

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.

	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	1300	1350
(escalated)		
Additional Cost for FIGLEAF system,	9.71	9.71
MM\$		
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

Major Parameters for Economic Analysis

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

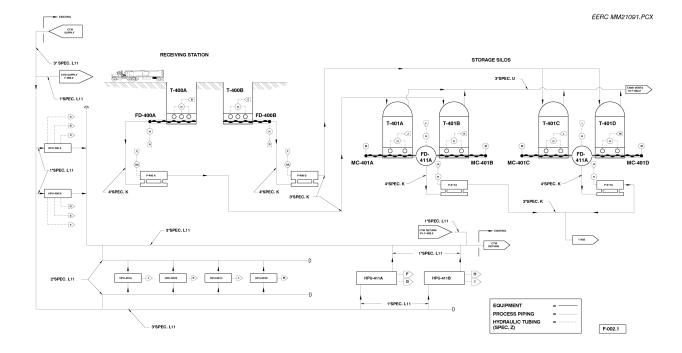


Figure C1. Process flow diagram for sludge receiving and storage systems.

RUN TANK

EERC MM21092.PCX

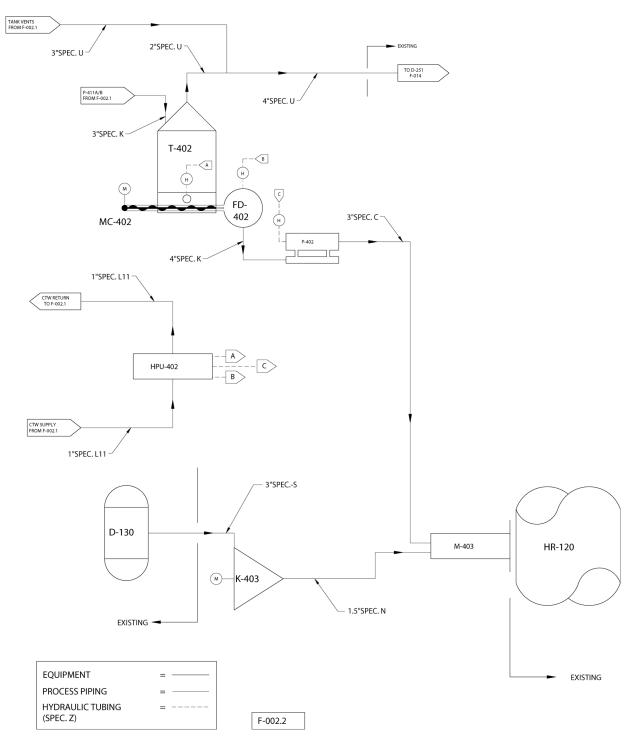


Figure C2. Process flow diagram for sludge high-pressure feeding system.

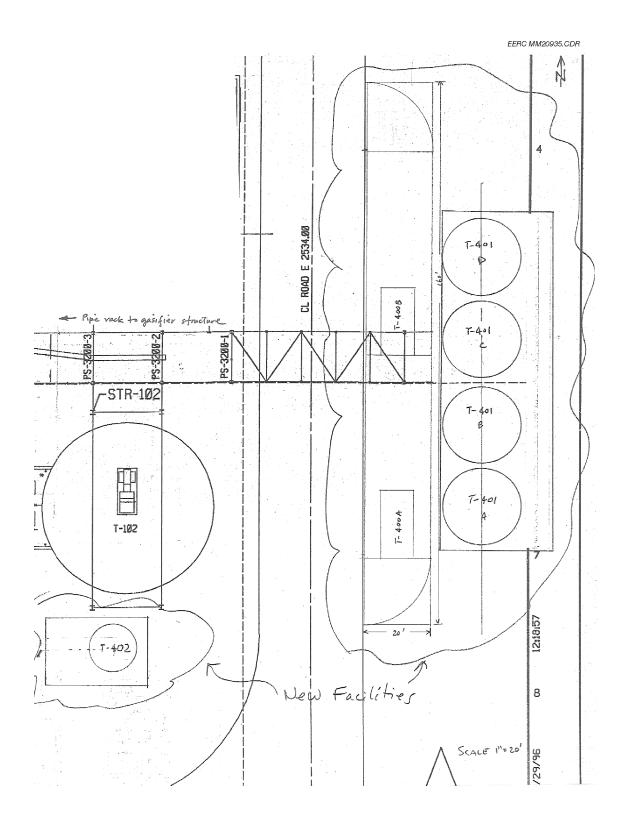


Figure C-3. Facility plot plan.

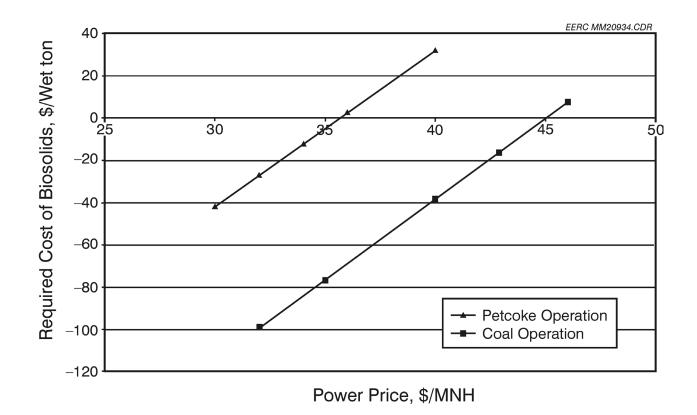


Figure C4. Municipal sludge cost vs. power price.

FIGLEAF	FIGLEAF PROJECT - EQUIPMENT LIST							1000
f* = redundant equi	= redundant equipment within train]				Nor	Nominal Size		Conn.
T 26 #	Equipment Description	Qty	Materials of Constr.	Capacity 1	Units	Capacity 2	Units	du
T 400 A/B	Pereiving Bunkers (w/ sliding frame bottom)	2	A-36 C-StI	3,850 ft^3	ft^3	20'L x 9.5'W x 20' H		hydraulic
	Porout Ecodore	2						nyaraulic
FU-400 A/B	OCIEW FEEDEIS	10		160	160 gpm			hydraulio
P-400 A/B		10						200
HPU-400 A/B	Hydraulic Power Units	1						
				10,000	5143	23'D Y 46'H		hvdraulic
T-401 A-D	Storage Silos (w/ sliding frame bottom)	4	A-36 C-Stl	200,01	2			25
HPU-401 A-D	Hvdraulic Power Units	4	[VFD]					25
MC-401A-D	Extraction Convevors	4						
ED 411 A/R	Scraw Feeders	2						inyuraui
	Columba Dimpe	2		160	160 gpm			Invaraulic
P-41 AD	Olduge Futtipe	6						200
HPU-411 AB	Hydraulic Power Units	1						
				1 718 41/3	51A3	135 D × 12 H		hydraulic
T-402	Run Tank (w/ sliding frame bottom)	-	A-36 C-Stl	017,1	2			
MC-402	Extraction Conveyor	-						hudraulic
ED-402	Screw Feeder	-						official and and
2010	Shidra Faad Pump	-		160	160 gpm			Inversion
HPI 1.402	Hvdraulic Power Unit	~						1
774-0								
		-	SUAL SS	15,000 lb/hr	lb/hr	800		psig 200
K-403	Recycle Syngas booster Compressor	-						
M-403	Sludge Mixer	_	HIGH NICKIE Alloy					

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			FOLIPM	FOUR NT/MATERIALS	S	-	LABOR		LINE
Account	Tao #	Description	Oty Units	Unit Cost	Total Cost	<u>otv</u>	Unit Cost	Total Cost	Total
Aucount		Receiving Station:						0000000	
cil Edui	T.400 A/R	Receiving Bunkers (w/ sliding frame bott			\$0	440	\$61	\$53,680	
	FD-400 A/B	Screw Feeders			\$0	80	\$61	29,760	
	P-400 A/B	Sludge Pumps	2	0\$	\$0	40	201	44,000	
	HPI1-400 A/B	Hvdraulic Power Units			\$0	40	La¢	44,000	000 040 10
		Subtotal		\$1,300,000	\$1,300,000			\$/3'200	07,070,14
		Storage Area:					624	C346 773	
	T-401 A-D	Storage Silos (w/ sliding frame bottom)	4		\$0	1421	100	0010400	
	HP11-401 A-D	Hvdraulic Power Units	4		\$0	40	105	\$9,700	
	MC-401A-D	Extraction Conveyors	4		\$0	150		230,000	
	FD-411 AB	Screw Feeders	2		02 02	08	- 40 10	00/00	
	P-411 A/B	Sludge Pumps	2		0,00	0.4	100	000,40	
	HPU-411 A/B	Hydraulic Power Units Subtotel	0 +	\$2 900.000	\$2,900,000	0 4	100	\$412,653	\$3,312,653
		00000	•						
		Run Tank:	,		C\$	120	\$61	S7.839	
	T-402	Run Tank (w/ sliding trame bottom)	-		9	150	561	\$9.150	
	MC-402	Extraction Conveyor			000	00	S61	\$4,880	
	FD-402	Screw Feeder	-		0.00	0	\$61	\$2.440	
	P-402	Sludge Feed Pump			00	40	\$61	S2,440	
	HPU-402	Hydraulic Power Unit Subtotal	-	S700 000	\$700.000	2		\$26,749	\$726,749
		Othor							
	1 400	Decide Sundae Bonster Compressor	-	\$240,000	\$240,000	250	\$61	\$15,250	\$255,250
	NA 402	Shidoa Miyar	-	\$75,000	\$75,000	20	\$61	\$1,220	\$76,220
	DOPT M	Subtotal		\$315,000	\$315,000			\$16,470	01 7 1 01
		Account Subtotal							10,441,06
Earthwork					00	0000	\$2 400	S4 800	\$4.80
		Clear & Grub (s/c)	-		0.00	DDE VHAR	55	S4.676	\$4.67
		Cut & Fill (s/c)	-		0\$	0 040		\$9,476	\$9,476
								000000000	LA CITO
Concrete		Receiving Station [A-F]	892 yd^3	\$170	\$151,640	5	505	200,000	5/30,172
		Storage Silos [G]	178 yd^3	\$127	\$22,606	14	- 193	\$20.496	\$23.544
		Run Tank [H]	24 yd~3	1716	040,040	583	561	\$6.046	S7,763
		Misc. [I] Account Subtotal	-	200	\$179,011	2		\$777,086	\$956,09
					011 00	r.	100	CR 735	\$18 005
Steel		Misc.	5 tons	\$1,954	\$9,770	71	00	002100	
Piping	1000		400 #	\$50	\$20.000	2.3	\$61	\$56,120	\$76,12
	Spec C (3')	000# 304L 33	520 ft	\$64	\$33,280	2.5	\$61	\$79,300	\$112,58
	Spec N (3)	150# 304L 30	100 ft	\$70	\$7,000	2.8	\$61	\$17,080	\$24,080
	Spec N (4)	150H CO	130 ft	\$16		1.3 ·	\$61	\$10,309	\$12,38
	Shec L11 (2")	150# CS	180 ft	\$20		1.5	\$61	\$16,470	\$20,07
	Spec L11 (3")	150# CS	780 ft	\$26		1.8	\$0 1	585,644	476,016 470,070
	Spec N (1.5")	900# 304L SS	335 ft	\$40		2 2	00	010,040	C26 052
	Cooo C (2")	300# 304L SS	120 ft	\$66	\$7,920	2.6	100	912,004	01040

TABLE III (cont'd)

Control ECUIMANCENTIANTESTINA ECUIMANCE	FIGLEAF - EQUIPMENT LIST &	IENT LIST & CAPITAL COST ESTIMATE	STIMATE						
Tape # Top # Lunt. Cost i and Loost i and Loo	Cast		EQUIPME	ENT/MATER	ALS	-	LABOR		LINE
(27) (16) (16) (16) (16) (16) (11) (16) (11) <th< th=""><th></th><th>Description</th><th>I</th><th>Unit Cost</th><th>Total Cost</th><th>¥0</th><th>Unit C</th><th>Tot</th><th>Total</th></th<>		Description	I	Unit Cost	Total Cost	¥0	Unit C	Tot	Total
(15') 150# 304L SS 255 ft Account Subtal 355 cold 255 cold 351 col	Spec L	150# 304L SS	80 ft	\$60	\$4,800	2.3	÷		\$16,024
(15') 150# 316L SS Account Subtatal 255 ft \$2.0 \$5.100 1.1 \$61 \$3.346 Starters 14 Scondard Subtatal 315,700 31,200 35,100 1.2 \$3.46 Starters 14 Scondard Subtatal 316 ft \$5.00 35,100 1.2 \$3.46 2 560 ft \$5.00 \$3.500 \$3.500 \$3.500 \$3.46 \$3.960 \$3.46 \$3.960 \$3.560 <t< td=""><td>Spec U (3")</td><td>150# 304L SS</td><td>285 ft</td><td>\$64</td><td>\$18,240</td><td>2.5</td><td>Ø</td><td></td><td>\$61,703</td></t<>	Spec U (3")	150# 304L SS	285 ft	\$64	\$18,240	2.5	Ø		\$61,703
Karteries Account Subtation 315, 700 4 \$336, 00 5	Spec Z (.5")	150# 316L SS	255 ft	\$20	\$5,100	4.4	÷		\$22,211
Starters 14 32,500 355 000 4 961 33,416 0 Account Subtata 2 5700 33,4200 12 561 33,416 0 Account Subtata 2 500 ft \$51,000 12 561 \$5,416 0 Account Subtata 2 500 ft \$51,000 12 561 \$53,416 0 Account Subtata 2 500 ft \$51,000 12 561 \$53,416 0 Account Subtata 3 1200 ft \$51,000 12 561 \$53,416 0 Account Subtata 3 300 ft \$53,000 14 \$53,320 17 \$54,320 0 Account Subtata 5 500 ft \$53,000 16 \$54,320 \$54,320 \$56,000 \$54,050 \$54,320 \$56,000 \$54,050 \$56,000 \$56,000 \$56,000 \$56,000 \$56,000 \$56,000 \$56,000 \$56,000 \$56,000 \$56,000 \$56,000 \$56,			3185 ft		\$135,700			\$396,622	\$532,322
Statters 14 52.500 54.100 12 53.416	Elect. Equip.								
14 sect. 5,300 54,200 14 53,446 53,446 2 Account Subtatal 2 57,000 54,300 12 561 53,446 2 3 120 ft 57,000 54,300 12 561 ft 53,446 2 3 120 ft 510 513 513 541 53,446 2 3 120 ft 513 513 513 541 53,466 3 50 ft 510 513 513 511 514 53,466 0.kemil 5 50 ft 513 513 511 514 514 5 50 ft 510 ft 513 513 514 514 514 5 50 ft 516	Motor Starters		14	\$2,500	\$35,000	4	G		\$38,416
a Account Subtatal 2 \$7,000 \$14,000 12 \$61 \$3,3,464 2 560 ft \$30,228 0.1 \$61 \$3,464 \$3,464 2 560 ft \$10	MCC		14 sect.	\$300	\$4,200	4	69		\$7,616
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530 komil 50 ft \$16 \$70 1 50 ft \$10 \$2,000	1/c 4/0	e	1290 ft	\$1.0	\$1,229	0.3	ŝ		\$24,836
Colon kernil Sec 1 S2.765 2.1 S61 56.774 RCSS 500 ft 53.000 1 5 361 345.500 RCSS 500 ft 5.32 \$2.000 1 5 561 545.500 RCSS 500 ft 5.32 \$2.000 3 2 561 \$50.00 RCSS RCS 50.00 3 2 561 \$50.00 1 \$56.500 \$45.500 RCSS RCS 80.00 3 \$50.00 4 \$51.500 \$45.500 \$56.500 </td <td>1/c 350 kcmil</td> <td>3</td> <td>50 ft</td> <td>\$1.6</td> <td>\$79</td> <td>-</td> <td>G</td> <td></td> <td>\$3,129</td>	1/c 350 kcmil	3	50 ft	\$1.6	\$79	-	G		\$3,129
RCS 500 ft \$51 00 \$50 00 \$51 00 \$52 00 \$51 00 \$51 00 \$52 00 \$51 00 \$52 00 \$51 00 \$52 00 \$51 00 \$52 00 \$51 00 <td>1/c 1000 kcmil</td> <td>Ş</td> <td>540 ft</td> <td>\$5.1</td> <td>\$2,765</td> <td>2.1</td> <td>S</td> <td></td> <td>\$71,939</td>	1/c 1000 kcmil	Ş	540 ft	\$5.1	\$2,765	2.1	S		\$71,939
RCS FRCS S201 S201 S201 S410 S411 S410 S411 S410 S411	1" RGS		500 ft	\$18	\$9,000	1.5	S		\$54,750
Ficos 290 (th \$30 \$3.700 3.2 \$6.600 \$6.600 \$6.600 \$6.600 \$6.600 \$6.73.820 \$6.600 \$6.73.820 \$6.800 \$6.810 \$6.700 \$6.810 \$6.700 \$6.810 \$6.7100 \$6.810 \$6.7100 \$6.810 \$6.810 \$6.810 \$6.810 </td <td>2" RGS</td> <td></td> <td>90 ft</td> <td>\$23</td> <td>\$2,070</td> <td>2</td> <td>S</td> <td></td> <td>\$13,050</td>	2" RGS		90 ft	\$23	\$2,070	2	S		\$13,050
RCS FRCS	3" RGS		290 ft	\$30	\$8,700	3.2	S		\$65,308
Image: Mark Second Subtation Account Subtation \$30,071 \$30,071 \$30,071 \$2266,505 \$30,071 \$30,070 \$30,070 \$30,070 \$30,070 \$30,070 \$30,070 \$30,070 \$30,070 \$30,070 \$30,070 \$30,070 \$31,070 \$31,070 \$31,070 \$31,070 \$31,070 \$31,070 \$31,070 \$31,070 \$31,070 \$31,070 \$31,070 \$31,070 \$31,070 \$31,070 \$31,070 \$31,070 \$31,070	4" RGS		150 ft	\$40	\$6,000	4.8	S	_	\$49,920
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T (inc)uded w equipment) 7 \$480 \$3,360 \$51,708 \$5,380 S (inc)uded w equipment) 7 \$480 \$3,360 4 \$61 \$5,380 S (inc)uded w equipment) 2 \$1,500 \$3,000 26 \$61 \$5,300 OV Account Subtotal 2 \$17,500 \$3,000 56 \$61 \$3,500 OV Account Subtotal 2 \$17,500 \$3,000 56 \$61 \$56,000 \$6 \$610 \$3,500 Sulation (s/c) 1 1 1 \$610 \$610 \$50,000 \$6 \$56,000 \$6 \$610 \$55,000 \$5 \$61 \$56,000 \$6 \$610	SH	(included w/ equipment)	5		\$0	7.	69		\$2,135
3 1 5480 33,360 4 561 51,708 F 7 84,500 2 \$1,500 26 561 \$2,818 T 2 \$1,500 \$5,000 2 \$1,500 \$561 \$317 OV Account Subtotal 2 \$1,500 \$5,000 5 \$50,000 \$571 \$51,677 \$561,00	L]	(included w/ equipment)	7		\$0	12.6	Ś		\$5,380
S (Included w/ equipment) 7 \$\$1,500 \$\$1,500 \$\$2,610 \$\$2,600 \$\$2,600 \$\$2,600 \$\$2,600 \$\$2,600 \$\$2,600 \$\$2,600 \$\$2,600 \$\$2,600 \$\$2,6000 \$\$2,6000 \$\$2,600 \$\$2,6000 \$\$2,600 \$\$2,6000 \$\$2	TG		7	\$480	\$3,360	4	S		\$5,068
T 2 \$1,500 \$3,000 2.6 56.1 53.17 53.17 53.17 53.17 53.17 53.17 53.17 53.17 53.17 53.17 53.15 <td>PS</td> <td>(included w/ equipment)</td> <td>7</td> <td></td> <td>\$0</td> <td>6.6</td> <td>G</td> <td></td> <td>\$2,818</td>	PS	(included w/ equipment)	7		\$0	6.6	G		\$2,818
OV 2 \$17,500 \$35,000 5 \$61 \$610 sulation (s/c) Account Subtotal 1 \$41,360 \$41,360 \$55,677 \$15,677 sulation (s/c) 1 1 1 \$41,360 \$50,000 \$55,670 \$55,677 sulation (s/c) 1 1 1 1 \$510,000 \$55,677 ace (s/c) 1 1 1 1 \$50,000	FT		2	\$1,500	\$3,000	2.6	60 I		\$3,317
sulation (s/c) Account Subtotal 1 \$41,360 \$15,677 sulation (s/c) 1 1 \$50,000 \$15,677 sulation (s/c) 1 1 \$50,000 \$15,677 ace (s/c) 1 1 1 \$50,000 \$15,677 ace (s/c) 1 1 1 1 \$50,000 \$15,677 ace (s/c) 1 1 1 1 1 \$100,000 \$15,677 g (s/c) 600 sf \$50,000 \$10,000	MOV		2	\$17,500	\$35,000	Q	G		\$35,610
sulation (s/c) 1 1 1 \$50,000 \$50,000 9 ace (s/c) 1 1 1 1 1 \$100,000 9 g (s/c) 600 sf \$50 \$30,000 1 </td <td></td> <td>Account Subtotal</td> <td></td> <td></td> <td>\$41,360</td> <td></td> <td></td> <td>\$15,677</td> <td>\$57,037</td>		Account Subtotal			\$41,360			\$15,677	\$57,037
ace (s/c) 1 1 \$100,000 \$100,000 g (s/c) 600 sf \$50 \$30,000 1 1 PM 1 1 1 1 1 1 1 CRAND TOTAL CRAND TOTAL 1	Painting & Insulation	(s/c)	2					\$50,000	\$100,000
g (s/c) (s/c) 600 sf \$50 \$30,000 (sf \$50 } 90 (sf \$50 \$30,000 (sf \$50 \$30,0000 (sf \$50 \$30,000	Elec. Heat Trace	(s/c)	۴					\$100,000	\$150,000
g (s/c) 600 sf \$50 \$30,000 9 4									
PM GRAND TOTAL	Metal Building	(s/c)	600 sf	\$50	\$30,000				\$30,000
GRAND TOTAL 8	Engineering, PM								\$840,000
GRAND TOTAL	Contingency								\$921,000
									40 700 001
		GRAND IOIAL							\$\$'\no'na1