575452	574156	554716	560006

SHAMOKIN OPERATING COST SUMMARY

	21	22	23	24	25	26	27	28	29	30
LOAD FACT	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925
AVAILABILITY	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750
EFFICIENCY	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735
CA/S	2.000	3.000	4.000	5.000	4.000	4.000	4.000	4.000	4.000	4.000
CULM COST	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ASH DISP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LIMESTONE	5.500	5.500	5.500	5.500	0.000	2.000	4.000	6.000	8.000	10.000
SPF	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694	0.694
STM PROD	13875.	13875.	13875.	13875.	13875.	13875.	13875.	13875.	13875.	13875.
CULM IN	5470.	5470.	5470.	5470.	5470.	5470.	5470.	5470.	5470.	5470.
STONE IN	439.	659.	878.	1098.	878.	878.	878.	878.	878.	878.
ASH OUT	4137.	4290.	4444.	4598.	4444.	4444.	4444.	4444.	4444.	4444.
FIXED COST	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06
CULM COST	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
STONE COST	1.21	1.81	2.42	3.02	0.00	0.88	1.76	2.63	3.51	4.39
DISP COST	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
VARBL COST	34.26	34.26	34.26	34.26	34.26	34.26	34.26	34.26	34.26	34.26
\$/HR	64.53	65.14	65.74	66.34	63.32	64.20	65.08	65.96	66.84	67.72
\$/1000	4.651	4.694	4.738	4.781	4.564	4.627	4.690	4.754	4.817	4.880
\$/YR	565295	570585	575875	581164	554716	562410	570104	577798	585492	593186

SHAMOKIN OPERATING COST SUMMARY

	31	32	33	34	35	36	37	38	39	40
LOAD FACT	0.925	0.925	0.925	0.925	0.925	0.925	0.300	0.350	0.400	0.450
AVAILABILITY	0.750	0.750	0.750	0.750	0.750	1.000	1.000	1.000	1.000	1.000
EFFICIENCY	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735
CA/S	4.000	4.000	4.000	4.000	4.000	2.500	2.500	2.500	2.500	2.500
CULM COST	0.000	0.000	0.000	0.000	0.000	2.000	2.000	2.000	2.000	2.000
ASH DISP	0.000	0.000	0.000	0.000	0.000	2.000	2.000	2.000	2.000	2.000
LIMESTONE	12.000	14.000	16.000	18.000	20.000	5.500	5.500	5.500	5.500	5.500
SPF	0.694	0.694	0.694	0.694	0.694	0.925	0.300	0.350	0.400	0.450
STM PROD	13875.	13875.	13875.	13875.	13875.	18500.	6000.	7000.	8000.	9000.
CULM IN	5470.	5470.	5470.	5470.	5470.	7294.	2366.	2760.	3154.	3548.
STONE IN	878.	878.	878.	878.	878.	732.	237.	277.	317.	356.
ASH OUT	4444.	4444.	4444.	4444.	4444.	5618.	1822.	2126.	2429.	2733.
FIXED COST	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06
CULM COST	0.00	0.00	0.00	0.00	0.00	7.29	2.37	2.76	3.15	3.55
STONE COST	5.27	6.15	7.03	7.90	8.78	2.01	0.65	0.76	0.87	0.98
DISP COST	0.00	0.00	0.00	0.00	0.00	5.62	1.82	2.13	2.43	2.73
VARBL COST	34.26	34.26	34.26	34.26	34.26	40.05	24.42	25.67	26.92	28.17
\$/HR	68.59	69.47	70.35	71.23	72.11	84.03	58.32	60.38	62.43	64.49
\$/1000	4.944	5.007	5.070	5.134	5.197	4.542	9.720	8.625	7.804	7.166
\$/YR	600880	608574	616269	623963	631657	736099	510837	528904	546921	564938

SHAMOKIN OPERATING COST SUMMARY

	41	42	43	44	45	46	47	48	49	50
LOAD FACT	0.500	0.550	0.600	0.650	0.700	0.750	0.800	0.850	0.900	0.950
AVAILABLT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
EFFICIEN	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735
CA/S	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500
CULM COST	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
ASH DISP	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
LIMESTONE	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500
SPF	0.500	0.550	0.600	0.650	0.700	0.750	0.800	0.850	0.900	0.950
STM PROD	10000.	11000.	12000.	13000.	14000.	15000.	16000.	17000.	18000.	19000.
CULM IN	3943.	4337.	4731.	5125.	5520.	5914.	6308.	6702.	7097.	7491.
STONE IN	396.	435.	475.	514.	554.	593.	633.	673.	712.	752.
ASH OUT	3037.	3340.	3644.	3948.	4251.	4555.	4859.	5162.	5466.	5770.
FIXED COST	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06
CULM COST	3.94	4.34	4.73	5.13	5.52	5.91	6.31	6.70	7.10	7.49
STONE COST	1.09	1.20	1.31	1.41	1.52	1.63	1.74	1.85	1.96	2.07
DISP COST	3.04	3.34	3.64	3.95	4.25	4.56	4.86	5.16	5.47	5.77
VARBL COST	29.42	30.67	31.92	33.17	34.42	35.67	36.92	38.17	39.42	40.67
\$/HR	66.55	68.60	70.66	72.72	74.77	76.83	78.89	80.94	83.00	85.06
\$/1000	6.655	6.237	5.888	5.594	5.341	5.122	4.930	4.761	4.611	4.477
\$/YR	582955	600972	618989	637006	655023	673040	691057	709074	727091	745108

SHAMOKIN OPERATING COST SUMMARY

	51	52	53	54	55	56	57	58	59	60
LOAD FACT	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925
AVAILABLT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
EFFICIEN	0.600	0.650	0.700	0.750	0.800	0.735	0.735	0.735	0.735	0.735
CA/S	2.500	2.500	2.500	2.500	2.500	0.000	1.000	2.000	3.000	4.000
CULM COST	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
ASH DISP	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
LIMESTONE	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500
SPF	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925
STM PROD	18500.	18500.	18500.	18500.	18500.	18500.	18500.	18500.	18500.	18500.
CULM IN	8935.	8248.	7658.	7148.	6701.	7294.	7294.	7294.	7294.	7294.
STONE IN	897.	828.	769.	717.	672.	0.	293.	586.	879.	1171.
ASH OUT	6882.	6353.	5899.	5506.	5162.	5106.	5311.	5516.	5720.	5925.
FIXED COST	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06
CULM COST	8.93	8.25	7.66	7.15	6.70	7.29	7.29	7.29	7.29	7.29
STONE COST	2.47	2.28	2.11	1.97	1.85	0.00	0.01	1.01	2.42	3.22
DISP COST	6.88	6.35	5.90	5.51	5.16	5.11	5.31	5.52	5.72	5.93
VARBL COST	40.05	40.05	40.05	40.05	40.05	40.05	40.05	40.05	40.05	40.05
\$/HR	87.39	85.98	84.78	83.73	82.82	81.50	82.51	83.52	84.53	85.54
\$/1000	4.724	4.648	4.582	4.526	4.477	4.406	4.460	4.515	4.569	4.624
\$/YR	765516	753196	742636	733484	725477	713979	722827	731675	740523	749371

SHAMOKIN OPERATING COST SUMMARY

	61	62	63	64	65	66	67	68	69	70
LOAD FACT	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925
AVAILABTY	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
EFFICIEN	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735
CA/S	5.000	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500
CULM COST	2.000	0.000	2.000	4.000	6.000	8.000	10.000	12.000	14.000	16.000
ASH DISP	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
LIMESTONE	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500
SPF	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925
STM PROD	18500.	18500.	18500.	18500.	18500.	18500.	18500.	18500.	18500.	18500.
CULM IN	7294.	7294.	7294.	7294.	7294.	7294.	7294.	7294.	7294.	7294.
STONE IN	1464.	732.	732.	732.	732.	732.	732.	732.	732.	732.
ASH OUT	6130.	5618.	5618.	5618.	5618.	5618.	5618.	5618.	5618.	5618.
FIXED COST	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06
CULM COST	7.29	0.00	7.29	14.59	21.88	29.18	36.47	43.76	51.06	58.35
STONE COST	4.03	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01
DISP COST	6.13	5.62	5.62	5.62	5.62	5.62	5.62	5.62	5.62	5.62
VARBL COST	40.05	40.05	40.05	40.05	40.05	40.05	40.05	40.05	40.05	40.05
\$/HR	86.55	76.74	84.03	91.32	98.62	105.91	113.20	120.50	127.79	135.09
\$/1000	4.679	4.148	4.542	4.936	5.331	5.725	6.119	6.513	6.908	7.302
\$/YR	758220	672206	736099	799993	863886	927780	991673	1055570	1119460	1183350

SHAMOKIN OPERATING COST SUMMARY

	71	72	73	74	75	76	77	78	79	80
LOAD FACT	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925
AVAILABTY	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
EFFICIEN	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735
CA/S	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500
CULM COST	18.000	20.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
ASH DISP	2.000	2.000	0.000	2.000	4.000	6.000	8.000	10.000	2.000	2.000
LIMESTONE	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	0.000	2.000
SPF	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925
STM PROD	18500.	18500.	18500.	18500.	18500.	18500.	18500.	18500.	18500.	18500.
CULM IN	7294.	7294.	7294.	7294.	7294.	7294.	7294.	7294.	7294.	7294.
STONE IN	732.	732.	732.	732.	732.	732.	732.	732.	732.	732.
ASH OUT	5618.	5618.	5618.	5618.	5618.	5618.	5618.	5618.	5618.	5618.
FIXED COST	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06
CULM COST	65.64	72.94	7.29	7.29	7.29	7.29	7.29	7.29	7.29	7.29
STONE COST	2.01	2.01	2.01	2.01	2.01	2.01	2.01	2.01	0.00	0.73
DISP COST	5.62	5.62	0.00	5.62	11.24	16.85	22.47	28.09	5.62	5.62
VARBL COST	40.05	40.05	40.05	40.05	40.05	40.05	40.05	40.05	40.05	40.05
\$/HR	142.38	149.67	78.41	84.03	89.65	95.27	100.88	106.50	82.02	82.75
\$/1000	7.696	8.090	4.238	4.542	4.846	5.149	5.453	5.757	4.433	4.473
\$/YR	1247250	1311140	686886	736099	785313	834527	883740	932954	718467	724879

SHAMOKIN OPERATING COST SUMMARY

	81	82	83	84	85	86	87	88	89	90
LOAD FACT	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.000
AVAILABTY	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.000
EFFICIEN	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.000
CA/S	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	0.000
CULM COST	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	0.000
ASH DISP	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	0.000
LIMESTONE	4.000	6.000	8.000	10.000	12.000	14.000	16.000	18.000	20.000	0.000
SPF	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.000
STM PROD	18500.	18500.	18500.	18500.	18500.	18500.	18500.	18500.	18500.	0.
CULM IN	7294.	7294.	7294.	7294.	7294.	7294.	7294.	7294.	7294.	0.
STONE IN	732.	732.	732.	732.	732.	732.	732.	732.	732.	0.
ASH OUT	5618.	5618.	5618.	5618.	5618.	5618.	5618.	5618.	5618.	0.
FIXED COST	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	0.00
CULM COST	7.29	7.29	7.29	7.29	7.29	7.29	7.29	7.29	7.29	0.00
STONE COST	1.46	2.20	2.93	3.66	4.39	5.12	5.86	6.59	7.32	0.00
DISP COST	5.62	5.62	5.62	5.62	5.62	5.62	5.62	5.62	5.62	0.00
VARBL COST	40.05	40.05	40.05	40.05	40.05	40.05	40.05	40.05	40.05	0.00
\$/HR	83.48	84.21	84.94	85.68	86.41	87.14	87.87	88.60	89.34	0.00
\$/1000	4.512	4.552	4.592	4.631	4.671	4.710	4.750	4.789	4.829	0.000
\$/YR	731290	737702	744114	750526	756937	763349	769761	776172	782584	0

SHAMOKIN OPERATING COST SUMMARY

	<u>90</u>	<u>91</u>	<u>92</u>	<u>93</u>	<u>94</u>	<u>95</u>
LOAD FACT	.925	.925	.925	.925	.925	.925
AVAILABILITY	1.000	1.000	1.000	1.000	1.000	1.000
EFFICIENCY	.735	.735	.735	.735	.735	.735
Ca/S-	2.500	2.500	2.500	2.500	2.500	2.500
CULM COST	2.000	2.000	2.000	2.000	2.000	2.000
ASH DISP	2.000	2.000	2.000	2.000	2.000	2.000
LIMESTONE	5.500	5.500	5.500	5.500	5.500	5.500
POWER FACTOR	.750	.500	.250	0.000	1.000	1.000
LABOR FACTOR	1.000	1.000	1.000	1.000	.750	.500
SPF	.925	.925	.925	.925	.925	.925
STM PROD	18500	18500	18500	18500	18500	18500
CULM IN	7294	7294	7294	7294	7294	7294
STONE IN	732	732	732	732	732	732
ASH OUT	5618	5618	5618	5618	5618	5618
FIXED COST	29.06	29.06	29.06	29.06	22.85	16.65
CULM COST	7.29	7.29	7.29	7.29	7.29	7.29
STONE COST	2.01	2.01	2.01	2.01	2.01	2.01
DISP COST	5.62	5.62	5.62	5.62	5.62	5.62
VARBL COST	32.40	25.01	17.62	10.24	39.79	39.79
\$/HR	76.39	69.00	61.61	54.22	77.57	71.36
\$/1000	4.13	3.73	3.33	2.93	4.19	3.86
\$/YR	669,000	604,000	540,000	475,000	680,000	625,000

APPENDIX C-2

SHAMOKIN OPERATING COST SUMMARY
GROSS SALES OPTION

SHAMOKIN OPERATING COST SUMMARY
GROSS SALE OPTION

	1	2	3	4	5	6	7	8	9	10
LOAD FACT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
AVAIL	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925
EFFICIEN	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735
CA/S	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500
CULM COST	1.000	2.000	3.000	4.000	5.000	6.000	7.000	2.000	2.000	2.000
ASH DISP	2.000	2.000	2.000	2.000	2.000	2.000	2.000	6.500	3.100	-0.800
LIMESTONE	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500
STEAM SOLD	3000.	3000.	3000.	3000.	3000.	3000.	3000.	3000.	3000.	3000.
STEAM \$	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
POWER \$	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060
TURB EFF	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700
TURB ENTH	195.	195.	195.	195.	195.	195.	195.	195.	195.	195.
BLR ENTH	1003.	1003.	1003.	1003.	1003.	1003.	1003.	1003.	1003.	1003.
DEARATOR	825.	825.	825.	825.	825.	825.	825.	825.	825.	825.
STM PROD	20882.	20882.	20882.	20882.	20882.	20882.	20882.	20882.	20882.	20882.
CULM IN	7309.	7309.	7309.	7309.	7309.	7309.	7309.	7309.	7309.	7309.
STONE IN	733.	733.	733.	733.	733.	733.	733.	733.	733.	733.
ASH OUT	5630.	5630.	5630.	5630.	5630.	5630.	5630.	5630.	5630.	5630.
KW PROD	724.	724.	724.	724.	724.	724.	724.	724.	724.	724.
KW USED	616.	616.	616.	616.	616.	616.	616.	616.	616.	616.
KW SOLD	108.	108.	108.	108.	108.	108.	108.	108.	108.	108.
FIXED COST	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06
CULM COST	3.65	7.31	10.96	14.62	18.27	21.93	25.58	7.31	7.31	7.31
STONE COST	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02
DISP COST	5.63	5.63	5.63	5.63	5.63	5.63	5.63	18.30	8.73	-2.25
VARBL COST	11.58	11.58	11.58	11.58	11.58	11.58	11.58	11.58	11.58	11.58
TOTAL COST	82.76	86.41	90.07	93.72	97.37	101.03	104.68	99.08	89.51	78.53
STEAM REV	16.65	16.65	16.65	16.65	16.65	16.65	16.65	16.65	16.65	16.65
POWER REV	43.45	43.45	43.45	43.45	43.45	43.45	43.45	43.45	43.45	43.45
TOTAL REV	60.10	60.10	60.10	60.10	60.10	60.10	60.10	60.10	60.10	60.10
NET REV HR	-22.66	-26.31	-29.97	-33.62	-37.27	-40.93	-44.58	-38.98	-29.41	-18.43
NET REV YR	-198466	-230481	-262496	-294512	-326527	-358542	-390557	-341449	-257607	-161434

SHAMOKIN OPERATING COST SUMMARY
GROSS SALE OPTION

	11	12	13	14	15	16	17	18	19	20
LOAD FACT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
AVAIL	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925	0.925
EFFICIEN	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735
CA/S	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500
CULM COST	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
ASH DISP	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
LIMESTONE	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500
STEAM SOLD	4000.	5000.	6000.	7000.	8000.	9000.	3000.	3000.	3000.	3000.
STEAM \$	6.000	6.000	6.000	6.000	6.000	6.000	4.000	8.000	10.000	6.000
POWER \$	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.050
TURB EFF	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700
TURB ENTH	195.	195.	195.	195.	195.	195.	195.	195.	195.	195.
BLR ENTH	1003.	1003.	1003.	1003.	1003.	1003.	1003.	1003.	1003.	1003.
DEARATOR	825.	825.	825.	825.	825.	825.	825.	825.	825.	825.
STM PROD	20882.	20882.	20882.	20882.	20882.	20882.	20882.	20882.	20882.	20882.
CULM IN	7309.	7309.	7309.	7309.	7309.	7309.	7309.	7309.	7309.	7309.
STONE IN	733.	733.	733.	733.	733.	733.	733.	733.	733.	733.
ASH OUT	5630.	5630.	5630.	5630.	5630.	5630.	5630.	5630.	5630.	5630.
KW PROD	687.	650.	613.	576.	539.	502.	724.	724.	724.	724.
KW USED	616.	616.	616.	616.	616.	616.	616.	616.	616.	616.
KW SOLD	71.	34.	-3.	-40.	-77.	-114.	108.	108.	108.	108.
FIXED COST	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06
CULM COST	7.31	7.31	7.31	7.31	7.31	7.31	7.31	7.31	7.31	7.31
STONE COST	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02
DISP COST	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63	5.63
VARBL COST	11.58	11.58	11.58	11.58	11.58	11.58	11.58	11.58	11.58	11.58
TOTAL COST	86.41	86.41	86.41	86.41	86.41	86.41	86.41	86.41	86.41	86.41
STEAM REV	22.20	27.75	33.30	38.85	44.40	49.95	11.10	22.20	27.75	16.65
POWER REV	41.23	39.01	36.79	34.57	32.35	30.13	43.45	43.45	43.45	36.21
TOTAL REV	63.43	66.76	70.09	73.42	76.75	80.08	54.55	65.65	71.20	52.86
NET REV HR	-22.98	-19.65	-16.32	-12.99	-9.66	-6.33	-31.86	-20.76	-15.21	-33.55
NET REV YR	-201308	-172134	-142960	-113787	-84613	-55439	-279099	-181863	-133245	-293918

SHAMOKIN OPERATING COST SUMMARY
GROSS SALE OPTION

	21	22	23	24	25	26	27	28	0	0
LOAD FACT	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	99.000	0.000
AVAIL	0.925	0.925	0.925	0.925	0.925	0.925	0.925	1.000	0.000	0.000
EFFICIEN	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.735	0.000	0.000
CAYS	2.500	2.500	2.500	2.500	2.500	2.500	2.500	2.500	0.000	0.000
CULM COST	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	0.000	0.000
ASH DISP	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	0.000	0.000
LIMESTONE	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	0.000	0.000
STEAM SOLD	3000.	10000.	11000.	12000.	13000.	14000.	15000.	3000.	0.	0.
STEAM \$	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	0.000	0.000
POWER \$	0.040	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.000	0.000
TURB EFF	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.000	0.000
TURB ENTH	195.	195.	195.	195.	195.	195.	195.	195.	0.	0.
BLR ENTH	1003.	1003.	1003.	1003.	1003.	1003.	1003.	1003.	0.	0.
DEARATOR	825.	825.	825.	825.	825.	825.	825.	825.	0.	0.
STM PROD	20882.	20882.	20882.	20882.	20882.	20882.	20882.	22575.	0.	0.
CULM IN	7309.	7309.	7309.	7309.	7309.	7309.	7309.	7902.	0.	0.
STONE IN	733.	733.	733.	733.	733.	733.	733.	793.	0.	0.
ASH OUT	5630.	5630.	5630.	5630.	5630.	5630.	5630.	6087.	0.	0.
KW PROD	724.	465.	428.	391.	354.	317.	280.	783.	0.	0.
KW USED	616.	616.	616.	616.	616.	616.	616.	649.	0.	0.
KW SOLD	108.	-151.	-188.	-225.	-262.	-299.	-336.	134.	0.	0.
FIXED COST	29.06	29.06	29.06	29.06	29.06	29.06	29.06	29.06	0.00	0.00
CULM COST	7.31	7.31	7.31	7.31	7.31	7.31	7.31	7.90	0.00	0.00
STONE COST	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.18	0.00	0.00
DISP COST	5.63	5.63	5.63	5.63	5.63	5.63	5.63	6.09	0.00	0.00
VARBL COST	11.58	11.58	11.58	11.58	11.58	11.58	11.58	12.33	0.00	0.00
TOTAL COST	86.41	86.41	86.41	86.41	86.41	86.41	86.41	90.01	0.00	0.00
STEAM REV	16.65	55.50	61.05	66.60	72.15	77.70	83.25	18.00	0.00	0.00
POWER REV	28.97	27.91	25.69	23.47	21.25	19.03	16.81	46.97	0.00	0.00
TOTAL REV	45.62	83.41	86.74	90.07	93.40	96.73	100.06	64.97	0.00	0.00
NET REV HR	-40.79	-3.00	0.33	3.66	6.99	10.32	13.65	-25.04	0.00	0.00
NET REV YR-357356	-26266	2908	32082	61255	90429	119603	-219325	0	0	0

APPENDIX D
DEFINITION OF TERMS

APPENDIX D - DEFINITION OF TERMS

Ash Disposal Cost: Cost of ash disposal (fly ash and bottom ash) including trucking cost in dollars per ton of ash.

Availability: Fraction of total time that the boiler can operate when downtime, both planned and unplanned, is subtracted. Historically for the nine month test program this has been 0.925, which is used as the base case in all comparisons.

Boiler Efficiency: Enthalpy increase of the steam/water in the boiler divided by the higher heating value of the coal being fed per unit time. The design boiler efficiency of the Shamokin FBC is 0.735.

Ca/S Ratio: Molar ratio of calcium in the limestone to sulfur in the fuel.

Culm Cost: Cost of anthracite culm delivered to the plant in dollars per ton.

Deaerator or Internal Steam use: The quantity of steam required to heat the boiler feedwater to approximately 220° F at which point dissolved gases in the water are released. For the design base case 3,400 pph of steam is used by the deaerator to heat 20,000 pph of boiler feedwater from approximately 55° F, since no steam condensate is returned to the system. For cogeneration cases wherein condensate is returned, this quantity would be reduced.

Enthalpy: In thermodynamic analysis, the combination $U + PV$ occurs so frequently that it has been given the name enthalpy.

Limestone Cost: Cost of limestone delivered to the plant in dollars per ton.

Load Factor: Fraction of full boiler flow being considered as maximum. For historical case this is 0.75 (i.e., 15,000 pph) which is the current continuous maximum steam production because of limits of baghouse capacity, etc. All other cases utilize a 1.00 load factor as the base case, i.e., 20,000 pph net steam flow or 23,400 pph gross steam flow.

Power Price: Selling price of power generated by the plant in dollars per kW net or gross power production.

Steam Price: Selling price of steam generated by the plant in dollars per 1000 lb of steam.

Steam Production Factor: Product of load factor and availability. The steam production factor multiplied by the boiler capacity yields a net steam flow available for sale or other usage.

Turbine Enthalpy: Available enthalpy difference between inlet condition and condenser conditions for turbine power generation in Btu/lb steam.

Turbine Generator Efficiency: Fraction of the available enthalpy of steam, between entering conditions and condenser conditions, which is converted to electrical power. For industrial turbine generators in the size range useable at Shamokin, this efficiency is approximately 0.70.