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Conceptual Design of Power-Oil-Gas-Other Products (POGO) Processing Plant Capital Cost Validation

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ABSTRACT

The US Army Engineer Division, Huntsville (USAEDH) has reviewed, validated, and updated a capital cost estimate of the Power-Oil-Gas-Other Products (POGO) Commercial conceptual design, prepared by the Ralph M. Parsons Company. This facility was designed to have a feed rate of 43,200 tons per day of coal from a captive coal mine producing approximately 20 million tons per year for 20 years. The facility was designed to produce approximately 183 tons per day of Ammonia, 1000 MW of electricity, 1710 tons per day of Sulfur, 150 million standard cubic feet per day of synthetic Natural Gas, 15,000 barrels per day of liquidified petroleum gas, 34,800 barrels per day of gasoline, 27,000 barrels per day of fuel oil, and 1625 tons per day of coke. Results of the USAEDH estimate showed a fixed capital cost of $2,072,633,270 which is less than the Parsons estimate of $2,376,610,000. (Both estimates based on mid 1977 dollars). The overall confidence factor was determined to be plus or minus 12.8 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 commercial conceptual design of the Power-Oil-Gas-Other Products (POGO) capital cost estimate prepared by Ralph M. Parsons Company. This facility was designed to have a feed rate of 43,200 tons per day of coal from a captive coal mine producing approximately 20 million tons per year for 20 years. The facility was designed to produce approximately 183 tons per day of Ammonia, 1000 MW of electricity, 1710 tons per day of Sulfur, 150 million standard cubic feet per day of synthetic Natural Gas, 15,000 barrels per day of liquidified petroleum gas, 34,800 barrels per day of gasoline, 27,000 barrels per day of fuel oil, and 1625 tons per day of coke. Results of the USAEDH estimate showed a fixed capital cost of $2,072,633,270 which is less than the Parsons estimate of $2,376,610,000. (Both estimates based on mid 1977 dollars). The overall confidence factor was determined to be plus or minus 12.8 percent.

In this study USAEDH reviewed the costs of the Power-Oil-Gas-Other Products(POGO) - Coal Refinery Complex as designed and estimated by the Ralph M. Parsons Company. In most units the basic equipment costs, estimated or obtained by Parsons in the form of quotations, were substantiated.

USAEDH then applied Construction Factors (ratio of total construction cost to equipment cost) to specific pieces of equipment resulting in weighted average Construction Factors for types of equipment and finally a weighted average Construction Factor for each unit which appears in Table 1. The resulting Total Direct Field Costs in many instances differed from Parsons' Direct Costs. The USAEDH Construction Factors are based on data for similar equipment in other projects with appreciably more design completion and experience with other studies.

For other areas which were not estimated using Construction Factors to arrive at Total Direct Costs, USAEDH accepted Parsons' Direct Cost, either a quote for a "Black Box" as recieved by Parsons, or a detailed estimate prepared by Parsons' Estimating or Engineering Departments. USAEDH Equipment Costs, Construction Factor, and Total Direct Field Costs, appear in the first three columns of Table 1.

USAEDH then used a proven method to determine indirect costs, i.e., for every dollar of Direct Labor Cost there is a dollar of Indirect Field Cost. To the Direct Field Cost for each piece of equipment, USAEDH

applied a Labor Factor (man-hours per dollar) to arrive at man-hours associated with the installation of the equipment and all other material within the Direct Cost pertaining to the piece of equipment. This resulted in a weighted average Labor Factor for the types of equipment and finally a weighted average Labor Factor for each unit. This Labor Factor and the resulting man-hours appear in Column Four and Five of Table 1. To arrive at Total Field Indirect Cost, the man-hours for each unit were multiplied by $12 per man-hour to yield the Labor Costs that appear in Column Six.

In some instances Parsons' Labor Estimate was used by USAEDH, so the Labor 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, included in Table 1, and affect the weighted average Labor Factor for the project.

Table 2 shows that USAEDH then used the total for Column Six of Table 1 as Total Indirect 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 six percent and Fee of two percent were added. The resulting Total Cost is $2,072,633,270 and compares with Parsons' Total Cost of $2,376,610,000 for a difference of $303,976,730 (mid 1977 dollars). The overall confidence factor for the estimate is plus or minus 12.8 percent.

2.0 DETAILED ANALYSIS BY UNITS

UNIT 08 - COAL MINE

After review, USAEDH accepted Parsons' Total Direct Cost estimate as prepared by their Mining Division. This cost of $231,310,000 was then multiplied by a Labor Factor of .0083 (man-hours per dollar) for 1,919,873 man-hours and $23,038,476 which was used as Indirect Costs for this unit.

UNIT 09 - COAL PREPARATION

USAEDH accepted Parsons' estimate for Direct Field Costs (DFC) of $64,035,000 for this unit and applied a Labor Factor of .0142 for 907,375 man-hours and $10,888,500 to be used as Indirect Costs. (Note: this is approximately 17 percent of Direct Cost.)

UNIT 10 - COAL STORAGE, GRINDING AND DRYING

USAEDH accepted Parsons' estimate for DFC of $36,712,000 and applied a Labor Factor of .0095 to arrive at a labor figure of 349,900 man-hours which converts to $4,198,800 Indirect Costs. (11.4%)

UNIT 11 - OXYGEN PLANT

USAEDH accepted the quotation of $180,000,000 as received by Parsons and applied a Construction Factor of 1.05 for DFC of $189,000,000. This compares with Parsons' Construction Factor of 1.01 and DFC of $181,800,000. USAEDH then applied a Labor Factor of .0083 to the DFC to yield 1,568,700 man-hours and $18,824,400 used as Indirect Costs for this unit.

UNIT 12 - SRC DISSOLVING

This is the first unit which USAEDH separated into individual pieces of equipment to apply Construction Factors. A total of 20 vessels were assigned Construction Factors ranging from 1.20 for the very large to 11.00 for the very small for a weighted average of 1.37 for the 20 vessels. A total of 20 heat exchangers were assigned Construction Factors ranging from 1.10 for air coolers to 4.50 for a very small shell and tube exchanger. The weighted average for heat exchangers is 1.24. Three reactors were assigned a Construction Factor of 1.50. Other less-expensive pieces of equipment were assigned Construction Factors of more than 2.00 to bring the average for the unit to 1.515. (See Table 1.)

The individual Equipment Costs multiplied by their factor yielded Direct Field Costs totaling $132.453,995 for the unit. This compares with Parsons' Factor of 2.401 and DFC of $209,849,000.

USAEDH also applied Labor Factors to the individual pieces of equipment. The 20 vessels had Factors ranging from .0016 for the very large to .0335 for the very small. This resulted in a weighted average for vessels of .0046. The 20 heat exchangers had Factors of .0021 for the A/C Exchangers to .0270 for the very small shell and tube. Heat exchangers weighted average was .0061 man-hours per dollar. The three reactors were assigned a Labor Factor of .0075. The other equipment (pumps, compressors, heaters, etc.) were assigned larger Labor Factors bringing the average for the unit to .0097. (Table 1.)

The DFC for each piece of equipment was then multiplied by its respective Labor Factor to produce labor man-hours. These calculations resulted in totals for the unit of 1,287,920 man-hours and $15,455,040 Indirect Costs. (11.7%)

UNIT 13 - SRC ATMOSPHERIC DISTILLATION

In this unit five heat exchangers were assigned Construction Factors ranging from 1.10 for the A/C Exchangers to 2.90 for the smallest shell and tube, resulting in a weighted average of 1.22 for exchangers. Two compressors were assigned 2.60 and one furnace was assigned a Factor of 1.70. Other less expensive pieces of equipment raised the average for the unit to 1.84. (Table 1.)

The individual equipment costs for each piece of equipment of Parsons' estimate were multiplied by the Factors to yield $15,472,875 DFC for the unit. This compares with a Factor of 2.85 and DFC of $23,902,000 for Parsons.

USAEDH also applied Labor Factors to the five heat exchangers ranging from .0060 for the large shell and tube to .0165 for the smallest shell and tube, resulting in a weighted average of .0071. The two compressors were assigned a Labor Factor of .0200, and the furnace .0250. Other less expensive pieces of equipment raised the average for the unit to .0199. (Table 1.)

The individual Factors and their respective DFCs resulted in calculations of totals for the unit of 308,404 man-hours and $3,700,848 Indirect Costs. (23.9%)

UNIT 14 - SRC VACUUM DISTILLATION

In this unit USAEDH's Construction Factors ranged from a weighted average of 1.42 for eight heat exchangers, to 4.91 for 12 pumps. Two expensive columns were assigned a Construction Factor of 2.00 to bring the average for the unit to 2.19.

The Individual Equipment Costs from Parsons' estimate were multiplied by the Individual Factors for $22,692,820 DFC for the unit. This compares with Parsons' Factor of 2.70 and DFC of $27,970,000.

USAEDH then applied Labor Factors ranging from .0017 for the packaged plant to .0271 for the pumps. The Columns Factor of .0155 governed the average and the weighted average for the unit was .0186 (Table 1.) These individual Factors and their respective DFCs resulted in totals for the unit of 421,669 man-hours and $5,060,028 Indirect Costs. (22.3%)

UNIT 15 - PYROLYSIS

In this unit seven heat exchangers were assigned Construction Factors ranging from 1.10 for an A/C exchanger and a large shell and tube exchanger to 2.20 for a small shell and tube exchanger. The average for exchangers was 1.29, which was the lowest for the unit. Other

equipment had Construction Factors ranging to a maximum of 2.34. The weighted average for the unit was 1.75. (Table 1.)

USAEDH accepted Parsons' Equipment Costs and multiplied each by its Factor to arrive at $11,095,236 DFC. This compares with Parsons' Factor of 2.533 and DFC of $16,103,000.

USAEDH also applied Labor Factors to the seven heat exchangers ranging from .0060 for the A/C and large shell and tube to .0108 for a small shell and tube. The average for exchangers was .0067 which was the lowest Labor Factor in this unit. Other equipment had Labor Factors as high as .0280 for a weighted average for the unit of .0150. These Factors multiplied by their respective DFCs and totaled for the unit, result in 166,527 man-hours and $1,998,324 Indirect Cost. (18.0%)

UNIT 16 - PYROLYSIS ATMOSPHERIC DISTILLATION

Nine heat exchangers were the driving influence in this unit with Construction Factors ranging from 2.30 for the largest to 6.50 for the smallest, for a weighted average of 2.51. Vessels averaged 11.28 and pumps averaged 6.61 to bring the total weighted average for the unit to 2.86. (Table 1.)

USAEDH applied the Factors to Parsons' Equipment Costs for each item totaling $2,120,864 DFC. This compares with Parsons' 2.545 Construction Factor and $1,880,000 DFC.

USAEDH then applied Labor Factors to the nine heat exchangers ranging from .0500 for the smallest to .0096 for the largest. The average for exchangers was .0160, which was the lowest Labor Factor for this unit. Other equipment with Labor Factors as high as .0357 (vessels) brought the average up to .0263 for the unit. (Table 1.) These Factors along with their respective DFCs result in totals for the unit of 46,483 man-hours and $557,796 Indirect Cost. (26.3%)

UNIT 17 - SOUR GAS COMPRESSION

Two compressors with Construction Factors of 1.10 held the average down on this unit. Vessels ranged from 9.50 to 2.20 for an average of 3.14 and heat exchangers averaged 2.75 for the unit. The resultant weighted average for the unit is 1.61.

Parsons' Equipment Cost for each item and the Construction Factors result in $4,327,340 DFC for the unit. This compares with Parsons' 2.046 Factor and $5,492,000 DFC.

USAEDH then applied Labor Factors of .0074 to the compressors, an average of .0197 to the vessels and an average of .0135 to the heat exchangers for a weighted average of .0111 for the unit. These Factors multiplied by their respective DFCs and totaled for the unit, yielded 48,148 man-hours and $577,776 Indirect Costs. (13.4%)

UNIT 18 - PROCESS GASIFIER

Five vessels with Construction Factors ranging from 1.60 for the largest to 9.00 for the smallest average 1.87. Three heat exchangers ranged from 1.50 for the largest to 1.65 for the smallest and averaged 1.61. The driving influence was the separation equipment with an assigned Factor of 1.80 and the reactor with a Factor of 1.88. The resultant average was 1.85 for the unit.

Parsons' Equipment Costs for each item with the proper Factor yielded $17,815,212 DFC. This compares with Parsons' 2.492 Construction Factor and DFC of $24,042,000.

USAEDH then applied Labor Factors to the five vessels ranging from .0055 for the largest to .0318 for the smallest, for an average of .0095. The three heat exchangers averaged .0098, but the driving Factors of .0275 for Separation Equipment and .0155 for the reactor resulted in an overall average of .0181 for the unit. These individual Factors and their respective DFCs when multiplied and totaled for the unit, yielded 322,525 man-hours and $3,870,300 Indirect Costs. (21.7% of DFC.)

UNIT 19 - SHIFT CONVERSION

Twenty-four heat exchangers, accounting for more than half of the equipment cost, were assigned Construction Factors ranging from 1.10

for A/C exchangers to 2.20 for the small shell and tube exchangers. The average for exchangers was 1.42. Twelve reactors were given Construction Factors of 1.50 to 1.75 averaging 1.62. Four idnetical vessels were assigned a Factor of 3.00. The composite weighted average Construction Factor was calculated at 1.51. (Table 1.)

USAEDH accepted Parsons' Equipment Cost for each item, multiplied by the proper Factor and totaled $22,457,640 DFC. This compares with Parsons' Factor of 2.72 and DFC of $40,409,000.

USAEDH then applied Labor Factors to the 24 heat exchangers ranging from .0080 for the A/C to .0130 for the small shell and tube. Average for exchangers was calculated at .0085. The reactors were assigned Labor Factors of .0150 and .0160 averaging .0156, and the four vessels were assigned a Labor Factor of .0205. The weighted average Labor Factor for the unit is .0116. (Table 1.) These Labor Factors multiplied by their respective DFCs and totaled for the unit, yielded 260,362 man-hours and $3,124,344 Indirect Cost. (13.9%)

UNIT 20 - SELECTIVE ACID GAS REMOVAL

USAEDH agreed with Parsons' quotation, prorate number, escalation and analysis adjustment for this unit but did, however, apply all numbers to the Equipment Costs rather than the DFC. The $35,000,000 quotation of 7 January 1976 was multiplied by 1.12 analysis adjustment, 7.6%

escalation to mid-1977 and the prorate factor of 1.0482. This yielded $44,212,200 Equipment Cost. (Table 1.) To this USAEDH applied 1.10 Construction Factor for $48,633,400 DFC. This compares with Parsons' $48,633,000 DFC. To the DFC of $48,633,400 USAEDH applied a Labor Factor of .0170 for 826,768 man-hours and $9,921,216 Indirect Cost. (20.4%)

UNIT 21 - HEAVY LIQUIDS HYDROTREATING

Eighteen vessels were assigned Construction Factors ranging from 1.60 for the very large to 9.60 for the very small, to average 2.24. Heat exchangers ranged from 1.20 to 1.90 for a weighted average of 1.23 for 14 exchangers. Eight compressors with high initial costs spread from 2.00 to 2.50 with a weighted average of 2.15, but six reactors influenced the average highly with an assigned factor of 1.50. Other less expensive items added to the weighted average of 1.69 for all equipment in this unit.

Parsons' Equipment Costs for the individual items were used with individual factors for DFCs totaling $53,255,895. This compares with Parsons' Factor of 2.428 and $83,804,000 DFC.

USAEDH used Labor Factors ranging from .0050 to .0325 for the vessels for a weighted average of .0131. The heat exchangers ranged from .0060 to .0105 averaging .0067. Compressors were assigned factors from .0188 to .0222 averaging .0192 and reactors heavily influenced the average

with an assigned Labor Factor of .0155. The overall average for the unit when other less expensive equipment was included was .0159. The resultant totals of the Factors and DFC Products for the unit are 927,246 man-hours and Indirect Costs of $11,126,952. (19.1%)

UNIT 22 - THERMAL CRACKING

In this unit USAEDH's Construction Factors ranged from 1.10 to 1.50 on eight heat exchangers averaging 1.26. Two furnaces were assigned a Factor of 1.67 and other less expensive equipment ranged as high as 2.90, to bring the weighted average for the unit to 1.69.

The equipment Costs for each item estimated by Parsons was used with its Factor to yield DFC of $15,712,035. This compares with Parsons' Factor of 3.08 and DFC of $28,697,000.

USAEDH used Labor Factors of .0050 to .0080 for the heat exchangers averaging .0060. The two furnaces were assigned a Labor Factor of .0254 while the less expensive equipment had factors which contributed to a unit average of .0196. These Factors and their respective DFCs produced labor which totaled 308,429 man-hours and $3,701,148 Indirect Costs. (23.6%)

UNIT 23 - COKING

USAEDH accepted Parsons' DFC of $55,615,000 and applied a Labor Factor of .0083 man-hours per dollar to yield 461,605 man-hours and $5,539,260

Indirect Cost. (Table 1.) This is 10% of DFC.

UNIT 24 - NAPHTHA HYDROTREATING

Heat Exchangers were the governing influence in this unit and Construction Factors of 12 exchangers ranging from 1.10 to 3.25 average 1.42. Five compressors made up the next most expensive group of equipment with Factors of 2.35 to 3.00 averaging 2.47. One reactor was assigned 1.50 and other less expensive equipment all contributed to a weighted average Construction Factor of 1.70 for the unit.

The Equipment Costs of each item estimated by Parsons were used with individual Factors to total $12,603,068 DFC. This compares with Parsons' 2.59 Factor and $19,221,000 DFC.

Heat exchangers were also assigned Labor Factors which ranged from .0060 for the largest to .0190 for the smallest, with a weighted average of .0069. The compressors had Labor Factors from .0190 to .0370 to average .0221, and the reactor was assigned .0150. The weighted average for the unit was .0134. These individual Factors and their respective DFCs produced totals for the unit of 168,345 man-hours and $2,020,140 Indirect Costs. (16.0%)

UNIT 25 - NAPHTHA REFORMING

USAEDH accepted Parsons' DFC of $12,847,000 for this unit and multiplied it by a Labor Factor of .0083 for 106,630 man-hours and $1,279,560

Indirect Cost all numbers appearing in Table 1. Indirect cost is 10% of Direct Cost.

UNIT 26 - OLEFINIC GAS ACID GAS REMOVAL

USAEDH followed Parsons' procedure and used equipment costs from another project along with analysis adjustment, escalation and prorate factor. Construction Factors were then applied to each piece of equipment after these adjustments. Six columns received Factors ranging from 1.70 to 2.07 averaging 1.76. Six heat exchangers ranged from 1.10 for the A/Cs to 2.02 for a small shell and tube exchanger, averaging 1.26. Other equipment with lower cost but higher Factors brought the weighted average for the unit to 1.84. (See Table 1.)

The accumulated Equipment Costs calculated by USAEDH totaled $4,951,420 and the DFC is $9,102,736. This compares with Parsons' $11,756,000 DFC.

USAEDH also applied Labor Factors to the Direct Field Costs as calculated for each piece of equipment. The columns ranged from .0156 to .0188 and averaged .0160. The heat exchangers ranged from .0040 to .0140 and averaged .0065. Other equipment with Labor Factors as high as .0500 raised the weighted average to .0168 for the unit. The totals of the man-hours and Indirect Costs were 152,782 and $1,833,384. (20.1%)

UNIT 27 - SATURATE GAS/ACID GAS REMOVAL

Columns were the governing influence and received Construction Factors ranging from 1.50 for the largest to 1.95 for the smallest, with an average of 1.59. Heat exchangers were the next most influential and received Factors ranging from 1.10 for the A/Cs to 1.80 for the small shell and tube. This averaged 1.21 for the exchangers and with much larger Factors on inexpensive equipment gave a weight averaged Construction Factor of 1.66 for the unit.

The Factors multiplied by their respective estimated Equipment Costs totaled $12,531,294 DFC for the unit. This compares with 2.779 Factor and $20,982,000 DFC for Parsons.

USAEDH then applied Labor Factors to the individual pieces of equipment. Columns were assigned Factors of .0100 to .0172 averaging .0122. The heat exchangers received Factors from .0060 to .0110 averaging .0066. Other Factors ranged as high as .0500, but on less expensive equipment, resulting in a weighted average for the unit of .0138. The man-hours thus calculated came to 173,178 and the Indirect Costs were $2,078,136. (16.6%)

UNIT 28 - OLEFINIC RECOVERY AND POLYMERIZATION

Fourteen heat exchangers accounting for over half of the cost were assigned Construction Factors from 1.50 for the largest to 7.00 for the smallest. The average for the exchangers is 2.06. Eight vessels, the next largest category, ranged from 3.30 to 15.50 averaging 4.09.

Other less expensive items brought the weighted average for the unit to 2.63.

The Factors used with Parsons' Equipment Costs for each item add to a DFC of $2,976,486. This compares with Parsons' Factor of 2.92 and DFC of $3,307,000.

USAEDH then applied Labor Factors to the heat exchangers ranging from .0060 for the largest to .0410 for the smallest, averaging .0131. The vessels received Factors of .0170 to .0377 averaging .0213. Other Labor Factors as high as .0247 contributed to the unit average of .0177. These Factors and their respective DFCs multiplied together and accumulated for the unit resulted in 52,642 man-hours and $631,704 Indirect Cost. (21.2%)

UNIT 29 - HYDROGEN RECOVERY AND PURIFICATION

The package plant is the governing influence in this unit and was given a Construction Factor of 1.50 by USAEDH. Vessels were next most influential and received Factors ranging from 1.70 for six large ones to 9.80 for two very small ones, averaging 1.77. Other less expensive items had little effect on the weighted average of 1.57 for the unit. The DFC calculated with these Factors is $20,488,295. This compares with Parsons' Factor of 1.80 and DFC of $23,549,000.

USAEDH then used Labor Factors ranging from .0170 for the package plant to .0240 for pumps, to arrive at a composite weighted average Labor Factor of .0155 man-hours per dollar DFC. The labor calculated with these Factors totals 315,678 man-hours and $3,800,135 Indirect Cost. (18.5%)

UNIT 30 - SNG PURIFICATION

Three compressors make up the largest expense category and were given Construction Factors of 2.00 to 2.50 or 2.11 average. The package plant, the next most influential, was assigned a Construction Factor of 1.50. Ten heat exchangers received Factors from 1.10 to 2.39 averaging 1.39. Three reactors ranged from 2.10 to 3.88 helping to bring the average up. Other inexpensive equipment contributed and the unit average was 1.99. The DFC thus calculated is $18,173,379. This compares with Parsons' Factor of 2.21 and DFC of $21,156,000.

USAEDH then applied a Labor Factor of .0170 to the package plant and Factors ranging from .0180 to .0220 averaging .0182 to the compressors. Other Labor Factors as low as .0070 and as high as .0277 contributed to the weighted average of .0184 for the unit. (Table 1.) The labor thus calculated adds to 333,497 man-hours and the Indirect Cost is $4,001,964. (22.0%)

UNIT 31 - LPG FRACTIONATOR

Three packaged plants governed the size of the Construction Factor for this unit. They were given a Factor of 1.50 which was used with over

80% of the expenditure for equipment. The next largest block of equipment cost is one compressor which was assigned a Factor of 2.50. Seven exchangers helped hold the average Factor down being given Factors ranging from 1.42 to 2.85 averaging 1.64. Other less expensive equipment had little influence on the weighted average of 1.66. The DFC calculated from these Factors is $17,128,264. This compares with a Constructive Factor of 2.26 and DFC of $23,303,000 used by Parsons.

USAEDH then applied a Labor Factor of .0170 to the package plants and .0193 to the compressor. The exchangers received Factors ranging from .0060 to .0165 for an average of .0078. The overall weighted average for the unit was calculated at .0172 man-hours per dollar DFC. The man-hours calculated were 293,795 and the Indirect Costs for the unit were $3,525,540. (20.6%).

UNIT 32 - SULFUR PLANT

USAEDH accepted Parson's DFC of $33,700,000 for this plant as it was estimated completely installed. To arrive at Indirect Costs a Labor Factor was assigned to determine what part of the DFC might reasonably be considered labor expense. A Factor of .0170 multiplied by the DFC yields 572,900 man-hours and converts to $6,874,800 Indirect Cost. (20.4%)

UNIT 33 - FUEL GAS GENERATION

Fourteen heat exchangers, comprising the largest block of Equipment

Cost, were assigned Construction Factors ranging from 1.10, for the A/C and large shell and tube, to 1.60 for the smallest shell and tube averaging 1.19. The reactor is the second largest expense and was assigned a Factor of 1.90. Other less expensive items contributed to the weighted average Construction Factor of 1.62 for the unit. Total DFC thus calculated is $62,066,403. This compares with Parsons' Factor of 2.52 and DFC of $96,350,000.

USAEDH then assigned Labor Factors to the heat exchangers which ranged from .0033 to .0100 with an average of .0052. The reactor was determined to have a Factor of .0155, and the other equipment had little influence on the unit average of .0135 man-hours per dollar. The total labor was calculated at 835,942 man-hours and the Indirect Cost at $10,031,304. (16.2%)

UNIT 34 - FUEL GAS ACID GAS REMOVAL

USEADH accepted Parsons' Installed Cost for this unit which they had prorated and escalated from a mid-1976 quotation. Even though it is an Installed Cost, USAEDH includes the number in Table 1 under "Equipment Cost." This makes it convenient to apply a Factor of 1.10 to the Installed Cost of $52,381,000 to cover associated costs by the Contractor. The DFC thus calculated is $57,619,100. This compares with a Factor of 1.232 and DFC of $64,533,000 by Parsons.

To this DFC, USAEDH then applied a Labor Factor of .0170 to arrive at 979,525 man-hours for the unit. This converts to $11,754,300 Indirect Costs. (20.4%)

UNIT 35 - STEAM AND POWER GENERATION

USAEDH accepted Parsons' Equipment Cost for the Packaged Power Plant and used a Construction Factor of 1.07 to determine its contribution to DFC.

The estimate for tanks was changed slightly and given Factors from 1.32 to 2.03 averaging 1.38. Vessels received Factors of 3.20 and 2.80 for an average of 2.99. When the Factors were multiplied by their respective Equipment Costs and DFC for each item accumulated, the weighted average Construction Factor remained the same as the packaged plant, i.e., 1.07. The DFC for the unit was $372,328,780. This compares with Parsons' Factor of 1.004 and DFC of $348,000,000.

The same procedure followed with Labor Factors chosen at .0170 for the packaged plant, .0190 for the tanks and .0160 for the vessels and when the resulting man-hours were accumulated and divided by DFC it was found that the resultant Labor Factor for the unit was still .0170. The total man-hours are 6,330,705 and total Indirect Cost is $75,968,460. (20.4%) It may be pertinent to note that even though the tanks and vessels did not effect the average Factors, their contribution to DFC, man-hours and Indirect Cost is included in the totals for the unit. This is true of all units.

UNIT 36 - PROCESS WASTE WATER TREATING

Eight heat exchangers, the main contributors to the Equipment Cost, were assigned Construction Factors from 1.40 to 2.10 for an average of 1.50. Columns, the next largest category received Factors from 1.50 to 2.00 averaging 1.65. Vessels influenced the total by receiving Factors from 3.70 to 18.2 for an average of 4.88. Other equipment contributed slightly to an overall, weighted average of 2.11 for the unit. The resultant total DFC is $7,013,908. This compares with Parsons' Factor of 2.79 and DFC of $9,283,000.

The Indirect costs were calculated by assigning Labor Factors ranging from .0050 to .0140 to the heat exchangers, averaging .0063; .0110 to .0175 to the columns for an average of .0127 and other larger Factors to less expensive equipment. The overall weighted average Labor Factor was .0163. The resultant totals for the average are 114,077 man-hours and $1,368,924 Indirect Cost. (19.5%)

UNIT 37 - SHOPS AND BUILDINGS

USAEDH recalculated this part of the estimate utilizing Parsons' quantities but different Unit Costs. The resultant DFC is $12,317,000 and compares with Parsons' $16,133,000.

USAEDH then assigned a Labor Factor of .0400 to the DFC to yield 492,680 man-hours and $5,912,160 Indirect Costs. (48%)

UNIT 38 - FIREWATER SYSTEM

USAEDH accepted Parsons' DFC of $3,880,000 for this unit and applied a Labor Factor of .0320 for 124,160 man-hours and $1,489,920 Indirect Cost. (38.4%)

UNIT 39 - POTABLE AND SANITARY WATER SYSTEM

USAEDH extracted equipment costs from a 1976 estimate referred to by Parsons as being "identical" to this unit. To these costs were applied the analysis adjustment of 1.12 used by Parsons and the escalation of 7.7% used by Parsons. To the cost of the filter a Construction Factor of 2.00 was applied. To the cost of the storage tank a Construction Factor of 2.45 was applied, and to other less expensive items Factors of 7.90 and 15.00 brought the average for the unit to 3.59. This Factor is based on $38,790 equipment cost and DFC of $139,280. This compares with Parsons' use of 9.00 Construction Factor in the 1976 estimate and $391,000 DFC in this estimate.

USAEDH also applied labor factors to the adjusted equipment costs from the 1976 estimate. The filter received a Factor of .0200, the tank received .0310 and other equipment received .0395 and .0500 for a weighted average of .0354 for the unit. The labor thus calculated added to 4,933 man-hours and converted to $59,196 Indirect Cost. (42.5%)

UNIT 40 - RAW WATER SYSTEM

The cooling tower in this unit accounts for more than half of the equipment cost and was assigned a Construction Factor of 1.15. Three

pieces of separation equipment are the next most expensive category and received a Factor of 2.51. Seventeen pumps received Factors ranging from 2.50 to 5.80 for an average of 2.91. Other less expensive items contributed to the average Unit Factor of 1.63. The DFC for all equipment was $22,881,910. These compare with Parsons' 1.718 Factor and $24,284,000 DFC.

USAEDH assigned a Labor Factor of .0170 to the cooling tower, .0206 to the separation equipment and a range of Factors from .0205 to .0286 to the pumps averaging .0209. The other equipment contributed to the overall Factor of .0192 for the unit. The labor thus calculated added to 439,720 man-hours and converted to $5,276,640 Indirect Cost. (23.1%)

UNIT 41 - EFFLUENT WATER TREATMENT

USAEDH re-estimated this unit based on a 1976 estimate by Parsons, utilizing their escalation and equipment costs for an identical unit. This added up to $669,100 equipment costs. Almost half of this number is in three pieces of separation equipment which were assigned a Construction Factor of 2.50. Other less expensive equipment received Construction Factors as high as 6.31 for a weighted average for the unit of 2.90. The DFC calculated from these numbers is $1,939,819. This compares with Parsons' 1976 Factor of 2.22 and DFC in this estimate of $1,734,800.

To the DFC for each piece of equipment USAEDH applied a Labor Factor. Separation equipment governed with a Factor of .0200, followed by other less expensive equipment with Labor Factors as high as .0321 for a weighted average of .0224 for the unit. (Table 1.) The Labor thus derived was 43,448 man-hours or $521,376 Indirect Cost. (26.9%)

Two ponds were also included in this unit with DFC of $208,000 (Table 1). These were assigned a Labor Factor of .0500 for 10,400 man-hours and $124,800 Indirect Cost. (60.0%)

UNIT 42 - PRODUCT STORAGE

USAEDH estimated this unit from Parsons' Equipment List in the R&D Report and arrived at Equipment Costs of $13,861,600.

Twenty-nine pumps were assigned Construction Factors ranging from 2.60 to 7.90 for an average of 3.44. Forty-five tanks received Construction Factors ranging from 1.15 to 2.20 averaging 1.27. The weighted average Construction Factor for the unit was calculated at 1.32 and the DFC is $18,329,586. Parsons' DFC for this unit is $30,568,600.

To calculate Indirect Costs the equipment was then assigned Labor Factors, the pumps receiving a range from .0210 to .0394 for an average of .0236 and the tanks receiving a range from .0155 to .0292 for an average of .0176. The weighted average for the unit is .0180 and the labor calculated is 239,510 man-hours which converts to $3,954,120 Indirect Costs. (21.6%)

UNIT 43 - FLARE SYSTEM

USAEDH accepted Parsons' Equipment Cost for the Flare Unit of $177,800 and assigned a Construction Factor of 3.00. This resulted in DFC of $533,400 in the USAEDH estimate. Parsons used a Construction Factor of 8.18 with the same equipment cost for a DFC of $1,454,000.

USAEDH then used a Labor Factor of .0200 with the DFC to arrive at labor of 10,668 man-hours and Indirect Costs of $128,016. (24.0%)

UNIT 44 - SITE PREPARATION, ROADS AND RAILROADS

USAEDH re-estimated this unit using Parsons' quantities and arrived at a DFC of $18,861,000 compared to Parsons' $15,493,000.

Labor Factors were assigned to various areas of the USAEDH estimate ranging from .025 to .040 depending on the ratio of mechanical and civil work in the area. The average for the unit was calculated at .0325 man-hours per dollar of DFC, and the resultant labor was 614,925 man-hours or $7,379,100 Indirect Cost. (39.1%)

USAEDH total Direct Field Cost for the project is $1,645,378,020 compared with Parsons' $1,862,549,000. USAEDH total labor for the project is 22,633,074 man-hours and Parsons does not calculate man-hours.

USAEDH Field Indirect Costs for the project are $271,596,888 (16.5% of DFC) compared with Parsons' $298,008,000. (16.0%)

USAEDH calculated Home Office Expense for the project at $115,018,494 and Fee at $40,639,868 which must be added together for $155,658,362 to compare with Parsons' total for both of $216,055,000.

USAEDH's Total Cost for the project is $2,072,633,270 compared with Parsons' $2,376,610,000 or a difference of 12.8% using Parsons' estimate as a base.

TABLE 1

AREA NO.	SYSTEM DESCRIPTION	1 EQUIP. COST $	2 CONSTR FACTOR	3 TOTAL DIRECT FIELD COST $	4 LABOR FACTOR	5 LABOR MH	6 MH x $12.00 $
08	Coal Mine	----------	-----	231,310,000	.0083	1,919,873	23,038,476
09	Coal Preparation	----------	-----	64,035,000	.0142	907,375	10,888,500
10	Coal Storage, Grinding & Drying	----------	-----	36,712,000	.0095	349,900	4,198,800
11	Oxygen Plant	180,000,000	1.05	189,000,000	.0083	1,568,700	18,824,400
12	SRC Dissolving	87,415,200	1.515	132,453,995	.0097	1,287,920	15,455,040
13	SRC Atmospheric Distillation	8,389,500	1.84	15,472,875	.0199	308,404	3,700,848
14	SRC Vacuum Distillation	10,347,500	2.19	22,692,820	.0186	421,669	5,060,028
15	Pyrolysis	6,357,300	1.75	11,095,236	.0150	166,527	1,998,324
16	Pyrolysis Atmospheric Distillation	741,900	2.86	2,120,864	.0263	46,483	557,796
17	Sour Gas Compression	2,683,800	1.61	4,327,340	.0111	48,148	577,776
18	Process Gasification	9,647,600	1.85	17,815,212	.0181	322,525	3,870,300
19	Shift Conversion	14,871,600	1.51	22,457,640	.0116	260,362	3,124,344
20	Selective Acid Gas Removal	44,212,200	1.10	48,633,400	.0170	826,768	9,921,216
21	Heavy Liquids Hydrotreating	34,518,100	1.69	58,255,895	.0159	927,246	11,126,952
22	Thermal Cracking	9,303,800	1.69	15,712,035	.0196	308,429	3,701,148
23	Coking	----------	-----	55,615,000	.0083	461,605	5,539,260
24	Naphtha Hydrotreating	7,416,700	1.70	12,603,068	.0134	168,345	2,020,140

TABLE 1 (Continued)

UNIT NO.	SYSTEM DESCRIPTION	1 EQUIP. COST $	2 CONSTR FACTOR	3 TOTAL DIRECT FIELD COST $	4 LABOR FACTOR	5 LABOR MH	6 MH x $12.00 $
25	Naphtha Reforming	----------	-----	12,847,000	.0083	106,630	1,279,560
26	Olefinic Gas/Acid Gas Removal	4,951,420	1.84	9,102,736	.0168	152,782	1,833,384
27	Saturate Gas/Acid Gas Removal	7,563,500	1.66	12,531,294	.0138	173,178	2,078,136
28	Olefinic Recovery & Polymerization	1,131,500	2.63	2,976,486	.0177	52,642	631,704
29	Hydrogen Recovery & Purification	13,068,300	1.57	20,488,295	.0155	316,678	3,800,136
30	SNG Purification	9,572,200	1.99	18,173,379	.0184	333,497	4,001,964
31	LPG Fractionation	10,311,100	1.66	17,128,264	.0172	293,795	3,525,540
32	Sulfur Plant	----------	-----	33,700,000	.0170	572,900	6,874,800
33	Fuel Gas Generation	38,210,600	1.62	62,066,403	.0135	835,942	10,031,304
34	Fuel Gas Acid/Gas Removal	52,381,000	1.10	57,619,100	.0170	979,525	11,754,300
35	Steam & Power Generation	347,392,000	1.07	372,328,780	.0170	6,330,705	75,968,460
36	Process Waste Water Treating	3,323,000	2.11	7,013,908	.0163	114,077	1,368,924
37	Shops and Building	----------	-----	12,317,000	.0400	492,680	5,912,160
38	Fire Water System	----------	-----	3,880,000	.0320	124,160	1,489,920

TABLE 1 (Continued)

UNIT NO.	SYSTEM DESCRIPTION	1 EQUIP. COST $	2 CONSTR FACTOR	3 TOTAL DIRECT FIELD COST $	4 LABOR FACTOR	5 LABOR MH	6 MH x $12.00 $
39	Potable and Sanitary Water System	38,790	3.59	139,280	.0354	4,933	59,196
40	Raw Water System	14,078,300	1.63	22,881,910	.0192	439,720	5,276,640
41	Effluent Water Treating	669,100	2.90	1,939,819	.0224	43,448	521,376
	Add: Civil Work: 2 Ponds	----------	-----	208,000	.0500	10,400	124,800
42	Product Storage	13,861,600	1.32	18,329,586	.0180	329,510	3,954,120
43	Flare System	177,800	3.00	533,400	.0200	10,668	128,016
44	Site Preparation, Roads and Railroads	----------	-----	18,861,000	.0326	614,925	7,379,100
	TOTALS AND AVERAGES	na	na	$ 1,645,378,020	.01375	$22,633,074	$271,596,888

TABLE 2

USAEDH Total Direct Field Cost	$1,645,378,020
Indirect Cost @ 100% of Labor	271,596,888
Total Field Cost	$1,916,974,908
Home Office O/H @ 6%	115,018,494
Total Field and Office Costs	$2,031,993,402
Fee @ 2%	40,639,868
TOTAL USAEDH COST	$2,072,633,270
TOTAL PARSONS COST	$2,376,610,000
DIFFERENCE	$ 303,976,730

$$\text{Confidence Factor } \frac{\text{Difference}}{\text{Parson's Estimate}} = \frac{\$\ 303,976,730}{\$2,376,610,000} = \pm\ 12.8\%$$