FE-1759-6
Distribution Categories UC-90c, UC-90d

CONCEPTUAL DESIGN OF A COAL TO METHANOL COMMERCIAL PLANT CAPITAL COST VALIDATION

DATE PUBLISHED 10 FEBRUARY 1978

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UNDER CONTRACT EX-76-C-01-1759

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ABSTRACT

The US Army Engineer Division, Huntsville (USAEDH) has reviewed, validated, and updated a capital cost estimate of the Conceptual Design/Coal to Methanol Commercial Plant, prepared by Badger Plants, Inc. This facility was designed to have a feed rate of 74,000 tons per day of coal and 7,500 tons per day of limestone. The facility was designed to produce approximately 386,400 barrels per day of 96.5 weight percent methyl fuel, 28,600 barrels per day of chemical grade methanol, and 660 tons per day of sulfur. At full production, the plant will use approximately 330,000 kWh per hour and $11.4 million (1977 dollars) per year of catalysts and chemicals. At full capacity, the plant will employ approximately 1,715 people.

Results of the USAEDH estimate showed a fixed capital cost of $3,489,179,900 which is greater than Badgers estimate of $3,105,103,800 (both estimates based on late 1977 dollars). The overall confidence factor was determined to be plus or minus 12.4 percent.

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1.0 INTRODUCTION AND SUMMARY

Periodically the US Army Engineer Division, Huntsville (USAEDH) reviews, validates, and updates capital cost estimates that have been prepared for Department of Energy (DOE) by its contractors. USAEDH is qualified for this type work by their extensive experience on major construction projects with which they have been associated. This study includes a review and evaluation of the Conceptual Design/Coal to Methanol Commercial Plant capital cost estimate prepared by Badger Plants, Inc. The Badger conceptual design and capital cost estimates were for a facility having a daily feed rate of 74,000 tons of coal and 7,500 tons of limestone. The facility was designed to produce approximately 386,400 barrels per day of 96.5 weight percent methyl fuel, 28,600 barrels per day of chemical grade methanol, and 660 tons per day of sulfur. Badger estimated the fixed capital investment to be about $3.105 billion based on late 1977 dollars.

In this study USAEDH reviewed the costs for each area of the Coal to Methanol Plant as designed and estimated by Badger Plants, Inc. In most areas the basic equipment costs, estimated or obtained by Badger in the form of quotations, were substantiated. USAEDH then applied construction factors (ratio of total construction cost to equipment cost) to specific types of equipment resulting in Total Direct Field Costs which in many instances differed from Badger's Direct Costs. The USAEDH construction factors were based on data for similar items in other projects with appreciably more design completion.

For other areas which were not estimated using the "Construction Factor Method" USAEDH accepted Badger's "Direct Costs," either a quote for a "Black Box" as received by Badger, or a detailed estimate prepared by Badger's Estimating Department.

Results of the USAEDH estimate showed a fixed capital cost of $3.489 billion which is approximately $384 million greater than Badgers estimate of $3.105 billion (both estimates based on late 1977 dollars). The overall confidence factor was determined to be plus or minus 12.4 percent.

2.0 PROJECT CAPITAL COST VALIDATION

This study is a review of the "Conceptual Design of a Coal to Methanol Commercial Plant" Report FE-2416-21, prepared by Badger Plants, Inc., Cambridge, Mass. The Badger prepared commercial plant capital cost estimate was validated and a level of confidence of the estimate was determined. No effort was made to validate the technical adequacy or accuracy of the design.

Table 1 depicts USAEDH's estimate based on late 1977 dollars.

Table 2 depicts the validated comparative cost summary.

In most areas the basic equipment costs, estimated or obtained by Badger in the form of quotations, were substantiated. USAEDH then applied construction factors to specific types of equipment resulting in Total Direct Field Costs which in many instances differed from Badger's Direct Costs. USAEDH's Equipment Costs, Construction Factor, and Total Direct Field Costs for each area which were estimated in this manner, appear in the first three columns of Table 1.

For other areas that were not estimated using the Construction Factor Method, USAEDH accepted Badger's Direct Costs, either a quote for a "Black Box"as received by Badger, or a detailed estimate prepared by Badger's Estimating Department. These also appear in Column 3.

USAEDH used a proven method to determine indirect costs i.e., for every dollar of Direct Labor Cost there is a dollar of Indirect Costs. At this point, as indicated in Table 1, USAEDH applied a man-hour per dollar factor to the Direct Costs. This was applied to the total cost of each type of equipment and results in the man-hours for each area. This is shown in the fifth column of Table 1. The weighted average man-hour factors appear in Column 4. To arrive at a Total Field Indirect Cost, the man-hours were multiplied by the Basic Labor Rate of $13 per hour to yield the Labor Costs that appear in Column 6.

In some instances USAEDH chose to accept Badger's Labor Estimate, so the man-hour factor is a "back calculated" factor and does not represent experience by USAEDH for the specific equipment. In these instances the factors were checked for reasonableness.

Table 2 shows that USAEDH then used the total for Column 6 of Table 1 as Total Indirect Field Costs (on a dollar-per-dollar basis) as explained earlier. These Indirect Costs were added to the Direct Costs obtained in Table 1 and the Home Office Expense at 6 percent and Fee of 2 percent were added. The resulting Total Cost is $3,489,179,900 and compares with Badger's total cost of $3,105,103,800 for a difference of $384,076,100 (late 1977 dollars). The overall confidence factor for the estimate is determined to be plus or minus 12.4 percent.

TABLE 1 USAEDH ESTIMATE OF BADGER DESIGNED PLANT

AREA	SYSTEM DESCRIPTION	1 EQUIP. COST K$	2 CONSTR FACTOR	3 TOTAL DIRECT FIELD COST K$	4 LABOR FACTOR	5 LABOR MH	6 MH x $13.00 $
100	Coal Handling	50,395.0	1.43	72,046.0	.0175	1,258,114	16,355,480
100	Lime Handling	30,000.0	1.85	55,435.0	.0266	1,476,525	19,198,720
200	Coal Gasification	(14,576.0)	2.65	(38,635.0)	.0186	(719,528)	(9,353,864)
	X9 Trains	131,184.0	----	347,715.0	-----	6,475,842	84,185,910
200	Slag Removal	3,256.0	2.23	7,273.0	.017	125,048	1,625,630
300	Shift Unit	(7,854.0)	2.59	(20,337.0)	.020	(398,553)	(5,181,189)
	X6 Trains	47,124.0	----	122,022.0	-----	2,391,318	31,087,080
300	Acid Gas Removal	--------	----	353,100.0	.017	6,002,700	78,035,100
300	Sulfur Unit	--------	----	17,000.0	.017	289,000	3,757,000
300	Tail Gas Cleanup	--------	-----	12,500.0	.017	212,500	2,762,500
400	Syn. Gas Compression	(4,357.0)	2.00	(8,708.0)	.023	(201,785)	(2,623,210)
	X6 Trains	26,142.0	----	52,248.0	----	1,210,710	15,739,260
400	Methanol Synthesis	--------	----	360,000.0	.017	6,120,000	79,560,000
400	Cryogenic Recovery	--------	----	29,000.0	.017	493,000	6,409,000
500	Methyl Fuel Drying	(2,270.0)	2.38	(5,411.0)	.020	(107,854)	(1,402,102)
	X6 Trains	13,620.0	----	32,466.0	----	647,124	8,412,600
500	Methanol Purification	3,610.0	2.49	8,997.0	.020	177,023	2,301,300

AREA	SYSTEM DESCRIPTION	1 EQUIP. COST K$	2 CONSTR FACTOR	3 TOTAL DIRECT FIELD COST K$	4 LABOR FACTOR	5 LABOR MH	6 MH x $13.00 $
600	Product Storage & Shipping	--------	----	27,162.0	.03	814,860	10,593,180
600	By-Product Shipping	32.0	2.66	85.0	.020	1,679	21,800
700	Oxygen Units	--------	----	552,000.0	.011	5,852,000	76,076,000
700	Inert Gas Compression	500.0	1.62	810.0	.016	13,260	172,380
700	CO_2 Compressors	9,300.0	1.60	14,850.0	.017	257,850	3,352,050
800	Coal Pile Runoff	87.0	3.0	261.4	.023	6,045	79,590
800	Slaked Lime Feed	151.0	3.01	454.5	.025	11,232	146,020
800	Util. Boiler Fuel Gas Cleaning	15,118.0	2.64	39,937.0	.018	723,695	9,408,060
800	Reclaimed Water System	4,986.0	2.95	14,719.0	.018	271,522	3,529,780
800	Sour Condensate Trting	325.0	3.52	1,144.2	.022	24,610	319,934
800	Sanitary Trting Facility	103.0	2.69	275.0	.028	7,710	100,230
800	Solid Waste Handling	1,615.0	1.64	2,647.5	.022	57,000	741,000
800	Land Fill Management	423.0	1.65	698.0	.018	12,563	163,319
900	Steam Generating	86,965.0	1.60	139,179.0	.020	2,802,795	36,462,340
	Condensate & Boiler Feed	6,603.0	2.78	18,349.0	.020	371,810	4,833,540
900	Power Generating (Emg.)	--------	----	4,500.0	.011	49,500	643,500

SYSTEM	SYSTEM DESCRIPTION	1 EQUIP. COST K$	2 CONSTR FACTOR	3 TOTAL DIRECT FIELD COST K$	4 LABOR FACTOR	5 LABOR MH	6 MH x $13.00 $
1100	Railroad	--------	----	7,800.0	.026	202,800	2,636,400 MH x $15.49
1200	Elec. Supply & Distributed	--------	----	61,600.0	.012	739,000	11,452,000 MH x $13.00
1300	Buildings	--------	----	6,355.0	.03	190,650	2,478,450
1400	Parking Lots, Roads, Land Clearing & Fences	--------	-----	6,830.0	.025	170,750	2,219,750
1500	Fire Protection Piping	--------	-----	4,400.0	.05	229,000	2,977,000
1600	Flares	--------	-----	4,056.0	.02	81,120	1,054,560
1700	Water Supply System-Potable	56.0	2.89	161.8	.038	6,132	79,720
	BFW/Total D.S.	10,187.0	2.08	21,173.0	.019	394,881	5,133,450
1800	Security & Communications	--------	----	1,250.0	.03	33,000	429,000
1900	Mobil Equipment	--------	----	3,903.0	---	-------	----------
2000	Auxiliary Fuel Systems	411.0	2.23	917.0	.027	24,871	323,330
1700	Other Water System						
	Filtered	1,595.0	4.56	7,274.0	.029	212,064	2,756,830
	Cooling H_2O	43,640.0	2.34	102,290.0	.020	2,080,929	27,065,080

SYSTEM	SYSTEM DESCRIPTION	1 EQUIP. COST	2 CONSTR FACTOR	3 TOTAL DIRECT FIELD COST K$	4 LABOR FACTOR	5 LABOR MH	6 MH x $13.00 $
2100	Pipe Racks			3,635.0	.05	180,000	2,340,000
2200	Cool H_2O Dist.			14,023.0	.021	295,000	3,835,000
2300	Potable H_2O Dist.			568.0	.058	33,000	429,000
2400	1500 lb Steam Pipe			37,888.0	.016	616,000	8,008,000
2500	600 lb Steam Pipe			2,937.0	.027	78,000	1,014,000
2600	300 lb Steam Pipe			1,938.0	.031	59,800	777,400
2700	65 lb Steam Pipe			2,440.0	.034	84,000	1,092,000
2800	Boiler Feed Pipe			949.0	.034	32,700	425,100
2900	Condensate			5,893.0	.027	158,000	2,054,000
3000	Blow Down			268.0	.043	11,500	149,500
3100	CO_2 Pipe			150.0	.040	6,000	78,000
3200	N_2 Pipe			1,147.0	.059	67,400	876,200
3300	Low BTU Gas Pipe			767.0	.043	33,000	429,000
3400	Flares Piping			4,006.0	.016	65,300	848,900

SYSTEM	SYSTEM DESCRIPTION	1 EQUIP. COST	2 CONSTR FACTOR	3 TOTAL DIRECT FIELD COST K$	4 LABOR FACTOR	5 LABOR MH	6 MH x $13.00 $
3500	Computer System			12,000.0	.0042	50,000	650,000
3600	Contaminated Sewer Sym.			2,922.0	.062	180,000	2,340,000
3700	Sanitary Sewer			795.0	.065	52,000	676,000
3800	Surface Drainage			1,646.0	.078	128,000	1,664,000
3900	Process Inteconnecting Piping			29,690.0	.016	479,000	6,227,000
	TOTALS AND AVERAGES			$ 2,638,545.4	.017	45,130,932	$588,590,973

TABLE 2 VALIDATED COMPARATIVE COST SUMMARY

USAEDH Total Direct Field Cost	$2,638,545.4
Indirect Cost @ 100 percent of Labor	588,591.8
Total Field Cost	3,227,136.4
Home Office Cost @ 6 percent	193,628.2
Total Field and Office Costs	3,420,764.6
Fee @ 2 percent	68,415.3
TOTAL USAEDH COST	3,489,179.9
TOTAL BADGER COST	3,105,103.8
DIFFERENCE	384,076.1

Confidence Factor $\frac{\text{Difference}}{\text{Badger Estimate}} = \pm 12.4$ percent

NOTE: $ expressed in thousands

3.0 DETAILED ANALYSIS BY AREA

Area 100 - Coal Storage & Preparation

USAEDH used a Construction Factor of 1.43 to obtain total Direct Field Costs (DFC) of $72,046,000. This compares to Badger's Construction Factor of 1.57 which they must have applied to the wrong Equipment Cost, since they arrived at only $67,463,000 for DFC.

USAEDH applied a Labor Factor of 0.0175 to the DFC to yield 1,258,114 manhours compared to Badger's 1,032,000 manhours. When multiplied by $13/manhour and used as Indirect Costs, this amounted to $16,355,480.

Area 100 - Lime Handling

USAEDH used a Construction Factor of 1.85 to obtain DFC of $55,435,000. This compares with Badger's Construction Factor of 2.01, which gave them $60,300,000 for DFC.

USAEDH applied a Labor Factor of 0.0266 to the DFC to yield 1,476,525 manhours compared with Badger's 1,254,000 manhours. USAEDH then multiplied by $13 to yield $19,198,720 used as Indirect Costs for this system.

Area 200 - Coal Gasification

USAEDH applied a Construction Factor of 2.65 to the Equipment Costs of $14,576,000 for one train of this 9-train Unit, to obtain DFC of $38,635,000. This compares with Badger's Construction Factor of 2.56 for the same Equipment Costs which gave them $37,300,000 DFC. USAEDH then applied a Labor Factor of 0.0186 to the DFC to yield 719,528 manhours compared with Badger's 797,000 manhours. USAEDH multiplied the 719,528 by $13/manhour to obtain $9,353,864 Indirect Costs. All numbers were then multiplied by nine (the number of trains) for use in Table 1.

Area 200 - Slag Removal

USAEDH applied a Construction Factor of 2.23 to the Equipment Costs of $3,256,000 to obtain DFC of $7,273,000. This compares with Badger's Construction Factor of 2.04, which gave them $6,658,000 DFC.

USAEDH then applied a Labor Factor of 0.0170 to the DFC to yield 125,048 manhours compared with Badger's 149,000 manhours. The 125,048 manhours multiplied by $13/manhour yields $1,625,630 Indirect Costs for the system.

Area 300 - Shift Unit

USAEDH used a Construction Factor of 2.59 with the Equipment Cost of $7,854,000 to arrive at DFC of $20,337,000. This compares with Badger's Construction Factor of 2.57 for DFC of $20,160,000.

USAEDH then applied a Labor Factor of 0.0200 to the $20,337,000 to obtain 398,553 manhours compared with Badger's 452,000 manhours. USAEDH's manhours multiplied by $13/manhour yields $5,181,189 Indirect Costs.

All numbers were then multiplied by six (the number of trains) for use in Table 1.

Area 300 - Acid Gas Removal

This is one of the "Black Box" systems for which USAEDH accepted the DFC of $353,100,000 in Badger's Estimate.

To the DFC of $353,100,000 USAEDH applied a Labor Factor of 0.017 for 6,002,700 manhours. This resulted in the use of $78,035,100 Indirect Costs for this unit. Badger estimated 8,300,000 manhours for the unit.

Area 300 - Sulfur Unit

USAEDH accepted the DFC for this unit and again applied a Labor Factor of

0.0170. The DFC is $17,000,000 and the resultant Labor is 289,000 manhours. This equals $3,757,000 for Indirect Costs. Badger's Estimate as received by USAEDH seemed to be in error since they showed only 60,000 manhours for both this unit and the next.

Area 300 - Tail Gas Cleanup

USAEDH accepted the DFC for this unit and again applied a Labor Factor of 0.0170. The DFC is $12,500,000 and the resultant Labor is 212,500 manhours. This equals $2,762,500 for Indirect Costs.

Area 400 - Methanol Synthesis

USAEDH accepted the DFC of $360,000,000 for this system and applied a Labor Factor of 0.0170 to arrive at a labor figure of 6,120,000 manhours which converts to $79,560,000 Indirect Cost. This is the cost for six units.

Area 400 - Synthesis Gas Compression

USAEDH arrived at an average Construction Factor of 2.0 for this system. Although it is composed of Heat Exchangers and pumps with high Construction Factors, the majority of the money is in the Compressors and Tanks, which have low Construction Factors. USAEDH's Factor of 2.0 times the Equipment Cost of $4,357,000 for one train yields $8,708,000 DFC. This compares with Badger's Factor of 2.25 and DFC of $9,811,000.

USAEDH then applied a Labor Factor of 0.023 to the DFC to arrive at Labor of 201,785 manhours. Indirect Costs were then determined to be $2,623,210. All numbers were then multiplied by six (the number of trains) for use in Table 1. Badger's Labor for one train is 201,000 manhours.

Area 400 - Cryogenic Recovery

USAEDH accepted the "Black Box" DFC of $29,000,000 and applied a Labor

Factor of 0.017 to yield 493,000 manhours. Badger estimated 328,000 manhours for the unit. USAEDH's Indirect Cost calculated from the Labor figure is $6,409,000.

Area 500 - Methyl Fuel Drying

USAEDH accepted the Equipment Cost for one train $2,270,000 and applied a Construction Factor of 2.38 for a DFC of $5,411,000. This unit consists of varied Equipment with Construction Factors ranging from 1.1 to 5.8, however, the majority of the money is in Air Fin Coolers which brings the average to 2.38. Badger arrived at a Construction Factor of 2.51 and DFC to $5,700,000.

USAEDH then applied a Labor Factor of 0.020 to the DFC and arrived at 107,854 manhours for one train. This converts to $1,402,102 Indirect Costs. Badger used 142,000 manhours for one train. All numbers were then multiplied by six (the number of trains) for use in Table 1.

AREA 500 - Methanol Purification

USAEDH multiplied Badger's $3,610,000 Equipment Costs by a Construction Factor of 2.49 to yield DFC of $8,979,000. This compares with Badger's Factor of 2.52 and DFC of $9,110,000.

USAEDH then applied a Labor Factor of 0.020 to the DFC and arrived at 177,023 manhours and $2,301,000 Indirect Costs. Badger estimates 211,000 manhours for this unit.

Area 600 - Product Storage and Shipping

USAEDH accepted a portion of Badger's Direct Field Costs which they had estimated in detail. The portion representing transfer from process to

to storage was assumed to have been included in USAEDH's factors for previous units and was subtracted from the DFC before applying the Labor Factor. To the remaining $27,162,000 a Factor of 0.03 representing "ordinary construction," was applied to arrive at 814,860 manhours and $10,593,180 Indirect Costs. Badger had arrived at 757,000 manhours for the same work.

Area 600 - By-Product Shipping

USAEDH used Badger's Equipment cost of $32,000 and applied a Construction Factor of 2.66 for DFC of $85,000. Badger used a Factor of 2.10 applied to $31,000 for DFC of $65,000.

To the $85,000 USAEDH then applied a Labor Factor of 0.020 to arrive at 1,679 manhours, or $21,800 Indirect Costs. Badger had 2,000 manhours for this unit.

Area 700 - Oxygen Units

USAEDH used Badger's quotation of $552,000,000 Direct Field Costs and applied a Labor Factor of 0.011 to obtain Labor of 5,852,000 manhours and Indirect Costs of $76,076,000. Badger used 3,090,000 manhours for Labor in these units.

Area 700 - Inert Gas Compression

USAEDH applied a Construction Factor of 1.62 to Badger's Equipment Cost of $500,000 to arrive at a DFC of $810,000. This unit is composed mostly of compressors which should have small construction factors. Badger used a construction factor of 2.5 for DFC of $1,250,000. USAEDH then applied a labor factor of 0.016 to the DFC to yield 13,260 manhours. This compares with Badger's 29,000 manhours. The 13,260 manhours computes to $172,380 Indirect Costs.

Area 700 - CO_2 Compressors

USAEDH applied a Construction Factor of 1.60 to the Equipment Cost of $9,300,000 proposed by Badger to yield $14,850,000 DFC. Badger used a Construction Factor of 2.15 for $20,000,000 DFC. The same reasoning was used by USAEDH for this unit as for the last; large compressors have small factors.

USAEDH then used a labor factor of 0.017 to arrive at 257,850 manhours for the unit. This computes to $3,352,050 Indirect Costs. Badger estimated 431,000 manhours for the unit.

Area 800 - Coal Pile Runoff

USAEDH used Badger's Equipment Cost of $87,000 and applied a Construction Factor of 3.00 for $261,400 DFC. Badger used 3.13 for $272,000 DFC.

USAEDH further applied a Labor Factor of 0.023 to the DFC to yield 6,045 manhours and $79,590 Indirect Costs. Badger computed 7,500 manhours for this unit.

Area 800 - Slaked Lime Feed

Badger's Equipment Cost of $151,000 was multiplied by 3.01 by USAEDH to yield $454,500 DFC. Badger used a Construction Factor of 2.87 for $435,000 DFC. USAEDH then used a Labor Factor of 0.025 to arrive at 11,232 manhours and $146,020 Indirect Cost. Badger calculated 12,500 manhours for the unit.

Area 800 - Utility Boiler Flue Gas Cleanup

USAEDH used Badger's Equipment Cost of $15,118,000 and multiplied it by a Construction Factor of 2.64 for a $39,937,000 DFC. Badger used a factor

of 2.51 for $33,000,000 DFC.

USAEDH then applied a Labor Factor of 0.018 for Labor of 723,695 manhours used to compute Indirect Costs for $9,408,060. Badger estimated 839,000 manhours for this unit.

Unit 800 - Reclaimed Water System

To Badger's Equipment Costs of $4,986,000 USAEDH applied a Construction Factor of 2.95 for $14,719,000 EFC. Badger used a Construction Factor of 2.55 to produce a DFC of $12,720,000. USAEDH then used a Labor Factor of 0.018 for a Labor figure of 271,522 manhours and Indirect Costs computed at $3,529,780. Badger's Labor for this unit is 299,000 manhours.

Area 800 - Sour Condensate Treating

Large Construction Factors for pumps and heat exchangers held the weighted average for this unit to 3.52 for USAEDH. When applied to the Equipment Cost of $325,000 USAEDH estimated the DFC at $1,144,200. Badger used a construction factor of 3.38 and a DFC of $1,100,000.

USAEDH then used a Labor Factor of 0.022 to determine the labor at 24,610 manhours and the Indirect Costs of $319,934. Badger used 29,000 manhours in this unit.

Area 800 - Sanitary Treating Facility

USAEDH computed a Construction Factor of 2.69 for this unit which is largely filters and feed equipment. This factor when used with Badger's Equipment Cost of $103,000 yields DFC of $275,000. Badger used a factor of 3.03 to produce a DFC of $313,000. To the $275,000 USAEDH then applied a

Labor Factor of 0.028 for 7,710 manhours and a computed Indirect Cost of $100,230. Badger used 8,200 manhours in this unit.

Area 800 - Solid Waste Handling

USAEDH used a Construction Factor of 1.64 with Badger's Equipment Cost of $1,615,000 yielding $2,647,500 DFC. Badger used a factor of 1.74 with the same equipment cost for $2,814,000 DFC. USAEDH then applied a Labor Factor of 0.022 for 57,000 manhours and computed Indirect Costs of $741,000. Badger's Labor for this unit is $52,000.

Area 800 - Land Fill Management

USAEDH used a Construction Factor of 1.65 with Badger's $423,000 Equipment Cost to arrive at a DFC of $698,000. Badger used 1.74 for a DFC of $737,000. USAEDH then applied a Labor Factor of 0.018 to produce labor of 12,563 manhours and Indirect Costs of $163,319. Badger calculated 13,600 manhours for this unit.

Unit 900 - Steam Generation

USAEDH accepted Badger's Equipment Cost of $86,965,000 and raised it to $139,179,000 DFC with a Construction Factor of 1.60. Badger did not show a Factor but arrived at $143,000,000 DFC which would be a Factor of about 1.64.

USAEDH's Labor Factor of 0.020 produced a labor figure of 2,802,795 manhours and at $13/manhour computes Indirect Costs of $36,462,340. Badger calculated 2,213,000 manhours for the unit.

Unit 900 - Condensate and Boiler Feed Water

Pumps weighed heavily in the selection of 2.78 Construction Factor for this unit. When used with Badger's Equipment Cost of $6,603,000, USAEDH

arrived at $18,349,000 DFC. Badger arrived at $16,740,000 DFC which would indicate a Construction Factor of about 2.54.

USAEDH then applied a Labor Factor of 0.020 for 371,810 manhours or $4,833,540 Indirect Costs. Badger used 419,000 manhours in this unit.

Area 900 - Power Generating (Emg.)

USAEDH accepted Badger's DFC of $4,500,000 and applied a Labor Factor of 0.011 for 49,500 manhours and computed Indirect Costs of $643,500. Badger calculated 46,000 manhours for this unit.

System 1100 - Railroad

USAEDH accepted Badger's DFC of $7,800,000 and calculated Indirect Costs by applying a Labor Factor of 0.026 for 202,800 manhours and used $13/manhour to arrive at $2,636,400 Indirect Costs.

System 1200 - Elec. Supply and Distribution

USAEDH arrived at a Direct Field Cost of $61,600, 000 compared to Badger's $83,400,000. To the $61,600,000 a Labor Factor of 0.012 was applied yielding Labor of 739,000 manhours, and a calculated Indirect Cost of $11,452,000 at $15.49/manhour, a composite Civil and Electrical Subcontract rate. Badger's Labor for this system is 813,000 manhours.

System 1300 - Buildings

USAEDH accepted Badger's DFC of $6,355,000 for this system, and applied a Labor Factor of 0.030 for 190,650 manhours and $2,478,000 using $13/manhour. Badger's Labor for this system is 230,000 manhours.

System 1400 - Parking Lots, Roads, Land Clearing and Fences

This Civil estimate of $6,830,000 was accepted by USAEDH and Labor was calculated using a Factor of 0.025. The resulting 170,750 manhours was converted to Indirect Costs of $2,219,750. Badger estimated Labor at 219,800 manhours for this system.

System 1500 - Fire Protection Piping

USAEDH accepted Badger's DFC of $4,400,000 and Labor of 229,000 manhours and "back calculated" a Labor Factor of 0.05 for Table 1. The 229,000 manhours computed to $2,977,000 Indirect Cost.

System 1600 - Flares

USAEDH accepted Badger's DFC of $4,056,000 and applied a Labor Factor of 0.020 to it to yield 81,120 manhours and $1,054,560 Indirect Costs. Badger used 101,600 manhours for this system.

System 1700 - Series 17,100 Filtered Water Supply

USAEDH accepted Badger's Equipment Cost of $1,595,000 and applied a Construction Factor of 4.56 for DFC of $7,274,000. Badger used a Factor of 5.57 for DFC of $8,890,000. USAEDH then applied a Labor Factor of 0.029 to the DFC to yield 212,064 manhours and arrived at $2,756,830 Indirect Costs. Badger's manhour figure for this series was 347,600.

System 1700 - Series 17,200 - Cooling Tower Systems

USAEDH accepted Badger's Equipment Cost of $43,640,000 and applied a Construction Factor of 2.34 for DFC of $102,290,000. Badger's factor was 2.35 and DFC was $102,400,000. USAEDH then applied a Labor Factor of 0.020

to the DFC to yield 2,080,929 manhours and $27,065,080 Indirect Costs. Badger's Labor for this series was 2,169,000 manhours.

System 1700 - Series 17,300 Potable Water Supply

USAEDH calculated a composite Construction Factor of 2.89 for this series, which was influenced by the large Cost of tanks in the equipment. When used with Badger's Equipment Cost of $56,000 it yields DFC $161,800. Badger's Construction Factor of 4.3 gave them DFC of $241,000.

USAEDH then applied a Labor Factor of 0.038 to the DFC and arrived at Labor of 6,132 manhours and $79,720 Indirect Costs. Badger used 7,500 manhours for this series.

System 1700 - Series 17,400 - BFW/Total D. S.

USAEDH considered the "package Units" in this series to have very low Construction Factors and therefore arrived at a composite Factor of 2.08 compared with Badger's 2.42. When applied to the same Equipment Cost of $10,187,000 this gave USAEDH $21,173,000 DFC and Badger $24,680,000 DFC. USAEDH then applied a Labor Factor of 0.019, again very low due to the package units, to arrive at the Labor Figure of 394,881 manhours and Indirect Costs of $5,133,450. This compares with Badger's Labor of 555,000 manhours.

System 1800 - Security and Communications

USAEDH recalculated the DFC for this system and arrived at $1,250,000 compared with Badger's $1,940,000.

USAEDH calculated the labor at 33,000 manhours and Indirect Costs at $429,000. The 0.03 Labor Factor in Table 1 is a "Back Calculated" Factor.

System 1900 - Mobil Equipment

USAEDH estimated the DFC for this system at $3,903,000. No Labor involved.

System 2000 - Auxiliary Fuel Systems

USAEDH calculated Equipment Costs of $411,000 and a Construction Factor of 2.23 to arrive at $917,000 DFC. This compares with Badger's Equipment Cost of $413,000 and DFC of $842,000. They showed no Factor but it would have been 2.04.

USAEDH then arrived at Indirect Costs of $323,330 by multiplying the DFC by a Labor Factor of 0.027 for 24,871 manhours for this system. Badger computed 19,400 manhours for this system.

System 2100 - Pipe Racks

USAEDH estimated this system at $3,635,000 DFC with 180,000 manhours. This gives $2,340,000 Indirect Costs on the dollar of Indirect per dollar of Labor Costs basis. The 0.05 Labor Factor is "back calculated" and appears reasonable on a Civil type Construction estimate.

Badger's estimate is $5,960,000 DFC and 270,000 manhours.

System 2200 - Cooling Water Distribution

USAEDH accepted Badger's DFC of $14,023,000 and Labor of 295,000 manhours. This gives $3,835,000 Indirect Costs for USAEDH. The 0.021 Labor Factor in Table 1 is "Back Calculated" and is reasonable for a system containing many valves and fittings.

System 2300 - Potable Water Piping

USAEDH accepted Badger's DFC of $568,000 and Labor of 33,000 manhours. This gives $429,000 Indirect Costs by USAEDH Methods. The 0.058 Labor Factor in Table 1 is "Back Calculated" and is reasonable for a system with a high civil to mechanical ratio.

System 2400 - 1500 Pound Steam Pipe

USAEDH accepted Badger's DFC of $37,888,000 and Labor of 616,000 manhours. This gives $8,008,000 Indirect Costs for USAEDH. The 0.016 Labor Factor calculated from these numbers is reasonable for this system.

System 2500 - 600 Pound Steam Pipe

USAEDH accepted Badger's DFC of $2,937,000 and Labor of 78,000 manhours. This gives $1,014,000 Indirect Costs for USAEDH. The 0.027 Labor Factor calculated for Table 1 is reasonable for this system.

System 2600 - 300 Pound Steam Pipe

USAEDH accepted Badger's DFC of $1,938,000 and Labor of 59,800 manhours. This gives $777,400 Indirect Costs for USAEDH. The 0.031 Labor Factor calculated from these numbers is reasonable for this system.

System 2700 - 65 Pound Steam Pipe

USAEDH accepted Badger's DFC of $2,440,000 and Labor of 84,000 manhours. This gives $1,092,000 Indirect Costs in the USAEDH estimate. The 0.034 Labor Factor used in Table 1 is reasonable for this system.

System 2800 - Boiler Feed Pipe

USAEDH accepted Badger's DFC of $949,000 and Labor of 32,700 manhours.

This gives $425,100 Indirect Costs for USAEDH. The 0.034 Labor Factor thus calculated for this system is reasonable.

System 2900 - Condensate

USAEDH accepted Badger's DFC of $5,893,000 and Labor of 158,000 manhours. This gives $2,054,000 Indirect Costs for USAEDH. The 0.027 calculated by USAEDH from Badger's numbers is a reasonable Labor Factor for this system.

System 3000 - Blow Down Piping

USAEDH accepted Badger's DFC of $268,000, Labor of 11,500 manhours, and calculated Indirect Costs of $149,500. The 0.043 Labor Factor Calculated from these numbers is reasonable for this system.

System 3100 - CO_2 Pipe

USAEDH accepted Badger's DFC of $150,000 and Labor of 6,000 manhours. This gives $78,000 Indirect Costs for the USAEDH estimate. The 0.040 Labor Factor calculated from these numbers is reasonable for this system.

System 3200 - N_2 Pipe

USAEDH accepted Badger's DFC of $1,147,000 and Labor of 67,400 manhours for Indirect Costs calculated at $876,200. The 0.059 Labor Factor calculated from these numbers is reasonable.

System 3300 - Low BTU Gas Pipe

USAEDH accepted Badger's DFC of $767,000, Labor of 33,000 manhours, and calculated Indirect Costs of $429,000. The 0.043 Labor Factor calculated from these numbers is reasonable.

System 3400 - Flares Piping

USAEDH accepted Badger's DFC of $4,006,000 and Labor of 65,300 manhours. This gives $848,900 Indirect Costs and a calculated Labor Factor of 0.016 which is reasonable for this system.

System 3500 - Computer System

USAEDH accepted Badger's DFC of $12,000,000 and Labor of 50,000 manhours. This gives $650,000 Indirect Costs and a calculated Labor Factor of .0042 which is reasonable for this costly, easy to install system.

System 3600 - Contaminated Sewer System

USAEDH accepted Badger's DFC of $2,922,000, but assumed Badger made an error in calculating Labor on Sewer Pipe. USAEDH recalculated and arrived at 180,000 manhours compared with Badger's 800,500 manhours. This gives Indirect Costs of $2,340,000 and a "back calculated" Labor Factor of 0.062, which is reasonable for this system containing a high percentage of high labor earth work.

System 3700 - Sanitary Sewer

USAEDH accepted Badger's DFC of $795,000 Labor of 52,000 manhours and calculated Indirect Costs of $676,000. The 0.065 Labor Factor calculated from these numbers is reasonable for a heavily weighted civil work estimate of this type.

System 3800 - Surface Drainage

USAEDH accepted Badger's DFC of $1,646, 000, Labor of 128,000 manhours, and calculated Indirect Costs of $1,664,000. The Labor Factor of 0.078 calculated from these numbers is reasonable for this civil type estimate.

System 3900 - Process Interconnecting Piping

USAEDH accepted Badger's DFC of $29,690,000 and Labor of 479,000 man-hours and used these numbers to calculate Indirect Costs of $6,227,000. The "back calculated" Labor Factor of 0.016 is considered very good for this system.

USAEDH total direct cost for the project is $2,638,545,400 compared with Badger's $2,668,014,000. USAEDH total labor manhours for the project is 45,130,932 compared with Badger's 48,460,400.

USAEDH Field Indirect Costs for the Project are $588,590,973 compared with Badger's $127,089,800.

USAEDH Home Office Costs for the project are $193,628,200 compared with Badger's $248,000,000.

The USAEDH Fee for the Project is $68,415,300 compared with Badger's $62,000,000.

The USAEDH Total Cost is $3,489,179,900 compared with Badger's $3,105,103,800 or a difference of 12.4 percent using Badger's estimate as a base.

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