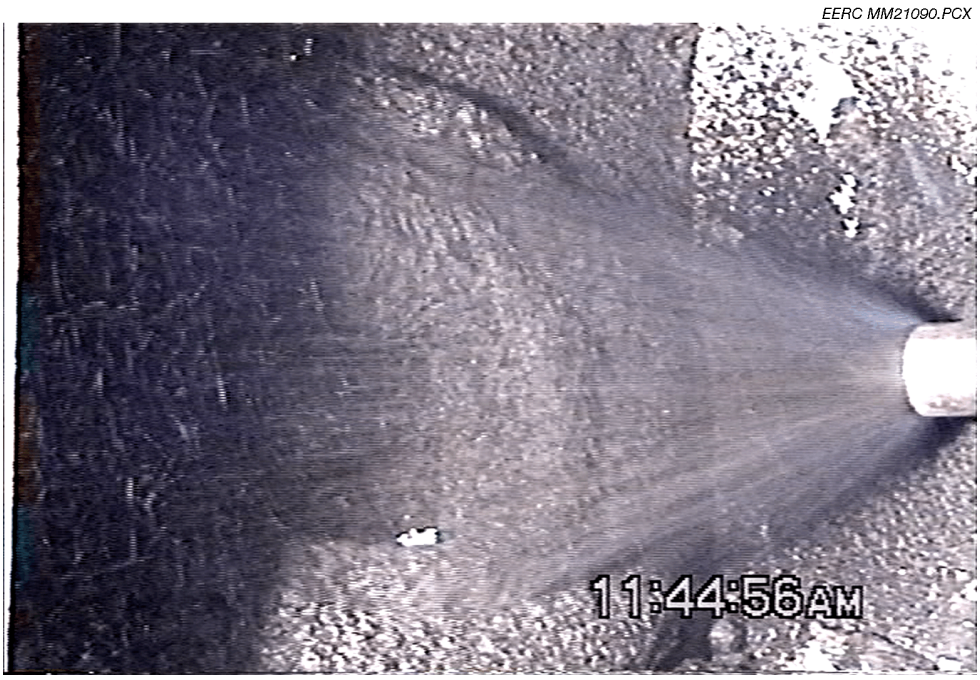

Figure B3. Sludge dispersion testing with EERC-2 nozzle.

APPENDIX C

ECONOMIC ANALYSIS OF SLUDGE-RECEIVING, STORAGE, AND FEEDING SYSTEM

ECONOMICS OF THE FIGLEAF PROJECT

I. FIGLEAF Project – Capital Estimate

A. Basis for the Cost Estimate

Scope

The scope of work associated with the project consists of the equipment, systems, and bulk materials required to offload, store, forward, and feed sludge cake to the second stage of the gasifier located at the Wabash River Coal Gasification Repowering Project. The scope of work associated with the addition of this facility is described in the accompanying conceptual design documents, including:

- Design criteria document (Table I)
- Process flow diagrams (Figures 1 and 2)
- Equipment list (sized) (Table II)
- Plot plan (marked up) (Figure 3)
- Major equipment quotations (Please refer to EERC descriptions)

Generation of the cost estimate associated with this facility, is described below.

Major Equipment

Sizing and quotations for the major equipment were obtained by EERC from Schwing America Inc. These included an overall description, basic specification data, and drawings of the equipment. The remainder of equipment was estimated based on similar equipment in similar service, using capacity as a scale factor.

Bulk Material Costs

Bulk material pricing was based on a combination of actual unit costs and rates from Wabash (escalated to current day) and recent industry data for craft labor factors and material costs.

Bulk Material Quantities

- Earthwork – takeoff based on plot plan
- Concrete – manual takeoff based on conceptual design sketches for pads, unloading structure, etc.
- Steel – assumed a small tonnage for miscellaneous structures, pipe rack modification, and pipe supports
- Piping – manual takeoff based on the plot plan and PFD
- Instruments – basic count taken from the equipment quotation (installation only) and the PFDs (supply and installation)
- Electrical – feeder cable and switchgear sized as part of the conceptual design. Costs associated with cable and conduit were estimated by manual takeoff from the plot plan.

- Painting and insulation rough estimated based on piping takeoff
- Electrical heat tracing rough estimated based on piping takeoff

Subcontracts

Although representing a relatively small portion of the overall work, the scope and cost associated with subcontracted work was factored based on similar industry experience at other sites.

Construction

The direct hire component of the work was estimated based on union labor unit rates typical to the industry. The union labor rate employed in the estimate is a built up ("all in") rate, which includes compensation, fringes, taxes, and construction indirects which include non-manual staffing, temporary facilities, small tools and consumables, etc. An all-in labor rate of $61/hr should be representative of the craft mix, at this location, barring any unique market influences or weather impacts.

Sales Tax

Excluded

Equipment Supplier Field Service

Field service by the major equipment supplier, consisting of 17 days including travel and per diem, was included as part of the equipment quotes.

Freight

Freight is included as part of the major equipment quotation

Escalation

No escalation has been applied to the estimate, aside from the use of actual historic Wabash data referenced above. Therefore this estimate is current day.

Spares

No spares have been included.

Interest During Construction

None has been applied; therefore, the estimate assumes "overnight" construction.

Home Office (Eng./Proj. Mgmt./Admin.)

The cost for detailed engineering (including procurement) and design, as well as project management and administration are included to cover roughly 10,000 staff hours at current industry rates, plus an allowance for travel and other expenses.

Contingency

A 10% contingency has been added to cover omissions, design changes, and contractor profit.

B. Total Cost

The total cost was determined to be $9.71MM. The estimate is accurate to within 10%. An item by item breakdown of the estimate is shown in Table III.

Table I

FIGLEAF PROJECT DESIGN CRITERIA

Feed Rate: 1000 tpd

Feed Material: Sewage Sludge

Slurry: 23% solids (weight)

Slurry Density: 60 lb/ft^3

Storage Capacity: 2 days (4 tanks @ 19,000 ft^3/lb per tank)

Trucking Criteria: 30 yd^3 (25 tons)

II. FIGLEAF Economic Analysis

This economic analysis reviews the impact of addition of biosolids to the gasifier utilizing the FIGLEAF developed systems. Two plants are analyzed, a petcoke IGCC and a coal IGCC. Both plants are single train facilities, nominally 300 MW for the coke cases and nominally 250 MW for the coal cases.

In this review, a cost model based on Department of Energy IGCC Model, Version 3 spreadsheet was developed for the nominal coke/coal IGCC and a target rate of return (IRR) determined. The spreadsheet was then run with a second case reflecting the addition of the biosolids fuel to the second stage and the model was adjusted for the impacts on capital cost, output and heat rate. The required tipping fee for the biosolids was determined to maintain the same level of economic performance as measured by the IRR and NPV as the single primary fuel cases.

Major Parameters for Economic Analysis

	Petcoke	Coal
Fuel Cost, $/ton (coke/coal)	$12.00	$23.00
Electrical Power Price, $/MWH	$34.00	$ 42.89
Capital Cost for single fuel plant, $/kW (escalated)	1300	1350
Additional Cost for FIGLEAF system, MM$	9.71	9.71
Availability, %	85	80
Contract Life, Years	20	20
Financing, Debt/Equity/Interest	70/ 30/ 9%	70/ 30/ 9%
Return, IRR%	12	12
NPV, MM$ @ 10% discount rate	29.7	29.7

A. Petcoke & Petcoke-Bio-solids Cases:

	Petcoke IGCC	FIGLEAF
Petcoke, TPD	2292	2095
BioSolids, TPD	0	1042
Net Output, MW	301.4	291.3
Heat Rate, Btu/kWhr HHV	8690	8851

Results:

The Petcoke only plant showed a 12% IRR with a NPV of $29.7MM at a 10% discount rate.

At a power price of $34/MWH, the Petcoke-Bio-solids plant (FIGLEAF) must be able to obtain biosolids with a tipping fee of $12.40 per ton (i.e. feedstock must have negative value) to obtain the same economic performance.

The sensitivity of the required cost (or tipping fee) of the bio-solid to the variation in power price is shown in the following and in Figure 4:

Electrical Power Price $/MWH	Cost of Bio-Solid $/Wet Ton
30	-41.8
32	-27.1
34	-12.4
36	2.3
40	31.7

B. Coal & Coal-Bio-solids Cases:

	Coal IGCC	FIGLEAF
Coal, TPD	2710	2459
BioSolids, TPD	0	881
Net Output, MW	268.2	255.7
Heat Rate, Btu/kWhr HHV	8955	9187

Results:

The Coal-only IGCC plant showed a 12% IRR with a NPV of $29.7MM at a 10% discount rate (note that this is with a higher power price than the petcoke-only IGCC).

The Coal-Biosolids plant (FIGLEAF) must be able to obtain biosolids with a tipping fee of $16**.70 per ton** (i.e. feedstock must have negative value) to obtain the same economic performance.

The sensitivity of the required cost (or tipping fee) of the bio-solid to the variation in power price is shown in the following and in Figure 4:

Electrical Power Price $/MWH	Cost of Bio-Solid $/Wet Ton
32	-99.8
35	-76.9
40	-38.8
42.9	-16.7
46	7.1

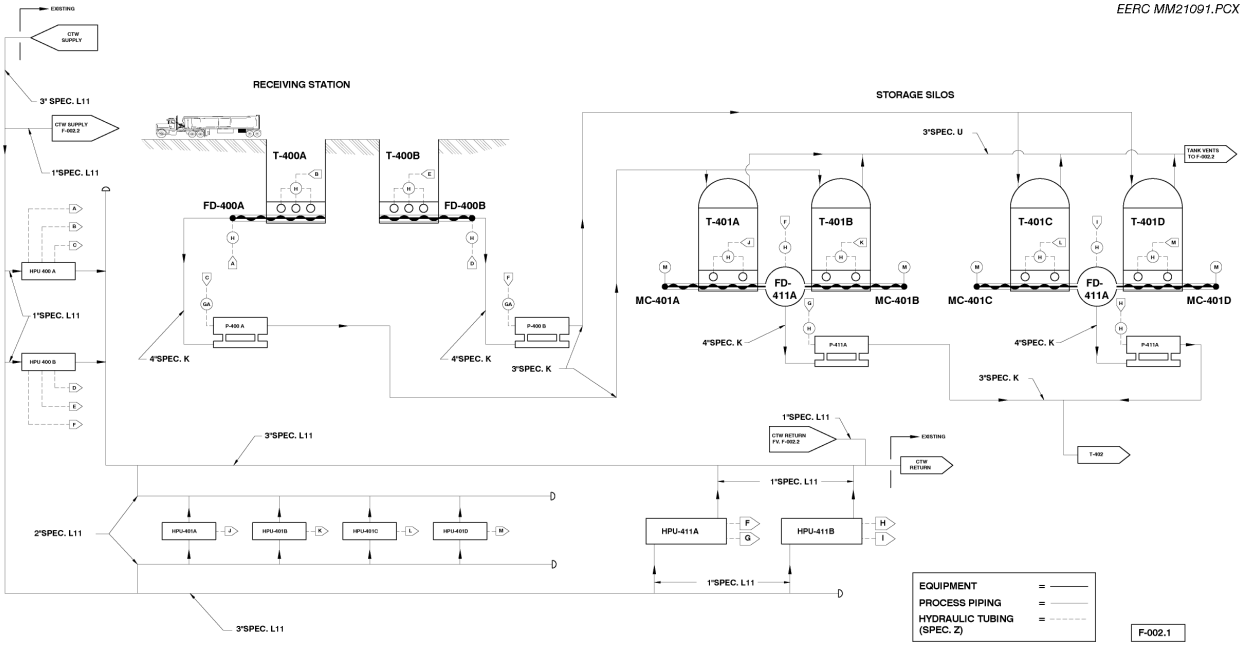

Figure C1. Process flow diagram for sludge receiving and storage systems.

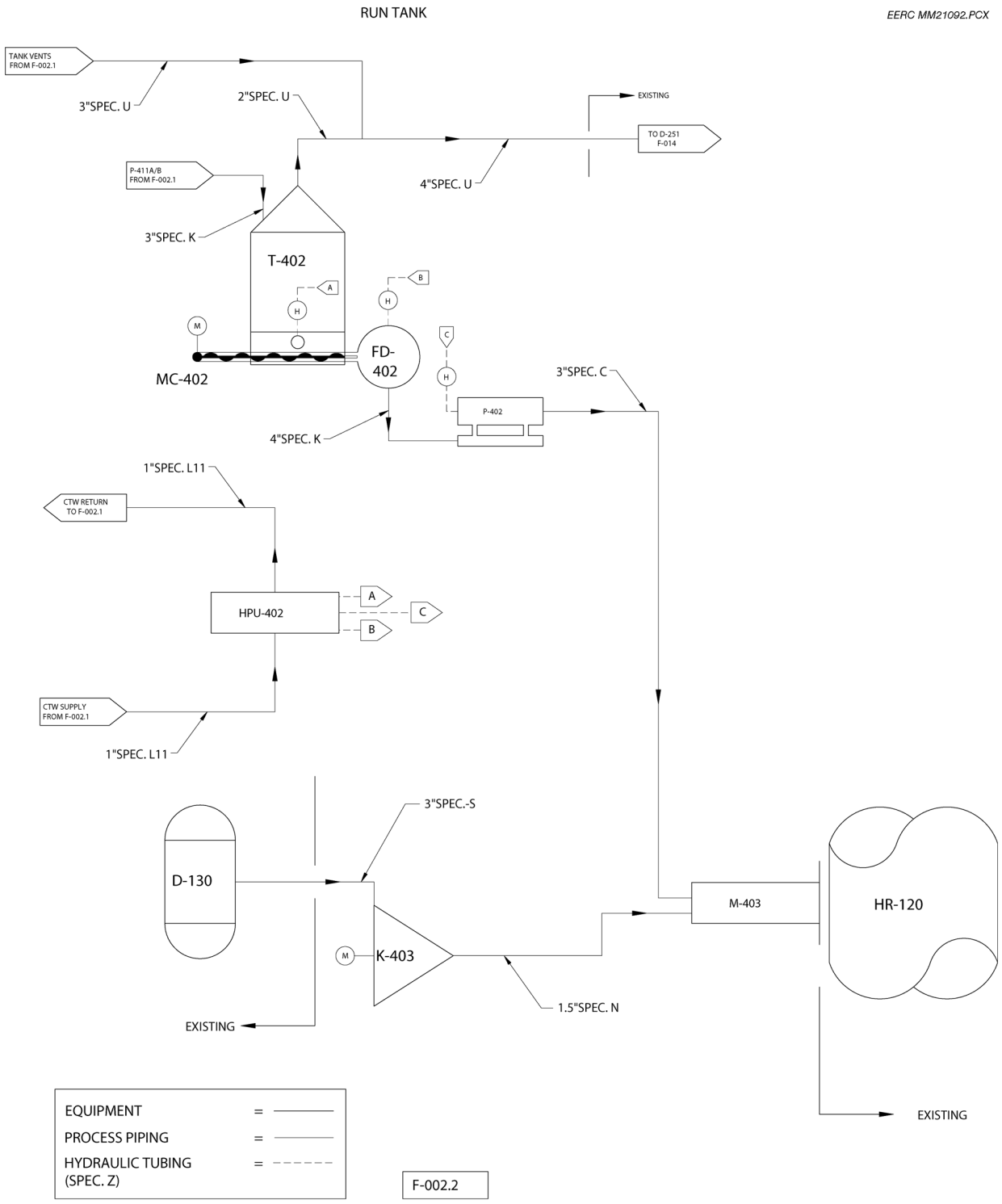

Figure C2. Process flow diagram for sludge high-pressure feeding system.

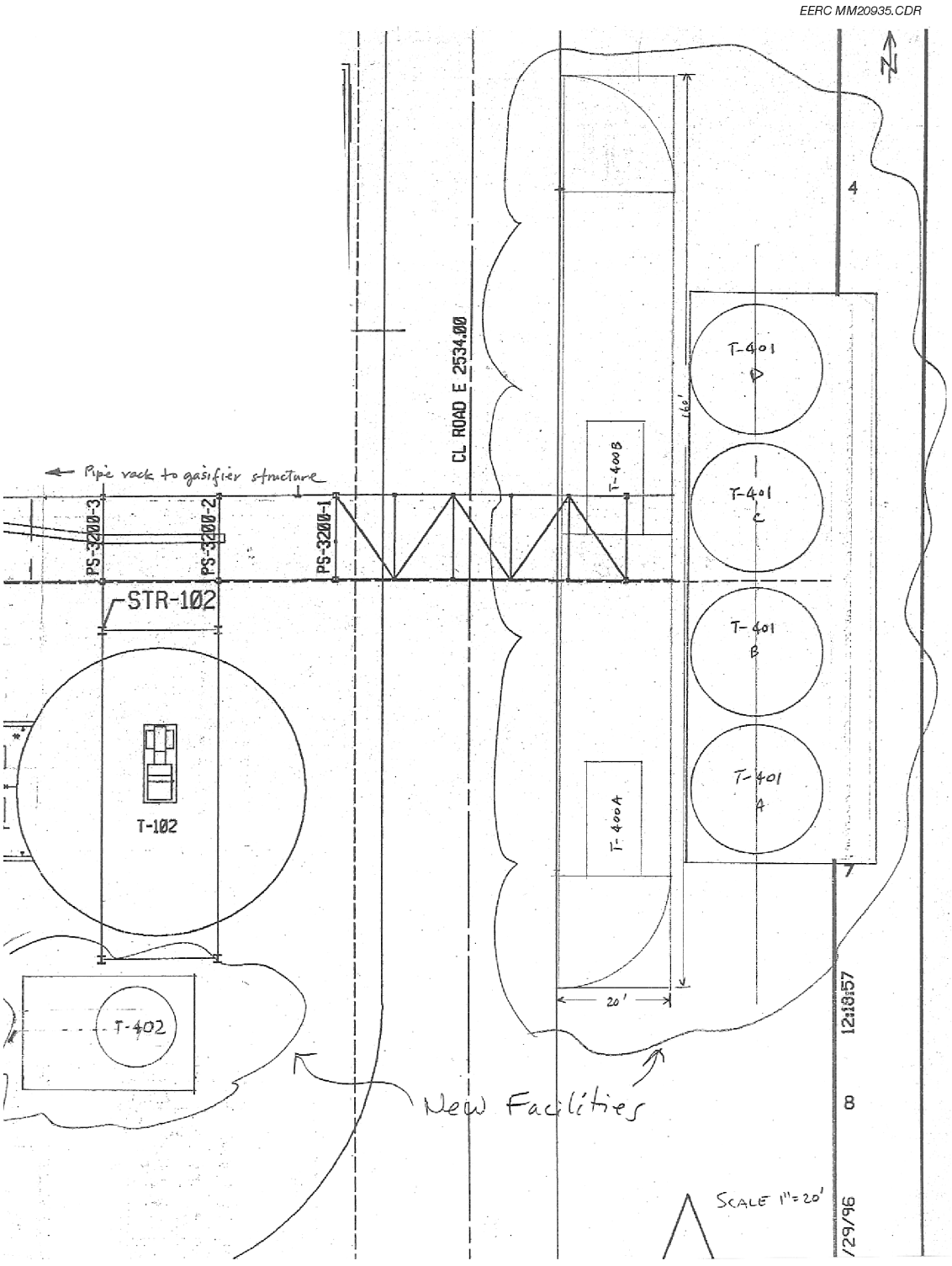

Figure C-3. Facility plot plan.

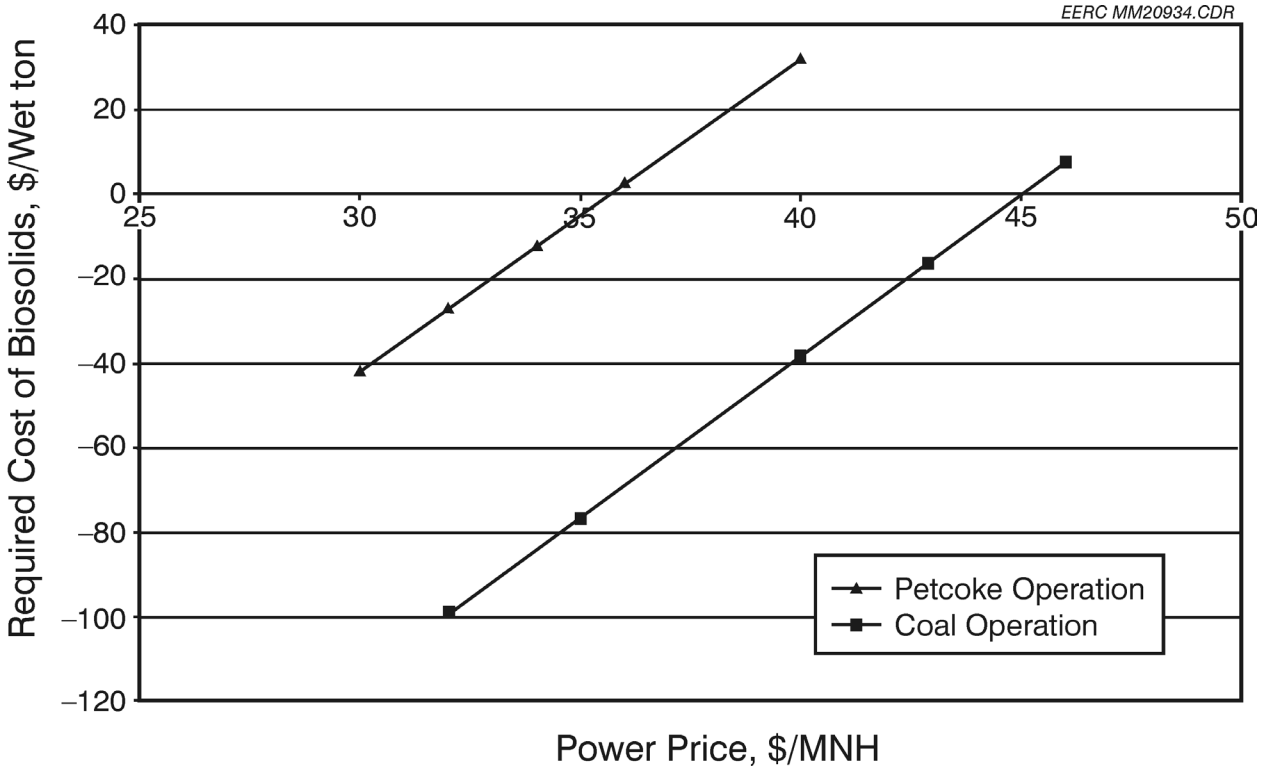

Figure C4. Municipal sludge cost vs. power price.

TABLE II

	FIGLEAF PROJECT - EQUIPMENT LIST								
[* = redundant equipment within train]					Nominal Size				Conn.
	Tag #	Equipment Description	Qty	Materials of Constr.	Capacity 1	Units	Capacity 2	Units	hp
	T-400 A/B	Receiving Bunkers (w/ sliding frame bottom)	2	A-36 C-Stl	3,850	ft^3	20'L x 9.5'W x 20' H		hydraulic
	FD-400 A/B	Screw Feeders	2						hydraulic
	P-400 A/B	Sludge Pumps	2		160	gpm			hydraulic
	HPU-400 A/B	Hydraulic Power Units	2						200
	T-401 A-D	Storage Silos (w/ sliding frame bottom)	4	A-36 C-Stl	19,000	ft^3	23'D x 46'H		hydraulic
	HPU-401 A-D	Hydraulic Power Units	4	[VFD]					25
	MC-401A-D	Extraction Conveyors	4						25
	FD-411 A/B	Screw Feeders	2						hydraulic
	P-411 A/B	Sludge Pumps	2		160	gpm			hydraulic
	HPU-411 A/B	Hydraulic Power Units	2						200
	T-402	Run Tank (w/ sliding frame bottom)	1	A-36 C-Stl	1,718	ft^3	13.5' D x 12' H		hydraulic
	MC-402	Extraction Conveyor	1						20
	FD-402	Screw Feeder	1						hydraulic
	P-402	Sludge Feed Pump	1		160	gpm			hydraulic
	HPU-402	Hydraulic Power Unit	1						250
	K-403	Recycle Syngas Booster Compressor	1	304L SS	15,000	lb/hr	800	psig	200
	M-403	Sludge Mixer	1	High Nickle Alloy					

TABLE III

FIGLEAF - EQUIPMENT LIST & CAPITAL COST ESTIMATE

Cost Account	Tag #	Description	EQUIPMENT/MATERIALS Qty	Units	Unit Cost	Total Cost	LABOR Qty	LF	Unit Cost	Total Cost	LINE Total
Mech Equip.		*Receiving Station:*									
	T-400 A/B	Receiving Bunkers (w/ sliding frame bott	2			$0	440		$61	$53,680	
	FD-400 A/B	Screw Feeders	2			$0	80		$61	$9,760	
	P-400 A/B	Sludge Pumps	2			$0	40		$61	$4,880	
	HPU-400 A/B	Hydraulic Power Units	2			$0	40		$61	$4,880	
		Subtotal	1		$1,300,000	$1,300,000				$73,200	$1,373,200
		Storage Area:									
	T-401 A-D	Storage Silos (w/ sliding frame bottom)	4			$0	1421		$61	$346,773	
	HPU-401 A-D	Hydraulic Power Units	4			$0	40		$61	$9,760	
	MC-401A-D	Extraction Conveyors	4			$0	150		$61	$36,600	
	FD-411 A/B	Screw Feeders	2			$0	80		$61	$9,760	
	P-411 A/B	Sludge Pumps	2			$0	40		$61	$4,880	
	HPU-411 A/B	Hydraulic Power Units	2			$0	40		$61	$4,880	
		Subtotal	1		$2,900,000	$2,900,000				$412,653	$3,312,653
		Run Tank:									
	T-402	Run Tank (w/ sliding frame bottom)	1			$0	129		$61	$7,839	
	MC-402	Extraction Conveyor	1			$0	150		$61	$9,150	
	FD-402	Screw Feeder	1			$0	80		$61	$4,880	
	P-402	Sludge Feed Pump	1			$0	40		$61	$2,440	
	HPU-402	Hydraulic Power Unit	1			$0	40		$61	$2,440	
		Subtotal	1		$700,000	$700,000				$26,749	$726,749
		Other:									
	K-403	Recycle Syngas Booster Compressor	1		$240,000	$240,000	250		$61	$15,250	$255,250
	M-403	Sludge Mixer	1		$75,000	$75,000	20		$61	$1,220	$76,220
		Subtotal			$315,000	$315,000				$16,470	$331,470
		Account Subtotal									$5,744,072
Earthwork											
		Clear & Grub (s/c)	1			$0	2	ac	$2,400	$4,800	$4,800
		Cut & Fill (s/c)	1			$0	926	yd^3	$5	$4,676	$4,676
		Account Subtotal				$0				$9,476	$9,476
Concrete		Receiving Station [A-F]	892	yd^3	$170	$151,640	11		$61	$598,532	$750,172
		Storage Silos [G]	178	yd^3	$127	$22,606	14		$61	$152,012	$174,618
		Run Tank [H]	24	yd^3	$127	$3,048	14		$61	$20,496	$23,544
		Misc. [I]	17	yd^3	$101	$1,717	5.83		$61	$6,046	$7,763
		Account Subtotal	1111	yd^3		$179,011				$777,086	$956,097
Steel		Misc.	5	tons	$1,954	$9,770	27		$61	$8,235	$18,005
Piping											
	Spec C (3")	600# 304L SS	400	ft	$50	$20,000	2.3		$61	$56,120	$76,120
	Spec K (3")	150# 304L SS	520	ft	$64	$33,280	2.5		$61	$79,300	$112,580
	Spec K (4")	150# 304L SS	100	ft	$70	$7,000	2.8		$61	$17,080	$24,080
	Spec L11 (1")	150# CS	130	ft	$16	$2,080	1.3		$61	$10,309	$12,389
	Spec L11 (2")	150# CS	180	ft	$20	$3,600	1.5		$61	$16,470	$20,070
	Spec L11 (3")	150# CS	780	ft	$26	$20,280	1.8		$61	$85,644	$105,924
	Spec N (1.5")	900# 304L SS	335	ft	$40	$13,400	2		$61	$40,870	$54,270
	Spec S (3")	300# 304L SS	120	ft	$66	$7,920	2.6		$61	$19,032	$26,952

TABLE III (cont'd)

FIGLEAF - EQUIPMENT LIST & CAPITAL COST ESTIMATE

Cost Account	Tag #	Description	EQUIPMENT/MATERIALS Qty	Units	Unit Cost	Total Cost	LABOR Qty	LF	Unit Cost	Total Cost	LINE Total
	Spec U (2")	150# 304L SS	80	ft	$60	$4,800	2.3		$61	$11,224	$16,024
	Spec U (3")	150# 304L SS	285	ft	$64	$18,240	2.5		$61	$43,463	$61,703
	Spec Z (.5")	150# 316L SS	255	ft	$20	$5,100	1.1		$61	$17,111	$22,211
		Account Subtotal	3185	ft		$135,700				$396,622	$532,322
Elect. Equip.											
	Motor Starters		14		$2,500	$35,000	4		$61	$3,416	$38,416
	MCC		14	sect.	$300	$4,200	4		$61	$3,416	$7,616
	Panels		2		$7,000	$14,000	12		$61	$1,464	$15,464
		Account Subtotal				$53,200				$8,296	$61,496
Cable & Raceway											
	3/c #12	2	560	ft	$0.4	$228	0.1		$61	$3,416	$3,644
	1/c 4/0	3	1290	ft	$1.0	$1,229	0.3		$61	$23,607	$24,836
	1/c 350 kcmil	3	50	ft	$1.6	$79	1		$61	$3,050	$3,129
	1/c 1000 kcmil	6	540	ft	$5.1	$2,765	2.1		$61	$69,174	$71,939
	1" RGS		500	ft	$18	$9,000	1.5		$61	$45,750	$54,750
	2" RGS		90	ft	$23	$2,070	2		$61	$10,980	$13,050
	3" RGS		290	ft	$30	$8,700	3.2		$61	$56,608	$65,308
	4" RGS		150	ft	$40	$6,000	4.8		$61	$43,920	$49,920
		Account Subtotal				$30,071				$256,505	$286,576
Instrumentation											
	PG	(included w/ equipment)	4			$0	1.5		$61	$366	$366
	PT	(included w/ equipment)	4			$0	9.6		$61	$2,342	$2,342
	HS	(included w/ equipment)	5			$0	7		$61	$2,135	$2,135
	LT	(included w/ equipment)	7			$0	12.6		$61	$5,380	$5,380
	TG		7		$480	$3,360	4		$61	$1,708	$5,068
	PS	(included w/ equipment)	7			$0	6.6		$61	$2,818	$2,818
	FT		2		$1,500	$3,000	2.6		$61	$317	$3,317
	MOV		2		$17,500	$35,000	5		$61	$610	$35,610
		Account Subtotal				$41,360				$15,677	$57,037
Painting & Insulation		(s/c)	1							$50,000	$100,000
Elec. Heat Trace		(s/c)	1							$100,000	$150,000
Metal Building		(s/c)	600	sf	$50	$30,000					$30,000
Engineering, PM											$840,000
Contingency											$921,000
		GRAND TOTAL									$9,706,081