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National Renewable Energy Laboratory

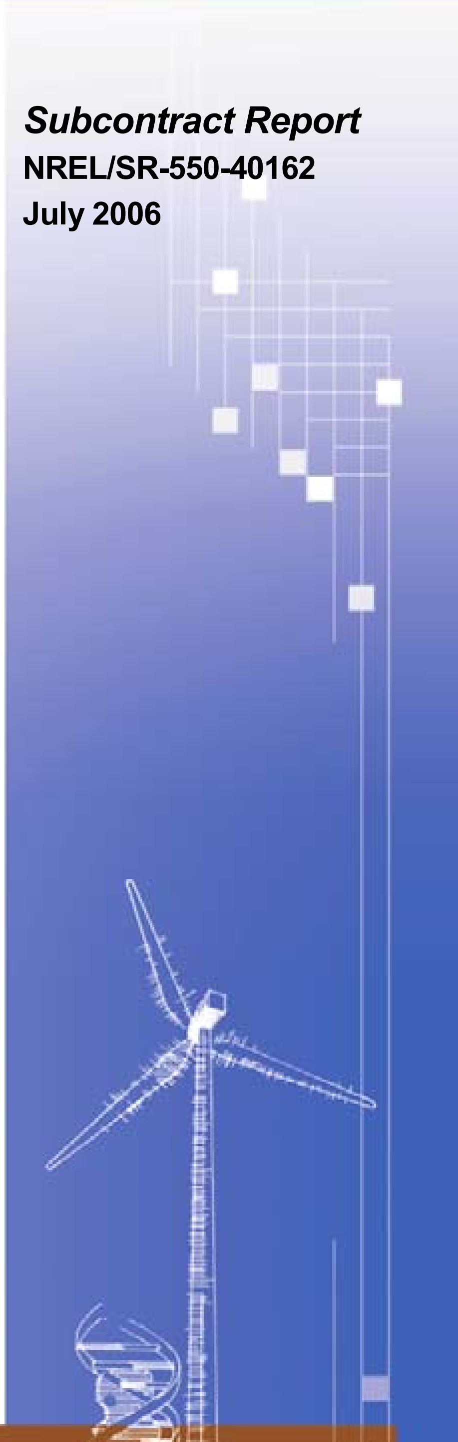
Innovation for Our Energy Future

Subcontract Report
NREL/SR-550-40162
July 2006

Nexant Parabolic Trough Solar Power Plant Systems Analysis

Task 1: Preferred Plant Size
January 20, 2005 — December 31, 2005

B. Kelly
Nexant, Inc.
San Francisco, California



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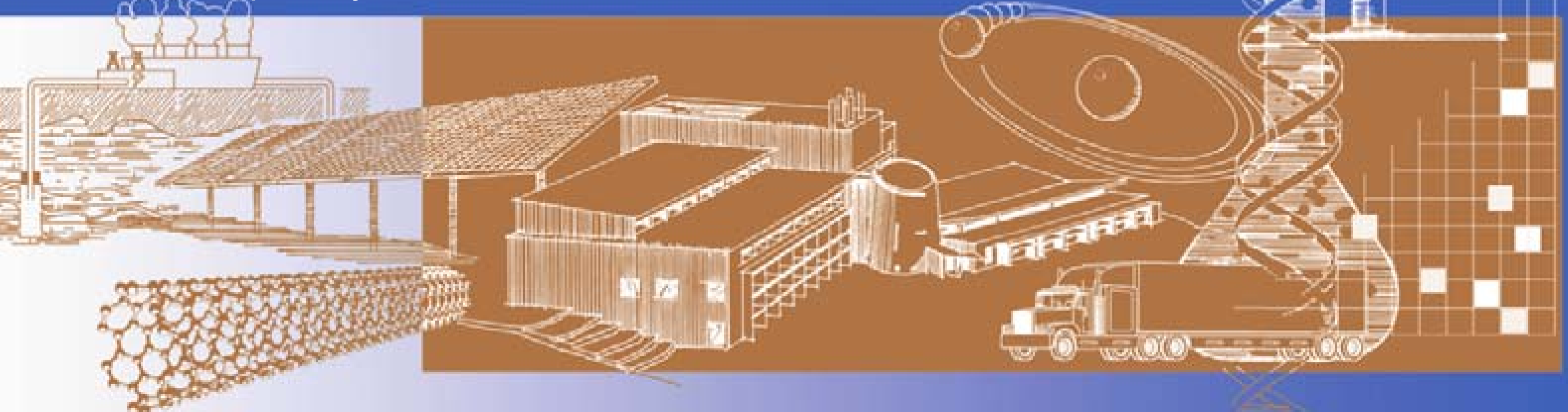

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Prepared under Subcontract No. LDC-5-55014-01

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Task 1
Preferred Plant Size

1. Introduction

The Rankine cycles for commercial parabolic trough solar projects range in capacity from 13.5 MWe at the Solar Electric Generating Station I (SEGS I) plant, to a maximum of 89 MWe at the SEGS VIII / IX plants. The series of SEGS projects showed a consistent reduction in the levelized energy cost due to a combination of improvements in collector field technology and economies of scale in both the Rankine cycle and the operation and maintenance costs. Nonetheless, the question of the optimum Rankine cycle capacity remains an open issue. The capacities of the SEGS VIII / IX plants were limited by Federal Energy Regulatory Commission and Public Utility Regulatory Policy Act requirements to a maximum net output of 80 MWe. Further improvements in the Rankine cycle efficiency, and economies of scale in both the capital and the operating cost, should be available at larger plant sizes.

An analysis was conducted to determine the effect of Rankine cycle capacities greater than 80 MWe on the levelized energy cost. The study was conducted through the following steps:

- Three gross cycle capacities of 88 MWe, 165 MWe, and 220 MWe were selected.

- Three Rankine cycle models were developed using the GateCycle program. The models were based on single reheat turbine cycles, with main steam conditions of 1,450 lb_f/in^2 and 703 °F, and reheat steam conditions of 239 lb_f/in^2 and 703 °F. The feedwater heater system consisted of 5 closed heaters and 1 open deaerating heater. The design condenser pressure was 2.5 in. HgA.

- The optimization function within Excelergy was used to determine the preferred solar multiple for each plant. Two cases were considered for each plant: 1) a solar-only project without thermal storage, and 2) a solar-fossil hybrid project, with 3 hours of thermal storage and a heat transport fluid heater fired by natural gas.

- For each of the 6 cases, collector field geometries, heat transport fluid pressure losses, and heat transport pump power requirements were calculated with a field piping optimization model.

- Annual electric energy outputs, capital costs, and annual operating costs were calculated for each case using the default methods within Excelergy, from which estimates of the levelized energy costs were developed. The plant with the lowest energy cost was considered the optimum.

2. Rankine Cycle Models

The Rankine cycle design for the 88 MWe, 165 MWe, and 220 MWe plants closely followed the designs developed by Fichtner for the 55 MWe AndaSol project in Spain, and by Luz for the 88 MWe SEGS VIII / IX projects. The cycle is a conventional, single reheat design; the live steam pressure and temperature are 1,450 lb_f/in^2 and 703 °F, respectively, and the reheat steam pressure and temperature are 269 lb_f/in^2 and 703 °F, respectively. Extraction steam pressures, terminal temperature differences, and drain cooler approach temperatures for the 3 low pressure, and the 2 high pressure, closed feedwater heaters were derived from the AndaSol heat balance. The operating conditions for the 1 open deaerating feedwater heater also duplicated the AndaSol data.

The GateCycle flow diagram is shown in Figure 1. A list of the calculated cycle efficiencies, together with a comparison with efficiency data from existing plants, is shown in Table 1.

Table 1
Calculated and Published Rankine Cycle Efficiencies

Gross cycle output, MWe	GateCycle calculation	Published efficiency
55	0.375	0.375 [1]
88	0.377	0.377 [2]
165	0.379	N/A
220	0.380	N/A

Notes:
1) Solar Millennium AndaSol heat balance, with steam chest leakage to condenser equal to 0.01 percent of live steam flow rate
2) SEGS IX heat balance, with steam chest leakage rate equal to 1.95 percent of live steam flow rate

High pressure turbine and intermediate/low pressure turbine expansion efficiencies in GateCycle were calculated using the General Electric Spencer-Cotton-Cannon correlations. In addition, the low pressure turbine efficiency was based on an exhaust loss at the entrance to the condenser of 5 Btu/lb_m, which was achieved by selecting an annulus area which yielded an exhaust velocity in the range of 500 to 550 ft/sec. For the two smaller plants, the agreements between the calculated and the published efficiencies were excellent.

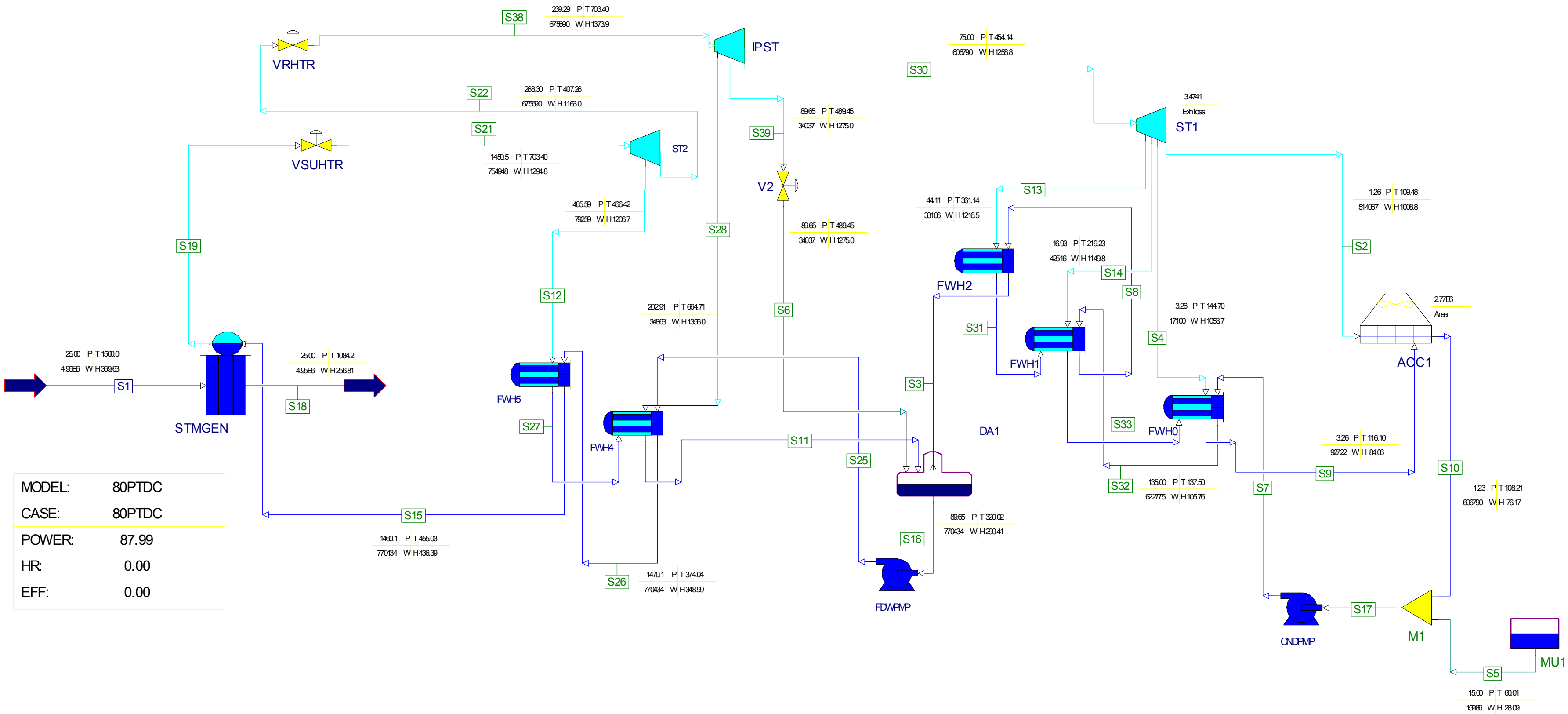

Figure 1 GateCycle Flow Diagram
88 MWe Rankine Cycle with Dry Heat Rejection

Overall expansion efficiencies, together with the gross cycle efficiencies, are shown in Figure 2. The overall expansion efficiencies were calculated on a weighted average approach, as follows:

$$\frac{(HP\ output,\ MW)(HP\ efficiency) + (IP\ output,\ MW)(IP\ efficiency) + (LP\ output,\ MW)(LP\ efficiency)}{(HP\ output + LP\ output + IP\ output,\ MW)}$$

The gross cycle efficiency improved by about 130 parts in 10,000 as the plant capacity increased from 50 MWe to 150 MWe. However, improvements in the cycle efficiency for plant sizes above 150 MWe were likely to be modest, with an asymptotic efficiency of perhaps 38.1 percent.

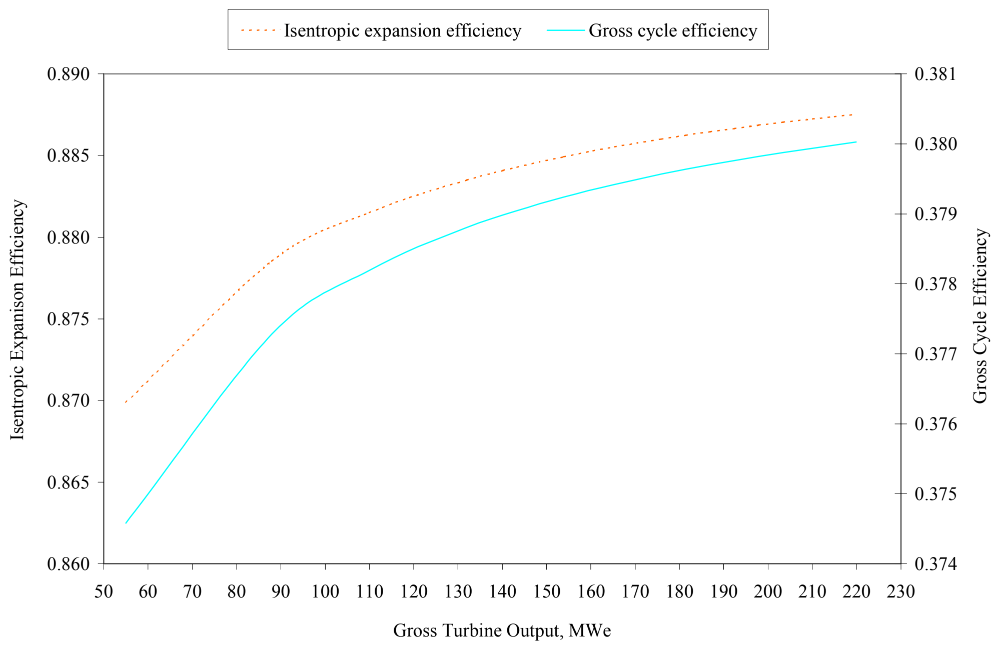

Figure 2 Turbine Expansion and Gross Cycle Efficiencies as a Function of Capacity

To help determine the source of the efficiency improvements with increasing capacity, isentropic expansion efficiencies were also calculated separately for the high pressure and the intermediate/low pressure turbine sections. The results are illustrated in Figure 3.

The increase in cycle efficiency was primarily a function of an increase in the high pressure turbine efficiency. The improvement can be traced to an increase in the length of the blades. The effect of non-uniform aerodynamic loads at the end of the blades decreased with length, and the (essentially) fixed steam leakage past the end of the blades represented a smaller portion of the total flow past the blade.

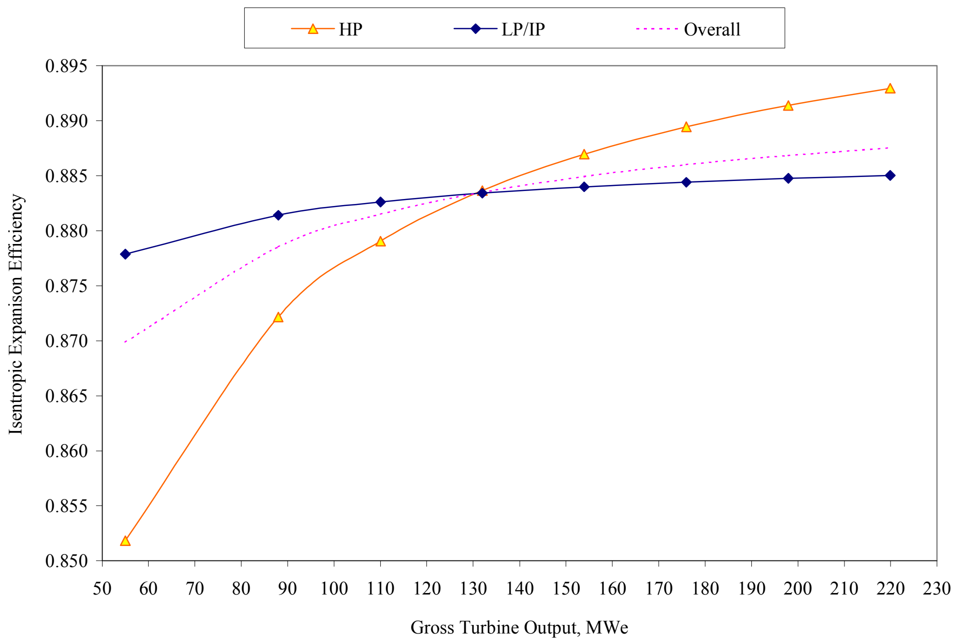

Figure 3 Turbine Section Expansion Efficiencies as a Function of Capacity

3. Solar Multiples

The optimization function within Excelergy was used to determine the preferred solar multiple for each of the 6 cases. The collector field design was based on the LS-2+ collector, with 6 solar collector assemblies in a loop. The annual performance calculations, capital cost estimates, and operating cost estimates were based on the default Excelergy methods. The results of the optimization calculations are shown in Table 2.

Table 2
Results from Excelergy Solar Multiple Optimization Calculations

Plant Capacity and Design	Optimum Solar Multiple	Collector Field Area, m^2
88 MWe		
- Solar-only	1.45	534,230
- Hybrid with thermal storage	1.80	662,144
165 MWe		
- Solar-only	1.45	1,000,740
- Hybrid with thermal storage	1.80	1,241,520
220 MWe		
- Solar-only	1.45	1,331,812
- Hybrid with thermal storage	1.80	1,651,598

The variations in the Rankine cycle efficiency and the heat transport fluid pump power demand with plant capacity were not strong enough to cause the optimum solar multiple to be other than 1.45 for all of the solar-only plants, and 1.80 for all of the hybrid plants with thermal storage.

4. Collector Field Piping Models

An optimization model was run for each of the 6 cases to determine the parasitic power demand of the heat transport fluid pumps. The results of the optimizations are listed in Table 3 for the solar-only plants, and in Table 4 for the hybrid plants with thermal storage.

The unit pump power demand, in kWe/m^2, increased from a value of 0.00688 for the 88 MWe solar-only plant, to a value of 0.00827 for the 220 MWe hybrid plant with thermal storage. The effect can be traced to the pressure losses in the cold header and the hot header; as the collector field became larger, the lengths of the primary headers increased. Similarly, the annual unit thermal losses (kWht/m^2), the annual unit pump energy demand (kWhe/m^2), and the unit capital cost (\$/m^2) all increased with field area due to the increase in header lengths.

Table 3
Collector Field Piping Model Results for Solar-Only Plants

	88 MWe	165 MWe	220 MWe
Collector area, m^2	541,786	1,015,848	1,354,464
Number of LS-2+ loops, each	192	360	480
Unit area, m^2/MWe	6,157	6,157	6,157
Pressure losses, bar			
- HTF pump outlet piping	0.20	0.17	0.19
- Cold header	1.96	2.78	3.22
- Loop	8.37	8.28	8.24
- Hot header	2.05	3.16	3.43
- HTF inlet piping	0.18	0.19	0.19
- Total	12.77	14.58	15.28
HTF pump power, kWe	3,729	7,653	10,538
Unit pump power, kWe / m^2	0.00688	0.00753	0.00778
Unit annual losses			
- Thermal, kWht / m^2	46.6	49.2	50.9
- Pumping, kWhe / m^2	11.1	11.7	11.9
Piping capital costs, $			
- Collector field	$12,507,459	$25,483,798	$35,789,690
- Steam generator area	$992,960	$1,931,914	$2,434,411
	--------------	--------------	--------------
- Total	$13,500,419	$27,415,712	$38,224,102
Unit capital cost, $ / m^2	$23.09	$25.09	$26.42

Table 4
Collector Field Piping Model Results for Hybrid Plants with Thermal Storage

	88 MWe	165 MWe	220 MWe
Collector area, m^2	654,658	1,241,592	1,670,506
Number of LS-2+ loops, each	232	440	592
Unit area, m^2/MWe	7,439	7,525	7,593
Pressure losses, bar			
- HTF pump outlet piping	0.21	0.17	0.20
- Cold header	2.05	3.26	3.64
- Loop	8.83	8.54	8.34
- Hot header	2.27	3.26	4.01
- HTF inlet piping	0.18	0.19	0.21
- Total	13.54	15.42	16.41
HTF pump power, kWe	4,826	9,903	13,819
Unit pump power, kWe / m^2	0.00737	0.00798	0.00827
Unit annual losses			
- Thermal, kWht / m^2	47.5	50.5	53.0
- Pumping, kWhe / m^2	12.1	12.5	12.5
Piping capital costs, $			
- Collector field	$15,502,121	$32,392,281	$46,754,547
- Steam generator area	$1,246,061	$2,370,909	$2,942,457
	----------------	----------------	----------------
- Total	$16,748,182	$34,763,190	$49,697,004
Unit capital cost, $ / m^2	$23.68	$26.09	$27.99

The influence of the collector field area on the electric power demand of the heat transport fluid pump is illustrated in Figure 4. The curve is an extremely shallow parabola; thus, the parasitic energy demand of the pumps did not have a strong influence on the preferred plant size.

The pump power demand for the larger plants is in the multi-megawatt range. As such, starting the pumps must be coordinated with the local utility to prevent voltage and frequency upsets to the local grid. To some extent, these restrictions may have a minor detrimental effect on the annual plant availability, but a quantitative analysis has yet to be performed.

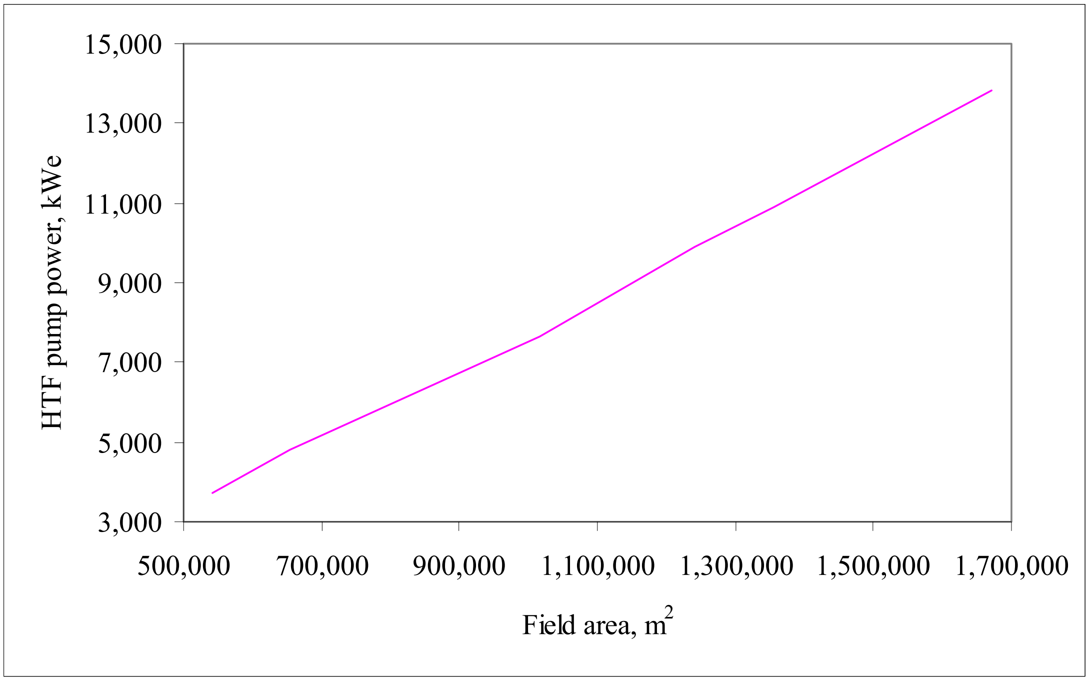

Figure 4 Heat Transport Fluid Pump Power Demand
as a Function of Collector Field Area

5. Annual Energy Calculations

The annual net electric energy delivered by each of the six plant designs was calculated by the Excelergy computer program. The plant site was assumed to be Barstow, California, and the input parameters for the model were the default Excelergy values. One exception to the default parameters was the parasitic power demand of the heat transport fluid pumps; here, the demand was based on a polynomial curve fit of the data in Figure 4.

The results of the annual energy calculations are shown in Table 5 for the solar-only plants, and in Table 6 for the hybrid plants with thermal storage.

Table 5
Annual Performance of Solar-Only Plants

	88 MWe	165 MWe	220 MWe
Nominal gross plant rating, MWe	88.0	165.0	220.0
Isentropic expansion efficiency	0.866	0.874	0.876
Gross Rankine cycle efficiency	0.377	0.379	0.380
Excelergy inputs			
- SfArea, m^2	541,786	1,015,848	1,354,464
- Edesign, MWe	88.5	166.9	223.0
- NetCap, MWe	80.5	151.3	201.8
- Qdesign, MWt	234.7	440.0	586.7
- PTTmax, MWt	340.3	506.0	674.7
- PTTmin, MWt	35.2	66.0	88.0
- SfPar, MWe	0.144	0.270	0.360
- ChtfPar, MWe	3.729	7.653	10.538
- BopPar, MWe	2.183	4.053	5.375
- CtPar, MWe	1.500	2.813	3.750
- PbFixPar, MWe	0.443	0.835	1.115
Excelergy outputs			
- Qdni, MWh	1,491,262	2,793,491	3,717,653
- Egr, MWhe	222,685	419,682	560,317
- Epar, MWhe	22,201	43,079	58,114
- Enet, MWhe	200,484	376,603	502,203
- Net efficiency	0.134	0.135	0.135
Calculated efficiencies			
- Egr / Qdni	0.1493	0.1502	0.1507
- Epar / Egr	0.0997	0.1026	0.1037

The gross solar-to-electric efficiency increased with plant size, as shown by the ratio Egr / Qdni. The effect can be traced to the increase in Rankine cycle efficiency with capacity. However, the net solar-to-electric

Table 6
Annual Performance of Hybrid Plants with Thermal Storage

	88 MWe	165 MWe	220 MWe
Nominal gross plant rating, MWe	88.0	165.0	220.0
Isentropic expansion efficiency	0.866	0.874	0.876
Gross Rankine cycle efficiency	0.377	0.379	0.380
Excelergy inputs			
- SfArea, m^2	654,658	1,241,592	1,670,506
- Edesign, MWe	88.5	166.9	223.0
- NetCap, MWe	79.4	149.0	198.5
- Qdesign, MWt	234.7	440.0	586.7
- PTTmax, MWt	269.9	506.0	674.7
- PTTmin, MWt	35.2	66.0	88.0
- SfPar, MWe	0.174	0.330	0.444
- ChtfPar, MWe	4.826	9.903	13.819
- BopPar, MWe	2.183	4.053	5.375
- CtPar, MWe	1.500	2.813	3.750
- PbFixPar, MWe	0.443	0.835	1.115
Excelergy outputs			
- Qdni, MWh	1,848,325	3,465,609	4,610,310
- Qgas, MWh	7,496	14,042	18,845
- Egr, MWhe	276,760	522,265	697,064
- Epar, MWhe	27,950	54,086	73,051
- Enet, MWhe	248,809	468,178	624,013
- Net solar-to-electric efficiency	0.133	0.134	0.134
Calculated efficiencies			
- Egr / Qdni	0.1497	0.1507	0.1512
- Epar / Egr	0.1010	0.1036	0.1048

efficiency was essentially independent of the plant size. In effect, the increase in gross efficiency was offset by the increase in parasitic energy demand, as shown by the ratio Epar / Egr.

For the hybrid plants, the use of natural gas was limited to the summer peak periods to ensure the revenue from the energy sales was sufficient to justify the expense of burning the fuel. With 3 hours of thermal storage and a solar multiple of 1.8, the plant can satisfy essentially all of the peak period energy demands without requiring the use of the fossil-fired heater. Thus, the annual thermal energy contribution from natural gas was less than 0.5 percent of the annual solar energy contribution for each of the three plants.

6. Economic Analysis

Levelized energy costs were calculated for each of the six plants using the year-by-year cash flow analysis within Excelergy. The capital cost for the plants, together with the annual operation and maintenance costs, were developed from the default values in Excelergy.

The input and the output financial parameters for the solar-only plants, and for the hybrid plants with thermal storage, are listed in Table 7 and Table 8, respectively.

All of the plants were assumed to be built and financed under commercial conditions, as follows:

- The manufacturing capacities for the solar equipment were sufficiently large that all of the mirrors and the heat collection elements could be fabricated, shipped, and assembled within a two-year period for the plant engineering, procurement, and construction.

- The debt interest rate and the required return on equity were independent of the capital cost of the plant.

Table 7
Input and Output Financial Parameters for Solar-Only Plants

	88 MWe	165 MWe	220 MWe
Financial parameters - Inputs			
- Capital cost, $ 1000	$267,747	$465,148	$600,039
(Unit capital cost, $/kWe)	$3,314	$3,074	$2,978
- O & M cost, $ 1000	$4,777	$6,740	$8,118
(Unit O&M cost, $/MWhe)	$24	$18	$16
- EPC period, years	2.0	2.0	2.0
- Interest during construction rate	7.0 %	------>	------>
- Debt interest rate	6.0 %	------>	------>
- Debt term, years	20	------>	------>
- Minimum debt coverage ratio	140 %	------>	------>
- Return on equity	15 %	------>	------>
- Effective income tax rate	40 %	------>	------>
- Investment tax credit	10 %	------>	------>
- Depreciation period, years	5	------>	------>
Financial parameters - Outputs			
- Optimum debt fraction	59.7 %	59.7 %	59.7 %
- Average debt coverage ratio	152 %	152 %	152 %
- Nominal discount rate	9.6 %	9.6 %	9.6 %
Levelized energy cost, $/kWhe	$0.164	$0.146	$0.140

Table 8
Input and Output Financial Parameters for Hybrid Plants with Thermal Storage

	88 MWe	165 MWe	220 MWe
Financial parameters - Inputs			
- Capital cost, $ 1000	$351,427	$617,121	$800,519
(Unit capital cost, $/kWe)	$4,426	$4,145	$4,049
- O & M cost, $ 1000	$5,355	$7,817	$9,546
(Unit O&M cost, $/MWhe)	$22	$17	$15
- EPC period, years	2.0	2.0	2.0
- Interest during construction rate	7.0 %	------>	------>
- Debt interest rate	6.0 %	------>	------>
- Debt term, years	20	------>	------>
- Minimum debt coverage ratio	140 %	------>	------>
- Return on equity	15 %	------>	------>
- Effective income tax rate	40 %	------>	------>
- Investment tax credit	10 %	------>	------>
- Depreciation period, years	5	------>	------>
- Annual fuel use, 10^6 Btu	25,575	47,912	64,298
Financial parameters - Outputs			
- Optimum debt fraction	59.7 %	59.8 %	59.8 %
- Average debt coverage ratio	152 %	151 %	151 %
- Nominal discount rate	9.6 %	9.6 %	9.6 %
Levelized energy cost, $/kWhe	$0.169	$0.153	$0.147

The levelized energy costs for the six plants are shown in Figure 5. Both the solar-only and the hybrid plants with thermal storage showed decreases in the levelized energy costs with increases in the plant capacity. However, the lowest energy costs occurred with net plant capacities in the range of 220 to 250 MWe. For plant capacities above 250 MWe, the energy costs were likely to remain invariant, for the following reasons:

- The gross Rankine cycle efficiency increased with plant capacity, but appears to have an asymptotic value no larger than 0.381, as illustrated in Figure 2

- The unit annual parasitic energy demand of the heat transport fluid pumps, in kWhe/m^2, increased as the size of the collector field increased

- As discussed in Section 8, Conceptual Cost Estimate, various plant functions required multiple equipment items, even at the largest commercial size, be used. As a result, not all of the theoretical benefits of economies of scale could be realized.

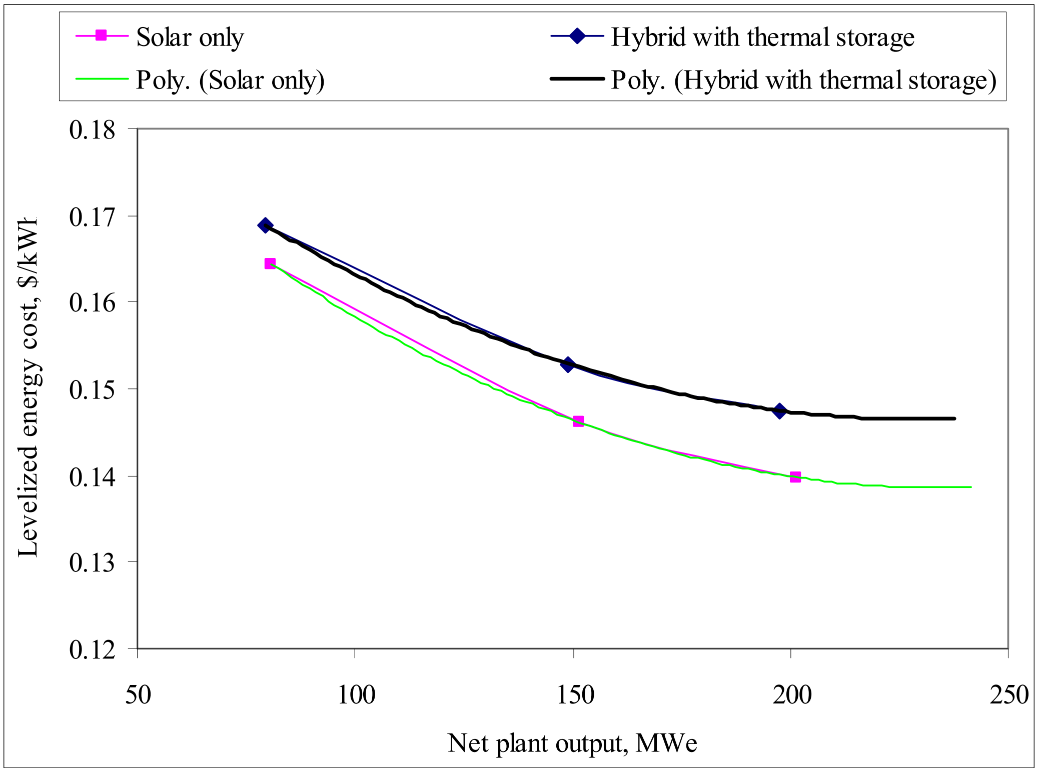

Figure 5 Levelized Energy Costs as a Function of Plant Capacity

7. Commercial Turbine-Generators

Large steam turbines are fabricated from standard frame sizes, with the mechanical output matched to the customer's needs by adjusting the lengths of the blades, and in some cases, the number of stages. A listing of commercial turbines in the size range of interest for large parabolic trough plants is shown in Table 9.

Table 9
Commercial Reheat Steam Turbine-Generator Capacities

Manufacturer	Model	Arrangement	Size range, MWe	Maximum steam conditions, lb_f/in^2 / °F/ °F
General Electric	D series	Dual flow HP/IP with separate LP	125-375	2,400 / 1,050 / 1,050
Alstom	STF25	Separate HP with combined IP/LP	210-275	2,540 / 1,004 / 1,004
Siemens	SST-3000	Separate HP with combined IP/LP	90-250	2,560 / 1,110 / 1,110
Siemens	SST-5000	Dual flow HP/IP with separate LP	120-500	2,560 / 1,110 / 1,110

On a conceptual level, the unit price for the turbine, in $/kWe, should be the lowest at the upper end of the power level of a particular frame size. In essence, the fixed costs associated with the casing and the shaft could be distributed over the largest number of kilowatts. However, this situation does not seem to be borne out in commercial practice. Two senior cost engineers at Bechtel have yet to observe any discontinuous change in the cost of a turbine-generator as a function of size. The effect can, perhaps, be traced to commercial pricing considerations. For example, the upper end of the Alstom STF25 frame capacity is at about the mid-point of the General Electric D series frame capacity. For General Electric to offer a 250 MWe turbine-generator which is competitive with the Alstom design, the price from General Electric may need to be lower than the theoretical value. Correspondingly, at other power levels, Alstom may need to adjust their prices to remain competitive with General Electric.

In terms of Task 1, any potential step changes in the cost of the turbine-generator from moving from one frame size to the next is likely to have a minor influence on selection of the preferred plant size. The potential penalties or benefits to moving to a different frame size are muted by the ability to change to a different turbine vendor. Thus, discontinuities in the levelized energy cost as a function of plant size are more likely to be determined by plant components other than the turbine. This is discussed a little more fully in Section 9, Observations. Further, the unit cost for the turbine-generator is perhaps $200/kWe. If a

5 percent advantage in the cost of the turbine-generator could be achieved by selecting a power output at the upper end of the frame size, the cost of energy from a plant with thermal storage could be reduced by approximately 0.25 percent. For a fully commercial industry, such as turn-key combined cycle power plants, such a cost advantage would be meaningful. However, for a maturing solar industry, which has yet to build a plant in the range of 150 to 250 MWe, the solutions to moving and storing very large quantities of Therminol and nitrate salt may be more expensive than anticipated. As such, the uncertainties in estimating the performance and the cost of large heat transport fluid and the thermal storage systems likely has as large an influence on the cost of energy as a step-change in the cost of the turbine.

8. Conceptual Cost Estimate

For the purposes of the study, a 250 MWe hybrid plant with 3 hours of thermal storage was selected as the design offering the lowest cost of energy. A conceptual capital cost estimate for the plant was developed from the following sources:

- Capital cost estimate from the conceptual design of a 100 MWe central receiver power plant developed for the Central Receiver Utility Studies. Equipment capacities and materials were modified to reflect the changes in the plant size (100 MWe to 250 MWe), the working fluid (nitrate salt to Therminol), and the peak working fluid temperature (1,050 °F to 735 °F).

- Capital cost estimate from the preliminary design of the 880 MWht thermal storage system at the 55 MWe AndaSol parabolic trough solar power plants in southern Spain

- AspenTech Icarus equipment and labor cost data base

- Bechtel cost estimating experience on similar power plant projects.

Heat Transport System Flow Diagram

With a gross plant rating of 265 MWe, a moderate Rankine cycle efficiency of 38 percent, and a limited temperature rise of 175 °F across the collector field, the volume flow rates of Therminol, nitrate salt, and steam within the plant were fairly large. As such, the flow rates and equipment capacities often required multiple equipment items, as outlined in Table 10.

A schematic heat transport fluid flow diagram is shown in Figure 6. The numbers in the circles are the nominal pipe diameters, in inches. Although not shown in the figure, a nitrogen supply and recovery system is also required for the thermal storage tank ullage.

Items Included in the Estimate

The estimate includes the direct and indirect material and labor costs required to construct the plant, together with the costs for engineering, procurement, construction management, startup, and checkout.

The estimate is arranged in the following system categories: Land; Structures and Improvements; Collector System; Thermal Storage System; Heat Transport Fluid System; Electric Power Generation System; and Master Control System. The system estimates are further divided into the following cost categories:
C - Columns and Vessels; D - Tanks; E - Exchangers; G - Pumps and Drivers; K - Compressors and Drivers;
T - Special Equipment; J - Instrumentation; P - Piping; M - Structural Steel; N - Insulation; P - Electrical;
Q - Concrete Work; S - Sitework; and X - Painting.

Table 10
Multiple Equipment Items
250 MWe Plant with 3 Hours of Thermal Storage

Thermal Storage System	
Storage Tanks	
Height, ft	43
Diameter, ft	108
Cold tanks, each	3
Hot tanks, each	3
Oil-to-salt heat exchangers	
Area, ft^2	42,400
Number, each	24
Heat Transport Fluid System	
Heat transport fluid pumps	
Motor power, bhp	3,500
Number, each	6
HTF pump header diameter, in.	60
Expansion vessels	
Diameter, ft.	14
Length, ft.	59
Number, each	8
Steam generator, number of shells	
Preheater	2
Evaporator	4
Superheater	2
Reheater	4

Contingencies are included for each of the principal cost estimate categories. The contingencies are allowances for items which have not yet been identified at this stage of the design (for example, the support steel for the cable trays), but which are expected to have been identified at the completion of the final design. The monies in each of the contingencies are expected to be spent at the completion of the project; thus, the funds are not intended to cover additions to the project scope or cost overruns.

Items Excluded from the Estimate

Items for which estimates have not been developed include the following: 1) escalation in equipment prices and labor costs beyond the second quarter of 2005; 2) interest expenses during final design and construction; 3) owner's engineering and construction management; and 4) environmental impact statements.

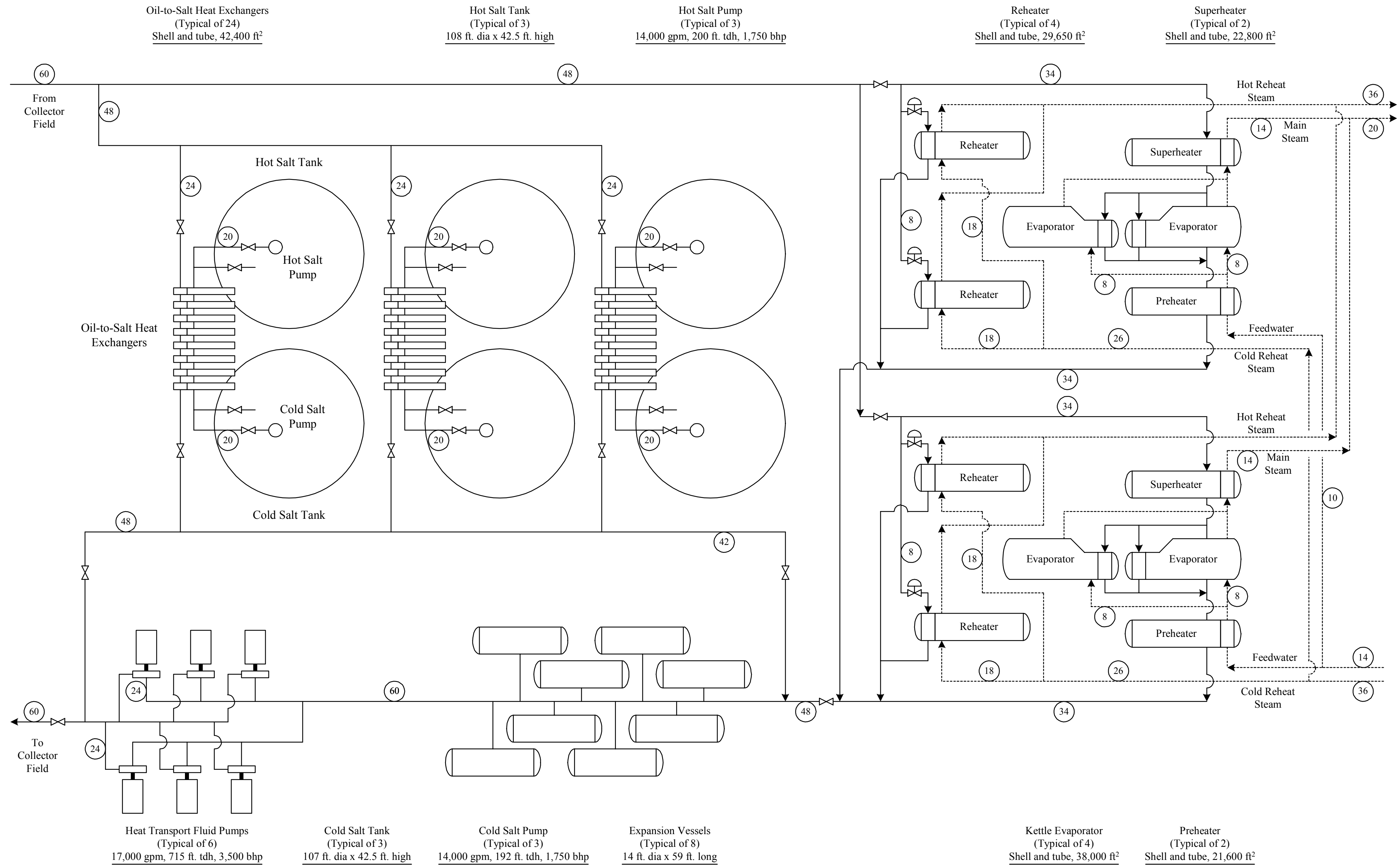

Figure 6 250 MWe Plant Heat Transport Fluid Flow Diagram

Labor Rates and Indirect Costs

Direct labor rates by craft, including payroll additives, for a generic site near a large metropolitan area in the Southwest United States were estimated as follows:

- Mechanical: $38.13 / hr
- Civil: $26.72 / hr
- Steel worker: $38.32 / hr
- Pipe fitter: $42.68 / hr
- Electrician: $29.42 / hr
- Instrument technician: $36.85 / hr

Equipment and material installation costs for items which are distributed among the craft hours were estimated as a percentage of the direct wage rates. These distributable costs included equipment rentals, welding supplies, construction utilities, labor for material handling, and labor for site clean-up. The distributable costs were estimated to be 84.5 percent of the direct labor costs. Thus, the total craft labor rates to the project were estimated as follows:

- Mechanical: $70.35 / hr
- Civil: $49.30 / hr
- Steel worker: $70.70 / hr
- Pipe fitter: $78.84 / hr
- Electrician: $54.28 / hr
- Instrument technician: $67.99 / hr

Single Line Diagrams

In support of the electric equipment and bulk materials estimates, single line diagrams were developed for the heat transport fluid system and the thermal storage system. The single line diagrams are shown in Figures 7 and 8.

Sales Tax

A sales tax of 7.4 percent is applied to all equipment and bulk material purchases. The tax consists of a state sales tax of 5.6 percent and a local sales tax of 1.8 percent.

Freight

An allowance for freight, equal to 4 percent of the equipment and materials cost, is included in the estimate.

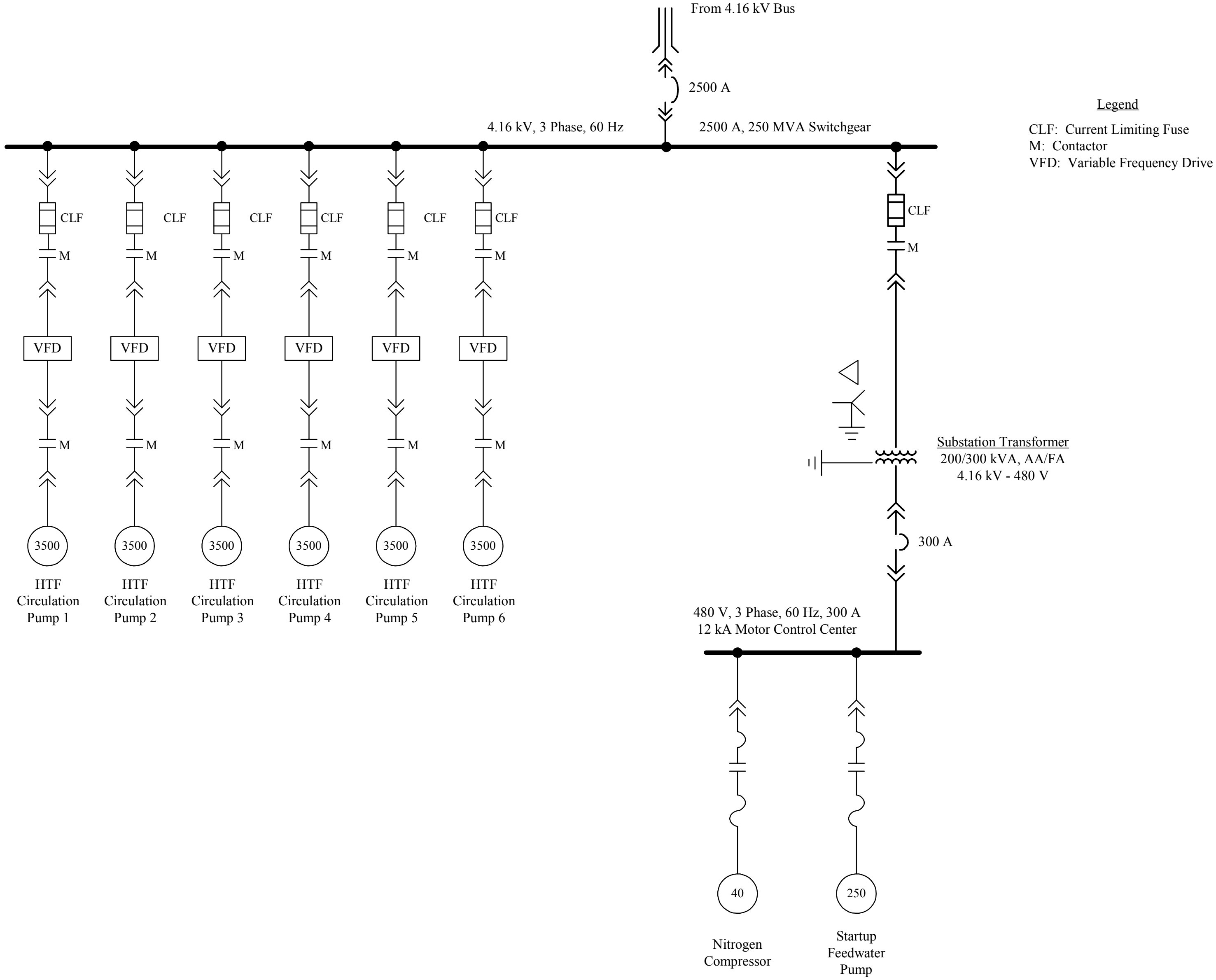

Figure 7 Heat Transport Fluid System - Single Line Diagram

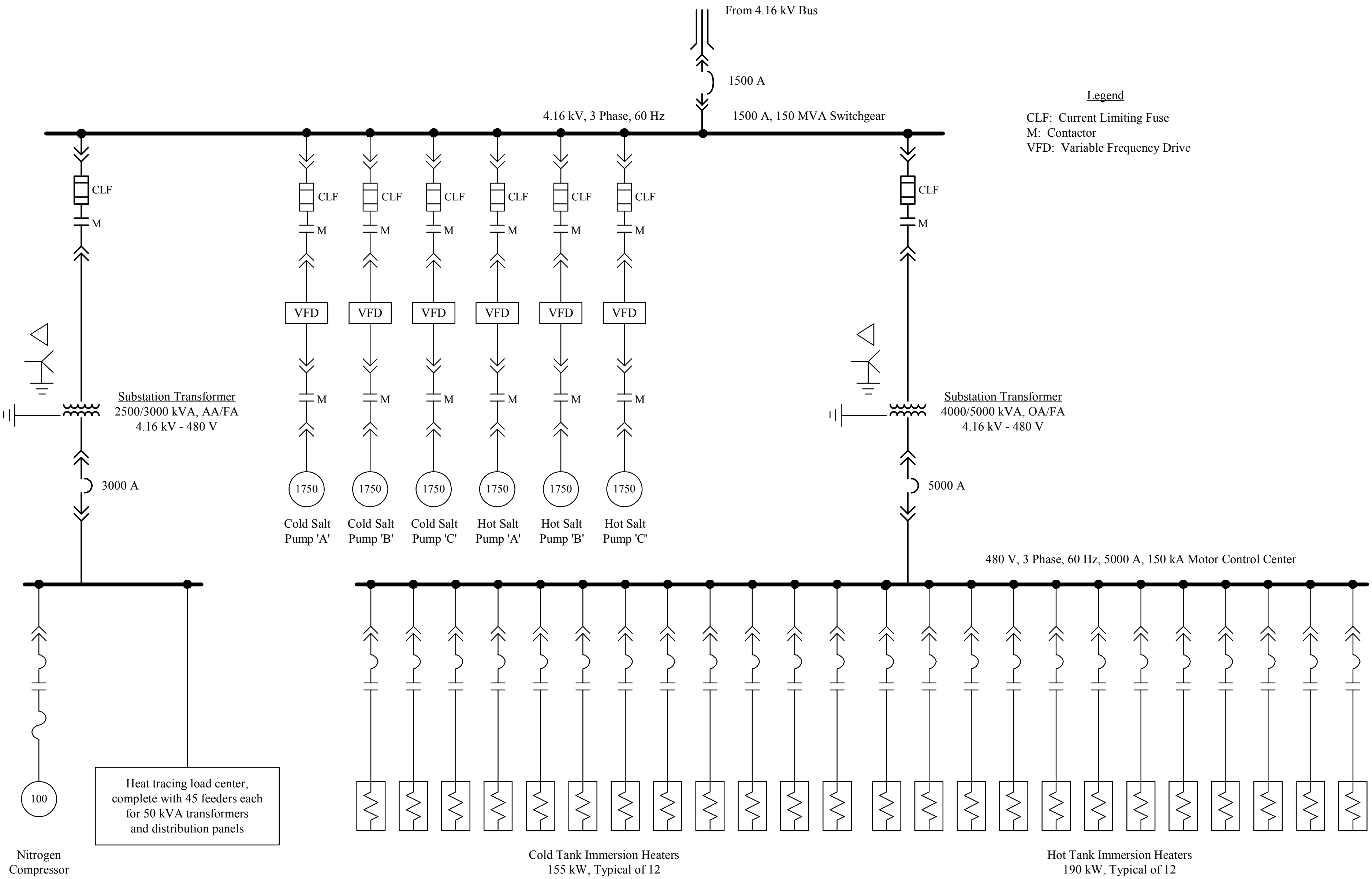

Figure 8 Thermal Storage System - Single Line Diagram

Escalation

The estimate was prepared using labor, equipment, and material costs current through the first quarter of 2004. Escalation from the first quarter of 2004 through the fourth quarter of 2005 was estimated to be 4.5 percent, based on cost indices prepared by Bechtel Corporation for current and planned refinery and chemical projects.

Contractor's Fee

The fee for the general contractor is assumed to be 3 percent of the total installed cost, including contingencies.

Cost Estimate Summary and Details

A summary of the overall estimate is shown in Table 11, and a breakdown of the total field costs by system category is shown in Table 12.

Table 11
Estimate Summary
4^{th} Quarter 2005 Overnight Construction Costs
250 MWe Plant with 3 Hours of Thermal Storage

Item	$1,000	Contingency	$1,000
Land	2,671	0%	2,671
Structures and Improvements	3,273	15%	3,763
Collector System	513,420	5%	539,091
Thermal Storage System	94,944	5%	99,691
Heat Transport Fluid System	60,173	10%	66,190
Electric Power Generation System	98,570	10%	108,428
Master Control System	2,270	15%	2,610
	---------	------	---------
Total Field Cost	775,321	6%	822,445
Engineering, Procurement, and Home Office	12,750	15%	14,662
Construction Management and Field Procurement	5,005	15%	5,756
Startup and Checkout	2,296	15%	2,640
Contractor Fee (3 percent)	23,861	0%	23,861
	--------	------	--------
	43,911	7%	46,919
Total Overnight Construction Cost	819,232	6%	869,363

Table 12
Total Field Cost Estimate Summary
4th Quarter 2005 Costs, Excluding Contingencies
250 MWe Plant with 3 Hours of Thermal Storage

	Land	Structures and Improvements	Collector System	Thermal Storage	Heat Transport	Electric Power Generation	Master Control
C - Columns and Vessels				258,110	1,392,430	147,430	
D - Tanks				10,756,506		1,366,660	
E - Exchangers				11,291,780	21,662,160	9,025,360	
G - Pumps and Drives				12,664,020	10,406,390	2,325,010	
K - Compressors and Drivers				92,300	19,360	337,950	
T - Special Equipment	2,671,050		513,420,000	31,641,402	15,404,070	54,467,900	2,121,560
J - Instrumentation				841,462	456,498		
L - Piping				4,170,970	2,545,650	11,639,382	
M - Structural Steel				1,461,180	157,080	210,630	
N - Insulation				7,876,460	3,296,310	862,674	
P - Electrical				4,371,827	931,029	10,722,693	
Q - Concrete Work				2,160,343	632,286	1,473,553	
S - Site Work		3,262,560		2,735,771	32,731	341,972	
X - Painting				27,597	7,840		
Subtotal	2,671,050	3,262,560	513,420,000	90,349,727	56,943,835	92,921,214	2,121,560
Sales Tax	0	10,027	0	4,594,502	3,229,077	5,649,268	148,000
Total Field Cost	2,671,050	3,272,587	513,420,000	94,944,229	60,172,911	98,570,481	2,269,560

Details of the system estimate are shown in Appendix 1. The labor, equipment, and material costs reflect fourth quarter 2005 prices.

The labor costs include both the direct and the distributable costs.

9. Observations

Annual Plant Availability

Multiple equipment items in the heat transport fluid system should improve the annual plant reliability. For example, maintenance could be conducted on one steam generator train during the winter. Although main steam production would be reduced by 50 percent, the availability of thermal storage should allow the daily energy output to remain nearly constant. However, multiple equipment items can have a detrimental effect on the plant availability. Although tanks, pumps, and heat exchangers are normally quite reliable, the supporting equipment, such as valve actuators, instruments, and sensors, can be problematic. As such, the additional support equipment brings additional failure modes.

The effect of multiple equipment items on the plant availability, although anticipated to be small, is not yet incorporated in the results of Section 5, Annual Energy Calculations.

Upper Limits on Plant Sizes

Therminol Heat Transport Fluid For plants with thermal storage, a capacity of 200 MWe is likely the upper limit for the most economic plant. The requirement for multiple equipment items in both the thermal storage and the heat transport fluid systems, together with Rankine cycle efficiencies approaching an asymptotic limit of about 38 percent, imply that larger plant sizes will not offer further reductions in the unit capital cost.

For plants without thermal storage, the largest economic plant size is probably 250 MWe. At this capacity, all of the economies of scale in the heat transport fluid system have been realized, and the Rankine cycle efficiency has likely reached its peak value.

Inorganic Heat Transport Fluids For this study, analyses were not conducted for designs based on inorganic heat transport fluids. However, the higher collector field outlet temperatures available with the inorganic fluids, together with the availability of direct, two-tank thermal storage systems, considerably reduces the volumes of fluids which must be circulated and stored. As such, the plant capacities at which equipment economies of scale are no longer available should be higher than the plants using Therminol. On a conceptual level, the upper limit on the plant capacities may be in the range of 250 to 300 MWe for plants with thermal storage, and perhaps 350 MWe for plants without storage.

Appendix 1
Details of 250 MWe Plant Total Field Cost Estimate

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 1)

				----- Unit Cost ------		Labor	MH	Total	------------------------------ $ ------------------------------			
Code	Description	Qty	Unit	Material	S/C	$ Rate	Rate	MH	Material	Labor	S/C	Total
0	**LAND**	1,336	AC		2,000						2,671,050	2,671,050
1	**STRUCTURES AND IMPROVEMENTS**											
1	SITE IMPROVEMENTS											
	Clear and Grub	1,048	AC		652						683,850	683,850
	Roads - Grading	25,600	SY		0.54						13,920	13,920
	Roads - 8 in. base	4,200	CY		13.05						54,790	54,790
	Roads - 3 in. asphalt	16,700	SY		6.52						108,930	108,930
	Roads - 6 ft. shoulders	7,200	SY		4.35						31,310	31,310
	Roads - Oil only	1,800	SY		0.54						980	980
	Railroad Spur	0	LF		81.54						0	0
	Site Fences	28,500	LF		13.05						371,810	371,810
	Evaporation Pond - Grading	49,300	SY		0.54						26,800	26,800
	Evaporation Pond - Excavation	10,500	CY		2.17						22,830	22,830
	Evaporation Pond - Clay Lining	36,400	CY		10.87						395,720	395,720
2	PIPING											
	Yard Piping - Excavation	15,000	CY		2.72						40,770	40,770
	Yard Piping - Back Fill	15,000	CY		5.44						81,540	81,540
	Domestic Water	1,300	LF			42.68	0.88	1,145	12,600	85,760		98,360
	Fire Protection	3,700	LF			42.68	0.88	3,256	53,800	243,870		297,670
	Primary Water Treatment	440	LF			42.68	1.56	687	13,100	51,460		64,560
	Raw Water	5,050	LF			42.68	0.57	2,882	49,000	215,860		264,860
	Sanitary Sewer and Drains	1,500	LF			42.68	0.55	825	7,000	61,790		68,790
3	MAINTENANCE / WAREHOUSE BUILDING	6,000	SF		54						326,140	326,140
4	CONTROL / ELECTRICAL / ADMINISTRATION BUILDING	4,000	SF		98						391,370	391,370
5	SECURITY / GATEHOUSE	150	SF		109						16,310	16,310
	Subtotal - Structures and Improvements								135,500	658,740	2,567,070	3,361,310
	Sales Tax								10,027			
1	TOTAL - STRUCTURES AND IMPROVEMENTS								145,527	658,740	2,567,070	3,371,337
2	**COLLECTOR SYSTEM**											
1	COLLECTOR SYSTEM - 1,990,000 m^2; COMPLETE INCLUDING FOUNDATIONS & FIELD WIRING	1,990,000	M^2		258						513,420,000	513,420,000

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 2)

Code	Description	Qty	Unit	----- Unit Cost ------ Material	S/C	Labor $ Rate	MH Rate	Total MH	---------- $ ---------- Material	Labor	S/C	Total
4	**THERMAL STORAGE SYSTEM**											
C	<u>COLUMNS AND VESSELS</u>											
1	Nitrogen Storage Vessel	3	EA	73,383		38.13	220	660	220,150	46,430		266,580
	Horizontal, cylindrical tank, ASTM A 516, Grade 70, carbon steel											
	14 ft diameter, 51 ft long, 35 psig design pressure											
	0.25 in. wall thickness, 27,000 lb vessel mass											
D	<u>TANKS</u>											
1	Cold Salt Storage Tank	3	EA		1,804,668						5,414,003	5,414,003
	Vertical cylindrical tank, self supporting roof, atmospheric pressure											
	102 ft diameter x 46 ft height, ASTM A 516, Grade 70, carbon steel											
	710,000 lb approximate weight											
2	Hot Salt Storage Tank	3	EA		1,924,254						5,772,763	5,772,763
	Vertical cylindrical tank, self supporting roof, atmospheric pressure											
	104 ft diameter x 46 ft height, ASTM A 516, Grade 70, carbon steel											
	750,000 lb approximate weight											
	Subtotal - Tanks										11,186,766	11,186,766
E	<u>HEAT EXCHANGERS</u>											
1	Oil-to-Salt Heat Exchangers	24	EA	460,951		38.13	385	9,240	11,062,830	650,030		11,712,860
	Straight shell, U-tube, 42,400 ft^2 heat transfer area each											
	Carbon steel shell, tubes, tubesheet, and channel											
	170,000 lb empty weight each, Cost from Heat Transfer Consultants											
2	Nitrogen-to-Air Heat Exchanger	1	EA	2,174		38.13	33	33	2,170	2,320		4,490
	Finned tube, forced draft heat exchanger											
	50 ft^2 bare tube area, 650 ft^2 finned tube area, 0.75 bhp electric fan											
	Subtotal - Heat Exchangers								11,065,000	652,350		11,717,350
G	<u>PUMPS AND DRIVERS</u>											
1	Cold Salt Pumps	3	EA	2,044,928		38.13	418	1,254	6,134,780	88,220		6,223,000
	Extended shaft turbine pump, 2 stages											
	14,000 gpm, 3705 lb_m/sec, 192 ft total developed head											
	1750 bhp motor variable speed drive											
2	Hot Salt Pumps	3	EA	2,044,928		38.13	418	1,254	6,134,780	88,220		6,223,000
	Extended shaft turbine pump, 2 stages											
	14,400 gpm, 3705 lb_m/sec, 200 ft total developed head											
	1750 bhp motor variable speed drive											

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 3)

Code	Description	Qty	Unit	Unit Cost Material	Unit Cost S/C	Labor $ Rate	MH Rate	Total MH	$ Material	$ Labor	$ S/C	$ Total
3	Spare Pump and Motor (without variable speed drive)	1	EA	717,519		38.13	0	0	717,520	0		717,520
	Extended shaft turbine pump, 2 stages											
	3705 lb_m/sec, 200 ft total developed head, 1750 bhp electric motor											
									-------------	---------		-------------
	Subtotal - Pumps and Drivers								12,987,080	176,440		13,163,520
K	<u>COMPRESSORS AND DRIVERS</u>											
1	Nitrogen Compressor	1	EA	54,357		38.13	569	569	54,360	40,030		94,390
	2 stage, positive displacement, with intercooler											
	132 actual ft^3/min outlet, 12 psia inlet / 50 psia outlet pressures											
	77,000 ft total developed head, 100 bhp motor variable speed drive											
T	<u>SPECIAL EQUIPMENT</u>											
1	Nitrate Salt Inventory	133,000,000	LB	0.22	0.027				28,918,170		3,614,771	32,532,941
	$0.20/lb for salt mixture, delivered											
	$0.025/lb for handling, melting, and loading the inventory											
2	Maintenance Crane	3	EA	105,562		38.13	262	785	316,690	55,220		371,910
	15 ton capacity, 10 ft span											
									-------------	---------	------------	-------------
	Subtotal - Special Equipment								29,234,860	55,220	3,614,771	32,904,851
J	<u>INSTRUMENTATION</u>											
1	Storage Tank Level Transmitters	6	EA	1,500		36.85	19.8	119	9,002	8,220		17,222
	Sitrans LC500 capacitance detectors											
2	Salt Pump Discharge Flow Meters	6	EA	19,862		36.85	26.4	158	119,173	10,910		130,083
	Venturi flow meters with Kaman KD-1911 impedance pressure transducers											
3	Salt Pump Discharge Pressure Transmitters	6	EA	8,991		36.85	26.4	158	53,944	10,910		64,854
	Kaman KD-1911 impedance transducers											
4	Inter-tank Ullage Line Pressure Transmitter	2	EA	8,991		36.85	26.4	53	17,981	3,660		21,641
	Kaman KD-1911 impedance transducer											
5	Nitrogen Storage Tank Pressure	1	EA	1,413		36.85	19.8	20	1,413	1,380		2,793
	Yokogawa EJA510A transmitter											
6	Nitrate Salt Pipe Temperatures	27	EA	721		36.85	25.3	683	19,461	47,170		66,631
	Type K thermocouple, located in carbon steel thermowell											
	Industrial protection head assembly											
	With A/D converter/transmitter											

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 4)

Code	Description	Qty	Unit	----- Unit Cost ------ Material	S/C	Labor $ Rate	MH Rate	Total MH	---- $ ---- Material	Labor	S/C	Total
7	Therminol Pipe Temperatures	27	EA	721		36.85	25.3	683	19,461	47,170		66,631
	Type K thermocouple, located in carbon steel thermowell											
	Industrial protection head assembly											
	With A/D converter/transmitter											
8	Storage Tank Inventory Temperatures	48	EA	656		36.85	25.3	1,214	31,466	83,850		115,316
	Type K thermocouple, Type 304 stainless steel braided sheath											
	Ceramic insulation, suitable for immersion; with transmitter											
	With A/D converter/transmitter											
9	Nitrogen Line Temperatures	2	EA	656		36.85	25.3	51	1,311	3,520		4,831
	Type K thermocouple, Type 304 stainless steel braided sheath											
	Ceramic insulation, with washer tab for pipe attachment											
	With A/D converter/transmitter											
10	I / P Transducers with Air Filter / Regulators	36	EA	646					23,248			23,248
11	Fiber Optic Data Highway											
	Fiber optic cable	1,000	FT	5.89		36.85	0.06	55	5,892	3,800		9,692
	Fiber optic cable terminations	12	EA	412		36.85	28	330	4,944	22,790		27,734
	1 in. rigid steel conduit	1,000	FT	1.69		36.85	0.23	234	1,685	16,180		17,865
12	Pneumatic Tubing	2,400	FT	0.38		36.85	0.055	132	913	9,120		10,033
13	Raceway for Pneumatic Tubing	600	FT	1.36		36.85	0.165	99	815	6,840		7,655
14	Instrument Air Subheader	2,000	FT	4.35		36.85	0.55	1,100	8,697	75,980		84,677
15	Thermocouple Low Energy Process Interface Unit	2	EA	21,634		36.85	44	88	43,269	6,080		49,349
16	Loop Check	300	EA			36.85	2.75	825		56,980		56,980
17	Calibration and Testing	210	EA			36.85	2.97	624		43,100		43,100
18	Operator Station (in control room, provided by others)	1	LT		36,477						36,477	36,477
	Subtotal - Instrumentation								362,677	457,660	36,477	856,814

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 5)

Code	Description	Qty	Unit	----- Unit Cost ------ Material	S/C	Labor $ Rate	MH Rate	Total MH	------ $ ------ Material	Labor	S/C	Total
L	<u>PIPING</u>											
1	Pipe and Fittings: Therminol and Nitrate Salt											
	48" Pipe - Carbon steel A106 Grade B, XS (Therminol hot header)	430	LF	438		42.68	3.20	1,376	188,530	103,060		291,590
	42" Pipe - Carbon steel A106 Grade B, Std wall (Therminol cold header)	400	LF	288		42.68	2.80	1,120	115,270	83,890		199,160
	24" Pipe - Carbon steel A106 Grade B, XS (Therminol to/from exchangers)	1,650	LF	217		42.68	2.08	3,432	357,910	257,060		614,970
	20" Pipe - Carbon steel A106 Grade B, XS (Nitrate salt)	900	LF	180		42.68	1.87	1,683	162,000	126,060		288,060
	3" Pipe - Carbon steel A106 Grade B, Sch 40 (Nitrate salt drain)	900	LF	13		42.68	0.70	630	11,790	47,190		58,980
	8" Pipe - Carbon steel A106 Grade B, Sch 20 (Tank ullage)	600	LF	39		42.68	1.12	672	23,190	50,330		73,520
	8" Pipe - Carbon steel A106 Grade B, Sch 20 (Foundation cooling)	9,000	LF	16		42.68	1.12	10,080	142,210	754,990		897,200
	2" Pipe - Carbon steel A106 Grade B, Sch 80 (Nitrogen recovery / supply)	900	LF	9		42.68	0.70	630	7,810	47,190		55,000
2	Pipe Welds											
	48" Pipe - Carbon steel A106 Grade B, XS (Therminol hot header)	54	EA			42.68	53.76	2,890		216,460		216,460
	42" Pipe - Carbon steel A106 Grade B, Std wall (Therminol cold header)	50	EA			42.68	16.00	800		59,920		59,920
	24" Pipe - Carbon steel A106 Grade B, XS (Therminol to/from exchangers)	206	EA			42.68	8.82	1,819		136,240		136,240
	20" Pipe - Carbon steel A106 Grade B, XS (Nitrate salt)	113	EA			42.68	7.49	843		63,140		63,140
	3" Pipe - Carbon steel A106 Grade B, Sch 40 (Nitrate salt drain)	180	EA			42.68	1.60	288		21,570		21,570
	8" Pipe - Carbon steel A106 Grade B, Sch 20 (Tank ullage)	60	EA			42.68	3.15	189		14,160		14,160
	8" Pipe - Carbon steel A106 Grade B, Sch 20 (Foundation cooling)	600	EA			42.68	3.15	1,890		141,560		141,560
	2" Pipe - Carbon steel A106 Grade B, Sch 80 (Nitrogen recovery / supply)	180	EA			42.68	1.60	288		21,570		21,570
3	Valves											
	20 in. gate, carbon steel, 150 lb class, motor operated, bellows seal (Salt isolation)	12	EA	6,692					80,310			80,310
	24 in. gate, carbon steel, 150 lb class, motor operated (Therminol isolation)	6	EA	9,850					59,100			59,100
	2 in. gate, carbon steel, 900 lb class, manual (Nitrogen isolation)	3	EA	1,123					3,370			3,370
	3 in. gate, carbon steel, 150 lb class, air operated, bellows seal (Salt vent / drain)	15	EA	446					6,690			6,690
	8 in. globe valve, carbon steel, 300 lb class, air operated (Therminol attemperation)	3	EA	3,729					11,190			11,190
	8 in. globe valve, carbon steel, 150 lb class, air operated (Therminol startup)	3	EA	3,271					9,810			9,810
	4 in. relief valve, carbon steel, 150 lb class (Tank pressure / vacuum)	6	EA	652					3,910			3,910
	2 in. relief valve, carbon steel, 150 lb class (Nitrogen storage vessel relief)	1	EA	652					650			650
	2 in. pressure regulating valve, carbon steel, 300 lb class (Nitrogen supply)	1	EA	1,200					1,200			1,200
4	Miscellaneous Piping Items and Operations											
	Hangers and supports (20% of installation manhours; $4/ft for material)	1	LT	59,120		42.68		5,726	59,120	428,880		488,000
	Waste allowance (10% of piping material)	1	LT	100,871					100,870			100,870
	Testing and inspection (7.5% of installation manhours)	1	LT			42.68		2,147		160,830		160,830
	Material handling (5% of installation manhours)	1	LT			42.68		1,432		107,220		107,220
	Freight (3% of material)	1	LT	35,548					35,550			35,550
	Subtotal - Piping								1,380,480	2,841,320		4,221,800

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 6)

Code	Description	Qty	Unit	----- Unit Cost ------ Material	S/C	Labor $ Rate	MH Rate	Total MH	---- $ ---- Material	Labor	S/C	Total
M	STRUCTURAL STEEL											
	Heavy steel (elevated platform)	372	T	1,468		38.32	11	4,089	545,570	288,440		834,010
	Light structural steel	57	T	1,957		38.32	44	2,526	112,360	178,180		290,540
	Deck plate	2,200	SF	38		38.32	1.43	3,146	84,190	221,920		306,110
	Stair tower	540	LF	67		38.32	0.64	345	36,100	24,340		60,440
									---------	---------		-----------
	Subtotal - Structural Steel								778,220	712,880		1,491,100
N	INSULATION											
1	Tanks											
	Cold tank - 12 in. calcium silicate and mineral wool	68,700	ESF	23		42.68	0.21	14,427	1,551,750	1,080,580		2,632,330
	Hot tank - 14 in. calcium silicate and mineral wool	70,600	ESF	24		42.68	0.21	14,826	1,701,370	1,110,470		2,811,840
2	Heat Exchangers	21,700	ESF	17		42.68	0.91	19,754	373,750	1,164,300		1,538,050
	8 in. calcium silicate block with aluminum jacket											
3	Piping: Stainless steel foil jacket; 25 mm mineral fiber blanket; calcium silicate block insulation; outer aluminum jacket											
	48" pipe, 6 in. thick, 1.1 fitting factor (Therminol hot header)	473	ELF	202		42.68	2.36	1,118	95,570	65,890		161,460
	42" Pipe, 4 in. thick, 1.1 fitting factor (Therminol cold header)	440	ELF	118		42.68	1.73	761	51,720	44,850		96,570
	24" Pipe, 6 in. thick, 1.1 fitting factor (Therminol to/from exchangers)	1,815	ELF	117		42.68	1.33	2,419	213,240	142,580		355,820
	20" Pipe, 6 in. thick, 1.1 fitting factor (Nitrate salt)	990	ELF	103		42.68	1.16	1,144	102,040	67,430		169,470
	3" Pipe, 4 in. thick, 1.5 fitting factor (Nitrate salt drain)	1,350	ELF	21		42.68	0.41	552	28,400	32,530		60,930
	8" Pipe, 4 in. thick, 1.1 fitting factor (Tank ullage)	660	ELF	34		42.68	0.56	369	22,440	21,750		44,190
	2" Pipe, 2 in. thick, 1.1 fitting factor (Nitrogen recovery / supply)	9,900	ELF	6		42.68	0.18	1,823	59,900	107,450		167,350
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	Subtotal - Insulation								4,200,180	3,837,830	0	8,038,010
P	ELECTRICAL											
1	Power Distribution											
	Substation transformer, 4000 / 5000 kVA, 4.16 kV - 480 V, OA / FA (480 V power to tank immersion heaters)	1	EA	81,536		29.42	363	363	81,536	22,380		103,916
	Substation transformer, 2500 / 3000 kVA, 4.16 kV - 480 V, AA / FA (480 V power to heat trace circuits and nitrogen compressor)	1	EA	54,357		29.42	363	363	54,357	22,380		76,737
	Heat trace power transformers, 50 kVA, 480 V - 50 V, AA	45	EA	2,718		29.42	28	1,238	122,304	76,280		198,584
	480 V motor control center	3	LT	98,278		29.42	286	858	294,835	52,890		347,725
	150 A combination starters for heat trace circuits	16	EA	Included in MCC price								
	400 A combination starters for cold tank immersion heaters	4	EA	Included in MCC price								
	400 A combination starters for hot tank immersion heaters	4	EA	Included in MCC price								
	Size 3 combination starters	4	EA	Included in MCC price								
	4.16 kV switchgear, 1500 A main breaker, 8 each current limiting fuses and contactors (6 salt pump contactors + 2 substation contactor)	1	LT	141,329		29.42	264	264	141,329	16,270		157,599
	480 V switchgear, 5000 A main breaker and transition section to MCC	1	LT	65,229		29.42	77	77	65,229	4,750		69,979
	480 V switchgear, 3000 A main breaker and transition section to MCC	1	LT	43,486		29.42	77	77	43,486	4,750		48,236
	480 V disconnect switches, 100 A	48	EA	506		29.42	6	264	24,265	16,270		40,535
	Distribution transformer, 45 kVA, 480 V - 240 V	3	EA	2,174		29.42	28	83	6,523	5,090		11,613

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 7)

				----- Unit Cost ------		Labor	MH	Total	----------------------------- $ -------------------------------			
Code	Description	Qty	Unit	Material	S/C	$ Rate	Rate	MH	Material	Labor	S/C	Total
	Heat trace power distribution panel	45	EA	2,718		29.42	33	1,485	122,304	91,540		213,844
	Lighting panel; 42 circuits	3	EA	1,712		29.42	33	99	5,137	6,100		11,237
	480 V disconnect switches, 30 A	3	EA	228		29.42	6	17	685	1,020		1,705
	Start / stop switches	30	EA	250		29.42	11	330	7,501	20,340		27,841
	Variable frequency drive (installation only)	7	EA	109		29.42	66	462	761	28,480		29,241
2	Storage Tank Immersion Heaters											
	Cold tank - 155 kW, 3 phase, 480 V, 190 A	12	EA	4,349		29.42	55	660	52,180	40,680		92,860
	Hot tank - 190 kW, 3 phase, 480 V, 230 A	12	EA	5,436		29.42	55	660	65,230	40,680		105,910
	Silicon controlled recitifier control packages	24	EA	217		29.42	22	528	5,218	32,550		37,768
3	Electric Heat Tracing											
	48" pipe, 14 active and 2 spare cables (Therminol hot header)	430	FT	80		29.42	0.18	76	34,197	4,660		38,857
	42" Pipe, 12 active and 2 spare cables (Therminol cold header)	400	FT	70		29.42	0.18	70	27,835	4,330		32,165
	24" Pipe, 6 active and 2 spare cables (Therminol to/from exchangers)	1,650	FT	40		29.42	0.18	290	65,610	17,880		83,490
	20" Pipe, 5 active and 2 spare cables (Nitrate salt)	900	FT	35		29.42	0.18	158	31,314	9,750		41,064
	3" Pipe, 1 active and 2 spare cables (Nitrate salt drain)	900	FT	15		29.42	0.18	158	13,420	9,750		23,170
	8" Pipe, 2 active and 2 spare cables (Tank ullage)	600	FT	20		29.42	0.18	105	11,929	6,500		18,429
	2" Pipe, 1 active and 1 spare cable (Nitrogen recovery / supply)	900	FT	10		29.42	0.18	158	8,947	9,750		18,697
	20 in. gate, 2 active and 2 spare cables, bellows seal (Salt isolation)	12	EA	261		29.42	22	264	3,131	16,270		19,401
	24 in. gate, 1 active and 1 spare cable (Therminol isolation)	6	EA	130		29.42	11	66	783	4,070		4,853
	2 in. gate, 0 cables (Nitrogen isolation)	3	EA	0		29.42	0	0	0	0		0
	3 in. gate, 2 active and 0 spare cables, bellows seal (Salt vent / drain)	15	EA	130		29.42	11	165	1,957	10,170		12,127
	8 in. globe valve, 1 active and 1 spare cable (Therminol attemperation)	3	EA	130		29.42	11	33	391	2,030		2,421
	8 in. globe valve, 1 active and 1 spare cable (Therminol startup)	3	EA	130		29.42	11	33	391	2,030		2,421
	4 in. relief valve, 1 active and 0 spare cables (Tank pressure / vacuum)	6	EA	65		29.42	6	33	391	2,030		2,421
	2 in. relief valve, 0 cables (Nitrogen storage vessel relief)	1	EA	0		29.42	0	0	0	0		0
	2 in. pressure regulating valve, 0 cables (Nitrogen supply)	1	EA	0		29.42	0	0	0	0		0
	Nitrate salt pump transition to top of salt tank	6	EA	652		29.42	22	132	3,914	8,140		12,054
	Heat exchangers; 28 active cables and 2 spare cables, each 45 ft. long	24	EA	6,751		29.42	44	1,056	162,029	65,090		227,119
	¾ in. rigid steel conduit	17,700	FT	2.05		29.42	0.20	3,549	36,312	218,750		255,062
	Electric power distribution cable, 6 gauge	123,900	FT	0.23		29.42	0.014	1,678	28,287	103,420		131,707
4	Lighting											
	Stanchions - 35 ft. poles	48	EA	1,383		29.42	15.8	759	66,377	46,780		113,157
	Pendant lights	30	EA	550		29.42	1.9	58	16,503	3,580		20,083
	Staircase lighting	15	EA	326		29.42	4.6	69	4,892	4,240		9,132
	Receptacles	6	EA	17		29.42	2.1	13	104	770		874
	Photocell	1	EA	130		29.42	1.8	2	130	110		240
	Lighting contactor	3	EA	478		29.42	9.2	28	1,435	1,700		3,135
	Junction boxes	3	EA	88		29.42	13.8	41	264	2,540		2,804
	Panelboards	3	EA	978		29.42	24.8	74	2,935	4,580		7,515
	¾ in. rigid steel conduit	11,000	FT	2.05		29.42	0.20	2,205	22,567	135,940		158,507
	2 conductor, 12 gauge wire	22,000	FT	0.15		29.42	0.0033	73	3,348	4,480		7,828
5	Welding Receptacle	3	EA	575		29.42	3	10	1,730	620		2,350

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 8)

				----- Unit Cost ------		Labor	MH	Total	---------- $ ----------			
Code	Description	Qty	Unit	Material	S/C	$ Rate	Rate	MH	Material	Labor	S/C	Total
6	Communication Stations											
	GAI-Tronics page/party station	6	EA	1,098		29.42	8.80	53	6,588	3,250		9,838
	Horn	6	EA	245		29.42	4.40	26	1,468	1,630		3,098
	U bracket for horn	6	EA	76					457			457
	5 party line cable	1,980	FT	2.99		29.42	0.08	157	5,920	9,670		15,590
	Single line cable	1,980	FT	0.54		29.42	0.03	61	1,076	3,760		4,836
	¾ in. rigid steel conduit	480	FT	2.05		29.42	0.20	96	985	5,930		6,915
7	Fire / Smoke Detectors											
	Emergency shutdown stations	6	EA	82		29.42	2.20	13	489	810		1,299
	Photoelectric smoke detectors	24	EA	163		29.42	2.20	53	3,914	3,250		7,164
	Thermal detectors	24	EA	163		29.42	2.20	53	3,914	3,250		7,164
	Strobe light and horn	6	EA	109		29.42	2.20	13	652	810		1,462
	Electric wire, 16 gauge	1,650	FT	0.15		29.42	0.010	16	251	1,010		1,261
	¾ in. rigid steel conduit	1,650	FT	2.05		29.42	0.20	331	3,385	20,390		23,775
	Terminal box	3	EA	435		29.42	5.50	17	1,305	1,020		2,325
8	Instrument Conduit											
	¾ in. rigid steel conduit	11,500	FT	2.05		29.42	0.20	2,306	23,592	142,120		165,712
	Terminations	460	EA	15.21		29.42	0.55	253	6,996	15,590		22,586
	Instrument wiring	13,800	FT	1.11		29.42	0.012	168	15,303	10,390		25,693
9	Cable Trays											
	12 in. power cable tray	1,440	FT	11		29.42	0.29	423	15,404	26,070		41,474
	12 in. instrument cable tray	1,980	FT	11		29.42	0.29	582	21,181	35,850		57,031
	24 in. 4.16 kV power cable tray	1,980	FT	12		29.42	0.41	821	23,743	50,610		74,353
	36 in. power cable tray	1,980	FT	16		29.42	0.57	1,128	31,987	69,540		101,527
	Tray covers	7,380	FT	Included		29.42	0.00	0	0	0		0
	Support columns	99	EA	326		29.42	33.0	3,267	32,288	201,380		233,668
	Support sleepers	72	EA	109		29.42	5.5	396	7,827	24,410		32,237
10	Wire and Cable											
	<u>4.16 kV</u>											
	3 conductor, 0000 gauge	4,500	FT	3.60		29.42	0.017	76	16,193	4,690		20,883
	Terminations	90	EA	1.75		29.42	0.130	12	158	720		878
	<u>480 V</u>											
	3 conductor, 12 gauge	13,860	FT	0.15		29.42	0.003	46	2,110	2,820		4,930
	3 conductor, 4 gauge	11,880	FT	0.34		29.42	0.006	74	4,004	4,560		8,564
	3 conductor, 0 gauge	30,600	FT	0.78		29.42	0.011	328	23,952	20,190		44,142
	3 conductor, 0000 gauge	19,200	FT	1.42		29.42	0.016	309	27,344	19,050		46,394
	Terminations	1,320	EA	1.16		29.42	0.099	131	1,535	8,060		9,595
	<u>Control and instrument</u>											
	7 conductor, 14 gauge	17,820	FT	1.59		29.42	0.015	274	28,285	16,920		45,205
	Twisted pair, 16 gauge	3,600	FT	1.11		29.42	0.012	44	3,992	2,710		6,702
	Twisted pair, 16 gauge, thermocouple	9,000	FT	1.11		29.42	0.012	110	9,980	6,770		16,750
	25 pair, 16 gauge	7,920	FT	7.89		29.42	0.052	410	62,510	25,290		87,800
	25 conductor, 14 gauge	5,400	FT	4.13		29.42	0.034	184	22,308	11,350		33,658
	Terminations	4,206	EA	15.21		29.42	0.550	2,313	63,970	142,590		206,560

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 9)

Code	Description	Qty	Unit	Unit Cost Material	Unit Cost S/C	Labor $ Rate	MH Rate	Total MH	$ Material	$ Labor	$ S/C	$ Total
	Termination boxes	12	EA	435		29.42	11.0	132	5,218	8,140		13,358
	Armored cable connections	150	EA	54		29.42	1.1	165	8,154	10,170		18,324
11	Cathodic Protection											
	Graphite anodes											
	Drilling	100	LF			29.42	0.89	89		5,490		5,490
	Anodes	10	EA	500		29.42	6.2	62	5,000	3,820		8,820
	Junction box	1	EA	819		29.42	7.1	7	820	440		1,260
	Rectifier	1	EA	6,255		29.42	154	154	6,260	9,490		15,750
	Test station	2	EA	76		29.42	1.83	4	150	230		380
	Reference cell	2	EA	54		29.42	4.58	9	110	570		680
	Electric cable, 3 conductor, armored, underground											
	6 gauge	300	FT	1.02		29.42	0.31	92	310	5,700		6,010
	8 gauge	240	FT	0.66		29.42	0.31	74	160	4,560		4,720
12	Grounding											
	Tanks and structural steel											
	1 conductor, 00 gauge, bare cable	4,650	FT	1.59		29.42	0.275	1,278	7,378	78,790		86,168
	Cadwelds	60	EA	11		29.42	1.26	75	650	4,650		5,300
	Grounding rods	30	EA	33		29.42	2.2	66	980	4,070		5,050
	Substation transformer											
	1 conductor, 00 gauge, bare cable	250	FT	1.59		29.42	0.275	69	397	4,240		4,637
	Cadwelds	24	EA	11		29.42	1.26	30	260	1,860		2,120
	Pipe rack											
	1 conductor, 00 gauge, bare cable	990	FT	1.59		29.42	0.275	272	1,571	16,790		18,361
	Cadwelds	108	EA	11		29.42	1.26	136	1,170	8,370		9,540
	Grounding rods	18	EA	33		29.42	2.2	40	590	2,440		3,030
	Mechanical equipment											
	Nitrate salt pumps	6	EA	11		29.42	1.10	7	70	410		480
	Motor operated valves	18	EA	11		29.42	1.10	20	200	1,220		1,420
	Heat exchangers	24	EA	11		29.42	1.10	26	260	1,630		1,890
	Nitrogen storage tank	1	EA	11		29.42	1.10	1	10	70		80
	Nitrogen cooler	1	EA	11		29.42	1.10	1	10	70		80
	Nitrogen compressor	1	EA	11		29.42	1.10	1	10	70		80
	1 conductor, 00 gauge, bare cable	440	FT	1.59		29.42	0.169	75	698	4,590		5,288
	1 conductor, 2 gauge, bare cable	530	FT	1.09		29.42	0.169	90	576	5,530		6,106
	Lighting protection for elevated platform	820	FT	3.26		29.42	0.169	139	2,674	8,560		11,234
13	Testing	1	LT	5,436		29.42	263	263	5,436	16,210		21,646
	Subtotal - Electrical								2,168,192	2,287,050		4,455,242

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 10)

				----- Unit Cost ------		Labor	MH	Total	----------------------------- $	-------------------------------		
Code	Description	Qty	Unit	Material	S/C	$ Rate	Rate	MH	Material	Labor	S/C	Total
====	===	====	===	=======	======	=====	=====	=====	=======	=======	========	========
Q	<u>CONCRETE WORK</u>											
1	Elevated Platforms											
	Formwork	8,130	SF	1.63		26.72	0.39	3,130	13,258	184,480		197,738
	Reinforcing steel	163	T	870		26.72	22	3,577	141,416	210,840		352,256
	Concrete	1,626	CY	92		26.72	1.65	2,683	150,285	158,130		308,415
	Embedded metals	8,130	LB	1.63		26.72	w/ forms		13,258			13,258
2	Tank Foundations											
	Formwork	4,034	SF	1.63		26.72	0.39	1,553	6,578	91,530		98,108
	Reinforcing steel	300	T	870		26.72	22	6,594	260,685	388,660		649,345
	Concrete	2,997	CY	92		26.72	1.65	4,946	277,032	291,490		568,522
	Embedded metals	3,747	LB	1.63		26.72	w/ forms		6,110			6,110
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	Subtotal - Concrete Work								868,621	1,325,130	0	2,193,751
S	<u>SITEWORK</u>											
	Excavation	6,451	CY			26.72	0.55	3,548		209,130		209,130
	Backfill and Compaction	4,301	CY	9		26.72	0.99	4,258	37,405	250,960		288,365
	Foamglas (tank foundation insulation)	79,603	CF	11		26.72	0.08	6,486	865,408	382,300		1,247,708
	Refractory brick, with mortar (tank perimeter foundation)	210,203	EA	1.6		26.72	0.06	11,561	342,784	681,410		1,024,194
	Sand (tank foundation)	167	CY	22		26.72	1.10	183	3,621	10,800		14,421
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	Subtotal - Sitework								1,249,217	1,534,600	0	2,783,817
X	<u>PAINTING</u>											
	Structural steel (allowance)	52,800	SF		0.54						28,701	28,701
									-------------	-----------	-----------	-------------
	Subtotal								64,569,038	13,966,940	14,866,715	93,402,693
	Sales Tax								4,778,109			4,778,109
									-------------	-----------	-----------	-------------
4	TOTAL - THERMAL STORAGE SYSTEM								69,347,147	13,966,940	14,866,715	98,180,802
5	**HEAT TRANSPORT FLUID SYSTEM**											
C	<u>COLUMNS AND VESSELS</u>											
1	Heat Transport Fluid Expansion Vessels Horizontal, cylindrical, 14 ft. diameter, 59 ft. long 0.52 in. shell and head thickness, 68,000 lb, carbon steel	8	EA	147,852		38.13	110	880	1,182,820	61,910		1,244,730
2	Nitrogen Ullage Gas Storage Vessel Horizontal, cylindrical, 12 ft. diameter, 60 ft. long 0.84 in. shell and head thickness, 85,000 lb, carbon steel	1	EA	184,815		38.13	220	220	184,820	15,480		200,300
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	Subtotal - Columns and Vessels								1,367,640	77,390	0	1,445,030

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 11)

Code	Description	Qty	Unit	Unit Cost Material	Unit Cost S/C	Labor $ Rate	MH Rate	Total MH	$ Material	$ Labor	$ S/C	$ Total
====	==	====	===	=======	======	=====	=====	=====	=======	=======	========	========
E	HEAT EXCHANGERS											
1	Steam Generator											
	U-tube / straight shell, 2 tube & 2 shell passes, carbon steel shell, tubes, and channel											
	- Preheater - Carbon steel shell and tubes, 21,600 ft^2 per shell	2	EA	281,789		38.13	297	594	564,000	41,790		605,790
	- Superheater - Carbon steel shell and tubes, 22,800 ft^2 per shell	2	EA	297,444		38.13	319	638	595,000	44,880		639,880
	- Reheater - Carbon steel shell and tubes, 29,650 ft^2 per shell	4	EA	386,808		38.13	407	1,628	1,547,000	114,530		1,661,530
	U-tube / straight shell, 2 tube & 1 shell passes, carbon steel shell, tubes, and channel											
	- Kettle Evaporator - Carbon steel shell and tubes, 38,000 ft^2 per shell	4	EA	991,480		38.13	528	2,112	3,966,000	148,580		4,114,580
2	Blowdown Heat Exchanger	1	EA						Included in T/G price			0
3	Heat Transport Fluid Heater	2	EA	3,859,380		38.13	53,130	106,260	7,719,000	7,475,380		15,194,380
	2 50-percent capacity; 1,190 million Btu/hr each; natural gas fired											
	550 F / 735 F Therminol inlet / outlet temperatures											
	Complete with air preheater, induced draft fans, and forced draft fans											
	Includes $3/kWe for NOx selective catalytic reduction system											
	and $1/kWe for CO oxidation catalyst system											
									-------------	-----------	--------	-------------
	Subtotal - Heat Exchangers								14,391,000	7,825,160	0	22,216,160
G	PUMPS AND DRIVERS											
1	Heat Transport Fluid Pumps - Horizontal, multi-stage	6	EA	1,720,957		38.13	935	5,610	10,325,740	394,660		10,720,400
	17,000 gpm, 715 ft tdh, 3500 bhp electric motor,											
	Variable speed drive, CS impeller and bowl											
2	Auxiliary Boiler Feedwater - Horizontal, multi-stage	1	EA	67,947		38.13	253	253	67,950	17,800		85,750
	250 gpm, 3000 ft tdh, 250 bhp electric motor,											
	Variable speed drive, CS impeller and bowl											
									------------	---------	---------	------------
	Subtotal - Pumps and Drivers								10,393,690	412,460	0	10,806,150
K	COMPRESSORS AND DRIVERS											
1	Expansion Vessel Nitrogen Ullage Gas Compressor	1	EA	6,523		38.13	186	186	6,520	13,090		19,610
	1300 lb_m/hr, 43,000 ft total developed head, 40 bhp											
	75 psia inlet / 175 psia outlet pressures, 28 actual ft^3/min discharge flow											
	2 stage with intercooler, variable speed drive											
T	SPECIAL EQUIPMENT											
1	Heat Transport Fluid	1,228,000	GAL	13					16,020,230			16,020,230
	Solutia Therminol VP-1, 0.614 gal /m^2 collector field area											

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 12)

Code	Description	Qty	Unit	Unit Cost Material	Unit Cost S/C	Labor $ Rate	MH Rate	Total MH	$ Material	$ Labor	$ S/C	$ Total
E	HEAT EXCHANGERS											
1	Storage Tank Level Transmitters Sitrans LC500 capacitance detectors	2	EA	1,500		36.85	19.8	40	3,001	2,760		5,761
2	Salt Pump Discharge Flow Meters Venturi flow meters with Kaman KD-1911 impedance pressure transducers	2	EA	8,991		36.85	26.4	53	17,981	3,660		21,641
3	Salt Pump Discharge Pressure Transmitters Kaman KD-1911 impedance transducers	2	EA	8,991		36.85	26.4	53	17,981	3,660		21,641
4	Inter-tank Ullage Line Pressure Transmitter Kaman KD-1911 impedance transducer	1	EA	8,991		36.85	26.4	26	8,991	1,800		10,791
5	Nitrogen Storage Tank Pressure Yokogawa EJA510A transmitter	1	EA	1,413		36.85	19.8	20	1,413	1,380		2,793
7	Therminol Pipe Temperatures Type K thermocouple, located in carbon steel thermowell Industrial protection head assembly With A/D converter/transmitter	7	EA	721		36.85	25.3	177	5,045	12,230		17,275
8	Storage Tank Inventory Temperatures Type K thermocouple, Type 304 stainless steel braided sheath Ceramic insulation, suitable for immersion With A/D converter/transmitter	16	EA	656		36.85	25.3	405	10,489	27,970		38,459
9	Nitrogen Line Temperatures Type K thermocouple, Type 304 stainless steel braided sheath Ceramic insulation, with washer tab for pipe attachment With A/D converter/transmitter	2	EA	656		36.85	25.3	51	1,311	3,520		4,831
10	Pneumatic Tubing	12,000	FT	0.38		36.85	0.055	660	4,566	45,590		50,156
11	Raceway for Pneumatic Tubing	1,500	FT	1.36		36.85	0.55	825	2,038	56,980		59,018
12	Instrument Air Subheader	1,200	FT	4.35		36.85	1.76	2,112	5,218	145,880		151,098
13	Loop Check	140	EA			36.85	2.75	385		26,590		26,590
14	Calibration and Testing	70	EA			36.85	2.97	208		14,370		14,370
15	Operator Station (in control room, provided by others)	1	LT		36,477						36,477	36,477
	Subtotal - Instrumentation								78,036	346,390	36,477	460,903

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 13)

				----- Unit Cost ------		Labor	MH	Total	------------------------------ $ ------------------------------			
Code	Description	Qty	Unit	Material	S/C	$ Rate	Rate	MH	Material	Labor	S/C	Total
L	<u>PIPING</u>											
1	Therminol Pipe and Fittings											
	60" Pipe - Carbon steel A106 Grade B, Std Wall (HTF pump headers)	500	LF	413		42.68	3.60	1,800	206,390	134,820		341,210
	24" Pipe - Carbon steel A106 Grade B, Std Wall (HTF pump inlet/outlet)	300	LF	136		42.68	1.87	561	40,760	42,020		82,780
	48" Pipe - Carbon steel A106 Grade B, Std Wall (To/From SGS)	120	LF	330		42.68	3.20	384	39,560	28,760		68,320
	42" Pipe - Carbon steel A106 Grade B, Std Wall (To/From SGS trains)	160	LF	288		42.68	2.80	448	46,110	33,560		79,670
	48" Pipe - Carbon steel A106 Grade B, Std Wall (To/From HTF heater)	200	LF	330		42.68	3.20	640	65,940	47,940		113,880
	34" Pipe - Carbon steel A106 Grade B, Std Wall (To/From each HTF heater)	200	LF	233		42.68	2.50	500	46,560	37,450		84,010
	34" Pipe - Carbon steel A106 Grade B, Std Wall (To/From SH/E/PH)	260	LF	233		42.68	2.50	650	60,520	48,680		109,200
	12" Pipe - Carbon steel A106 Grade B, Std Wall (To/From reheater trains)	160	LF	108		42.68	1.65	264	17,310	19,770		37,080
	8" Pipe - Carbon steel A106 Grade B, Std Wall (To/From reheaters)	300	LF	49		42.68	1.12	336	14,810	25,170		39,980
	6" Pipe - Carbon steel A106 Grade B, Sch 80 (Expansion vessel connection)	160	LF	33		42.68	0.86	138	5,250	10,340		15,590
	2" Pipe - Carbon steel A106 Grade B, Sch 80 (Vents and drains)	80	LF	9		42.68	0.70	56	690	4,190		4,880
2	Pipe Welds											
	60" Pipe - Carbon steel A106 Grade B, Std Wall (HTF pump headers)	63	EA			42.68	22.86	1,429		107,030		107,030
	24" Pipe - Carbon steel A106 Grade B, Std Wall (HTF pump inlet/outlet)	60	EA			42.68	8.82	529		39,620		39,620
	48" Pipe - Carbon steel A106 Grade B, Std Wall (To/From SGS)	15	EA			42.68	18.29	274		20,520		20,520
	42" Pipe - Carbon steel A106 Grade B, Std Wall (To/From SGS trains)	20	EA			42.68	16.00	320		23,970		23,970
	48" Pipe - Carbon steel A106 Grade B, Std Wall (To/From HTF heater)	25	EA			42.68	18.29	457		34,230		34,230
	34" Pipe - Carbon steel A106 Grade B, Std Wall (To/From each HTF heater)	25	EA			42.68	13.80	345		25,840		25,840
	34" Pipe - Carbon steel A106 Grade B, Std Wall (To/From SH/E/PH)	33	EA			42.68	13.80	449		33,630		33,630
	12" Pipe - Carbon steel A106 Grade B, Std Wall (To/From reheater trains)	20	EA			42.68	4.48	90		6,740		6,740
	8" Pipe - Carbon steel A106 Grade B, Std Wall (To/From reheaters)	38	EA			42.68	3.15	118		8,840		8,840
	6" Pipe - Carbon steel A106 Grade B, Sch 80 (Expansion vessel connection)	32	EA			42.68	2.40	77		5,770		5,770
	2" Pipe - Carbon steel A106 Grade B, Sch 80 (Vents and drains)	17	EA			42.68	1.60	27		2,020		2,020
3	Valves											
	60 in. Gate, CS, 300 lb class, Air operated	1	EA	138,714					138,710			138,710
	48 in. Gate, CS, 300 lb class, Air operated	2	EA	83,296					166,590			166,590
	42 in. Gate, CS, 300 lb class, Air operated	3	EA	61,645					184,930			184,930
	34 in. Gate, CS, 300 lb class, Air operated	4	EA	43,417					173,670			173,670
	8 in. Globe, CS, 300 lb class, Air operated	4	EA	3,729					14,920			14,920
	24 in. Gate, CS, 300 lb class, Air operated	12	EA	17,268					207,220			207,220
	24 in. Check, CS, 300 lb class	6	EA	17,991					107,950			107,950
	8 in. Gate, CS, 150 lb class, Manual	8	EA	966					7,730			7,730
4	Miscelleneous Piping and Operations											
	Hangers and supports (20% of installation manhours; $4/ft for material)	1	LT	9,760		42.68	1978	1,978	9,760	148,150		157,910
	Waste allowance (10% of piping material)	1	LT	54,390					54,390			54,390
	Testing and inspection (7.5% of installation manhours)	1	LT			42.68	742	742		55,580		55,580
	Material handling (5% of installation manhours)	1	LT			42.68	495	495		37,080		37,080
	Freight (3% of material)	1	LT	16,317					16,320			16,320
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	Subtotal - Piping								1,626,090	981,720	0	2,607,810

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 14)

Code	Description	Qty	Unit	Unit Cost Material	Unit Cost S/C	Labor $ Rate	MH Rate	Total MH	$ Material	$ Labor	$ S/C	$ Total
M	STRUCTURAL STEEL											
	Heavy steel	25.0	T	1,468		26.72	10	250	36,690	14,730		51,420
	Light structural steel	16.0	T	1,957		26.72	40	640	31,310	37,720		69,030
	Deck plate	5.0	T	1,087		26.72	20	100	5,440	5,890		11,330
	Stair tower	5.0	T	3,397		26.72	40	200	16,990	11,790		28,780
	Subtotal - Structural Steel								90,430	70,130		160,560
N	INSULATION											
1	Expansion Vessels											
	6 in. calcium silicate, aluminum jacket, 1.2 fitting factor	27,900	ESF	13		42.68	0.81	22,501	373,060	1,685,320		2,058,380
2	Steam Generator Heat Exchangers											
	8 in. calcium silicate, aluminum jacket, 1.2 fitting factor	7,600	ESF	17		42.68	0.91	6,918	130,900	518,160		649,060
3	Pipe: Calcium silicate with aluminum jacket											
	- 60" x 6" thick, 1.2 fitting factor	600	ELF	244		42.68	2.76	1,657	146,180	124,110		270,290
	- 24" x 4" thick, 1.2 fitting factor	360	ELF	74		42.68	1.10	395	26,700	29,590		56,290
	- 48" x 6" thick, 1.2 fitting factor	144	ELF	202		42.68	2.36	340	29,100	25,470		54,570
	- 42" x 6" thick, 1.2 fitting factor	192	ELF	181		42.68	2.13	408	34,780	30,560		65,340
	- 34" x 6" thick, 1.2 fitting factor	312	ELF	153		42.68	1.78	556	47,760	41,640		89,400
	- 12" x 6" thick, 1.2 fitting factor	192	ELF	74		42.68	0.82	157	14,180	11,760		25,940
	- 8" x 6" thick, 1.2 fitting factor	360	ELF	59		42.68	0.66	236	21,250	17,680		38,930
	- 6" x 4" thick, 1.4 fitting factor	224	ELF	29		42.68	0.50	112	6,460	8,390		14,850
	- 2" x 4" thick, 1.4 fitting factor	112	ELF	18		42.68	0.38	43	2,060	3,220		5,280
	Subtotal - Insulation								832,430	2,495,900	0	3,328,330
P	ELECTRICAL											
1	Power Distribution											
	Distribution transformer, 200 / 300 kVA, 4.16 kV - 480 V, AA / FA (3Φ power to nitrogen compressor and startup feedwater pump)	1	EA	30,440		29.42	28	28	30,440	1,700		32,140
	480 V motor control center	3	LT	5,436		29.42	88	264	16,307	16,270		32,577
	Size 1 combination starters	3	EA	1,631					4,892			4,892
	Size 3 combination starters	1	EA	2,609					2,609			2,609
	4.16 kV switchgear, 2500 A main breaker, 7 each current limiting fuses and contactors (6 HTF circulation pump contactors + 1 substation contactor)	1	LT	141,329		29.42	264	264	141,329	16,270		157,599
	480 V switchgear, 300 A main breaker and transition section to MCC	1	LT	3,261		29.42	44	44	3,261	2,710		5,971
	480 V disconnect switches, 100 A	3	EA	506		29.42	6	17	1,517	1,020		2,537
	Lighting panel; 42 circuits	1	EA	1,712		29.42	33	33	1,712	2,030		3,742
	480 V disconnect switches, 30 A	3	EA	228		29.42	6	17	685	1,020		1,705
	Start / stop switches	12	EA	250		29.42	11	132	3,001	8,140		11,141
	Variable frequency drive (installation only)	6	EA	109		29.42	66	396	652	24,410		25,062

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 15)

				----- Unit Cost ------		Labor	MH	Total	------------------------------ $	------------------------------		
Code	Description	Qty	Unit	Material	S/C	$ Rate	Rate	MH	Material	Labor	S/C	Total
2	Lighting											
	Stanchions	16	EA	326		29.42	5.5	88	5,218	5,420		10,638
	Pendant lights	10	EA	326		29.42	5.5	55	3,261	3,390		6,651
	Staircase lighting	5	EA	326		29.42	5.5	28	1,631	1,700		3,331
	Photocell	1	EA	130		29.42	2.2	2	130	140		270
	Lighting contactor	1	EA	478		29.42	11.0	11	478	680		1,158
	Receptacles	6	EA	54		29.42	2.2	13	326	810		1,136
	1 in. rigid steel conduit	1,125	FT	2.16		29.42	0.22	247	2,429	15,200		17,629
	1 1/2 in. rigid steel conduit	210	FT	2.97		29.42	0.26	54	624	3,360		3,984
	2 conductor, 12 gauge wire	7,170	FT	0.15		29.42	0.010	71	1,091	4,380		5,471
3	Welding Receptacle	1	EA	294		29.42	11	11	290	680		970
4	Communication Stations											
	GAI-Tronics page/party station	2	EA	1,098		29.42	8.80	18	2,196	1,080		3,276
	Horn	2	EA	245		29.42	4.40	9	489	540		1,029
	U bracket for horn	2	EA	76					152			152
	5 party line cable	660	FT	2.99		29.42	0.08	52	1,973	3,220		5,193
	Single line cable	660	FT	0.54		29.42	0.03	20	359	1,250		1,609
	1 in. rigid steel conduit	160	FT	2.16		29.42	0.22	35	345	2,160		2,505
5	Fire / Smoke Detectors											
	Emergency shutdown stations	2	EA	82		29.42	2.20	4	163	270		433
	Photoelectric smoke detectors	8	EA	163		29.42	2.20	18	1,305	1,080		2,385
	Thermal detectors	8	EA	163		29.42	2.20	18	1,305	1,080		2,385
	Strobe light and horn	2	EA	109		29.42	2.20	4	217	270		487
	Electric wire, 16 gauge	550	FT	0.15		29.42	0.010	5	84	340		424
	1 in. rigid steel conduit	840	FT	2.16		29.42	0.22	184	1,814	11,350		13,164
	Terminal box	1	EA	435		29.42	5.50	6	435	340		775
6	Instrument Conduit											
	1 3/4 in. rigid steel conduit	3,500	FT	2.97		29.42	0.26	908	10,408	55,960		66,368
	2 1/2 in. flexible connections to instruments	70	EA	22		29.42	2.20	154	1,522	9,490		11,012
7	Cable Trays											
	12 in. power cable tray	600	FT	11		29.42	0.29	176	6,419	10,860		17,279
	12 in. instrument cable tray	800	FT	11		29.42	0.29	235	8,558	14,480		23,038
	24 in. 4.16 kV power cable tray	660	FT	12		29.42	0.41	274	7,914	16,870		24,784
	36 in. power cable tray	660	FT	16		29.42	0.57	376	10,662	23,180		33,842
	Tray covers	2,460	FT	Included		29.42	0.00	0	0	0		0
	Support columns	33	EA	300		29.42	33.0	1,089	9,900	67,130		77,030
	Support sleepers	24	EA	100		29.42	5.5	132	2,400	8,140		10,540

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 16)

				----- Unit Cost ------		Labor	MH	Total	---------- $ ----------			
Code	Description	Qty	Unit	Material	S/C	$ Rate	Rate	MH	Material	Labor	S/C	Total
8	Wire and Cable											
	4.16 kV											
	3 conductor, 0000 gauge	4,500	FT	3.60		29.42	0.017	76	16,193	4,690		20,883
	Terminations	70	EA	1.75		29.42	0.130	9	123	560		683
	480 V											
	3 conductor, 6 gauge	7,200	FT	0.29		29.42	0.005	36	2,113	2,250		4,363
	Terminations	120	EA	1.16		29.42	0.083	10	140	610		750
	Control and instrument											
	7 conductor, 14 gauge	5,940	FT	1.59		29.42	0.015	91	9,428	5,640		15,068
	Twisted pair, 16 gauge	1,200	FT	1.11		29.42	0.012	15	1,331	900		2,231
	Twisted pair, 16 gauge, thermocouple	5,000	FT	1.11		29.42	0.012	61	5,544	3,760		9,304
	25 pair, 16 gauge	2,640	FT	7.89		29.42	0.052	137	20,837	8,430		29,267
	25 conductor, 14 gauge	2,200	FT	4.13		29.42	0.034	75	9,089	4,620		13,709
	Terminations	1,600	EA	17.97		29.42	0.715	1,144	28,753	70,520		99,273
	Termination boxes	8	EA	435		29.42	11.0	88	3,479	5,420		8,899
	Armored cable connections	150	EA	54		29.42	1.1	165	8,154	10,170		18,324
9	Cathodic Protection											
	Graphite anodes	2	EA	951		29.42	8.25	17	1,900	1,020		2,920
	Rectifier	2	EA	973		29.42	6.60	13	1,950	810		2,760
	Test station	2	EA	76		29.42	2.20	4	150	270		420
	Reference cell	2	EA	54		29.42	5.50	11	110	680		790
	Electric cable	300	FT	0.87		29.42	0.17	51	260	3,150		3,410
10	Grounding											
	Vessels and structural steel											
	1 conductor, 00 gauge, bare cable	1,550	FT	1.59		29.42	0.275	426	2,459	26,260		28,719
	Cadwelds	20	EA	11		29.42	1.26	25	220	1,550		1,770
	Grounding rods	10	EA	33		29.42	2.2	22	330	1,360		1,690
	Switchgear											
	1 conductor, 00 gauge, bare cable	125	FT	1.59		29.42	0.275	34	198	2,120		2,318
	Cadwelds	12	EA	11		29.42	1.26	15	130	930		1,060
	Pipe racks											
	1 conductor, 00 gauge, bare cable	330	FT	1.59		29.42	0.275	91	524	5,600		6,124
	Cadwelds	36	EA	11		29.42	1.26	45	390	2,790		3,180
	Grounding rods	6	EA	33		29.42	2.2	13	200	810		1,010
	Mechanical equipment											
	Heat transport fluid pumps	6	EA	11		29.42	1.10	7	70	410		480
	Heat transport fluid heaters	4	EA	11		29.42	1.10	4	40	270		310
	Motor operated valves	2	EA	11		29.42	1.10	2	20	140		160
	Heat exchangers	1	EA	11		29.42	1.10	1	10	70		80
	Nitrogen storage vessel	1	EA	11		29.42	1.10	1	10	70		80
	Nitrogen cooler	1	EA	11		29.42	1.10	1	10	70		80
	Nitrogen compressor	1	EA	11		29.42	1.10	1	10	70		80
	1 conductor, 00 gauge, bare cable	600	FT	1.59		29.42	0.169	102	952	6,270		7,222
	1 conductor, 2 gauge, bare cable	730	FT	1.09		29.42	0.169	124	794	7,620		8,414

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 17)

Code	Description	Qty	Unit	----- Unit Cost ------ Material	S/C	Labor $ Rate	MH Rate	Total MH	------ $ ------ Material	Labor	S/C	Total
11	Testing	1	LT	5,436		29.42	263	263	5,436	16,210		21,646
	Subtotal - Electrical								411,862	534,540		946,402
Q	<u>CONCRETE WORK</u>											
1	Steam Generator Heat Exchangers											
	Concrete	193	CY	82		26.72	1.65	318	15,710	18,740		34,450
	Forms	2,891	SF	1.63		26.72	0.39	1,113	4,710	65,600		70,310
	Reinforcing Steel	14	T	870		26.72	22	318	12,570	18,740		31,310
	Embedded Metal	964	LB	1.63		26.72	w/ forms		1,571			1,571
2	Heat Transport Fluid Expansion Vessels											
	Concrete	114	CY	82		26.72	1.65	188	9,280	11,080		20,360
	Forms	1,707	SF	1.63		26.72	0.39	657	2,780	38,720		41,500
	Reinforcing Steel	9	T	870		26.72	22	188	7,422	11,060		18,482
	Embedded Metal	569	LB	1.63		26.72	w/ forms		928			928
2	Heat Transport Fluid Heaters											
	Concrete	556	CY	82		26.72	1.65	917	45,300	54,050		99,350
	Forms	8,333	SF	1.63		26.72	0.39	3,208	13,590	189,080		202,670
	Reinforcing Steel	42	T	870		26.72	22	917	36,238	54,030		90,268
	Embedded Metal	2,778	LB	1.63		26.72	w/ forms		4,530			4,530
4	Heat Transport Fluid Pumps											
	Concrete	67	CY	82		26.72	1.10	73	5,440	4,300		9,740
	Forms	333	SF	1.63		26.72	0.35	117	540	6,900		7,440
	Reinforcing Steel	5	T		761						3,810	3,810
	Embedded Metal	333	LB	1.63		26.72	0.07	23	540	1,360		1,900
	Subtotal - Concrete Work								161,149	473,660	3,810	638,619
S	<u>SITEWORK</u>											
	Excavation	498	CY			26.72	0.55	274		16,130		16,130
	Backfill	249	CY	9		26.72	0.99	246	2,164	14,520		16,684
	Subtotal - Sitework								2,164	30,650	0	32,814
X	<u>PAINTING</u>											
	Structural steel (allowance)	15,000	SF		0.54						8,154	8,154
	Subtotal - Heat Transport Fluid System								45,381,241	13,261,090	48,441	58,690,772
	Sales Tax								3,358,212			3,358,212
5	TOTAL - HEAT TRANSPORT FLUID SYSTEM								48,739,453	13,261,090	48,441	62,048,984

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 18)

				Unit Cost		Labor	MH	Total	$			
Code	Description	Qty	Unit	Material	S/C	$ Rate	MH Rate	MH	Material	Labor	S/C	Total
6	**ELECTRIC POWER GENERATION SYSTEM**											
C	COLUMNS AND VESSELS											
1	Instrument Air Filters - Replaceable cartridge, 150 psig design pressure 5 micron filter, 33 scfm	2	EA	2,990		26.72	22	44	5,980	3,100		9,080
2	Compressed Air Receivers - Vertical, cylindrical, carbon steel with dished heads, 4 ft. diameter x 15' 6" tall, 200 ft^3 capacity	2	EA	10,871		26.72	66	132	21,740	9,290		31,030
3	Air Dryer - Dual tower desiccant dryer with automatic regeneration controls 200 scfm, 110 psig	1	LT	8,697		26.72	88	88	8,700	6,190		14,890
4	Liquid N_2 Storage - 1000 gallons, 400 psig, includes 300 scfm vaporizer	1	EA	10,871		26.72	88	88	10,870	6,190		17,060
5	Open Deaerating Feedwater Heater Tray and spray type, with external vent, 150 psig design pressure 12 ft. diameter x 19 ft. long, carbon steel, 0.800 in. wall, 31,000 lb	1	EA	67,403		26.72	176	176	67,400	12,380		79,780
	Subtotal - Columns and Vessels								114,690	37,150	0	151,840
D	TANKS											
1	Fuel Oil Storage - 5000 gallon, horizontal, double walled fiberglass, underground	1	EA	20,656		26.72	66	66	20,660	4,640		25,300
2	Diesel Generator Day - 200 gallon, horizontal, carbon steel Above ground with concrete catch basin	1	EA	13,046		26.72	22	22	13,050	1,550		14,600
3	Lubricating Oil Conditioner - centrifugal oil purifier, 7.5 bhp drive, 480 V Includes two 36 kW oil heaters	1	EA	65,773		26.72	176	176	65,770	12,380		78,150
4	Demineralizer - 100 gpm, skid mounted, dual string with cation, ion, and mixed bed ion exchangers, degas tower, includes piping, valves, and regeneration control, 1 bhp air blower and 25 bhp pumps	1	LT	761,004		26.72	2,200	2,200	761,000	154,770		915,770
5	Hyprochlorinator - 120 gallon / 60 gallon per day, panel mounted feeder with water powered metering pump, plastic tank, water analyzer, and controls	1	EA	5,979		26.72	176	176	5,980	12,380		18,360
6	Lime Grit Hopper - 12 ft^3, 20 in. diameter x 3 ft high, flat bottom, open top Carbon steel with outlet side gate valve	1	EA	2,718		26.72	26	26	2,720	1,830		4,550
7	Sand Filters - 35 ft^3, vertical flow with plastic internals, 100 gpm flow rate	2	EA	1,848		26.72	22	44	3,700	3,100		6,800
8	Soda Ash Mixing - 100 gallons, 30 in. diameter x 48 in. high, plastic Wing top with gauge glass and level switches	1	EA	544		26.72	22	22	540	1,550		2,090
9	Liquid Coagulant Mixing - 100 gallons, 30 in. diameter x 48 in. high, plastic Floating lip with gauge glass and level switches	1	EA	544		26.72	22	22	540	1,550		2,090

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 19)

Code	Description	Qty	Unit	----- Unit Cost ------ Material	S/C	Labor $ Rate	MH Rate	Total MH	--- $ --- Material	Labor	S/C	Total
10	Chemical Feed - 300 gallon, 48 in. diameter x 4 ft 6 in. high, 304 stainless steel with gauge glass and level switches, 2 with floating lid, 1 with wing lid	3	EA	14,350		26.72	26	79	43,050	5,560		48,610
11	Sodium Phosphate Dissolving Funnel - 100 gallon, 30 in. diameter x 4 ft high 304 stainless steel, 'V' bottom with outlet strainer	1	EA	2,392		26.72	22	22	2,390	1,550		3,940
12	Lime Soda Softener - 28,500 gallons, cone bottom, open top Carbon steel with plastic lining and internals, 18 ft. diameter x 16 ft. high	1	EA	81,536		26.72	132	132	81,540	9,290		90,830
13	Service Water Storage - 10,000 gallons, cone roof, fiberglass 12 ft. diameter x 13 ft. high	1	EA	19,569		26.72	70	70	19,570	4,920		24,490
14	Sludge Thickener - 3,000 gallons, cone bottom, open top Carbon steel with plastic lining and internals, 7 ft. 6 in. diameter x 10 ft. high	1	EA	16,307		26.72	194	194	16,310	13,650		29,960
15	Supernatant Storage - 400 gallon nominal capacity, vertical with cone roof 4 ft. diameter x 6 ft. high	1	EA	2,174		26.72	26	26	2,170	1,830		4,000
16	Sulfuric Acid Storage - 6,000 gallons, horizontal cylindrical, carbon steel 7 ft. diameter x 21 ft long	1	EA	15,546		26.72	66	66	15,550	4,640		20,190
17	Potable Water Storage - 1,000 gallon, horizontal cylindrical, carbon steel 4 ft. diameter x 12 ft 6 in. long, 150 psi design pressure	1	EA	7,719		26.72	66	66	7,720	4,640		12,360
18	Liquid Coagulant Storage - 350 gallons, horizontal cylindrical, carbon steel 42 in. diameter x 72 in. long	1	EA	1,087		26.72	26	26	1,090	1,830		2,920
19	Caustic Soda Storage - 3,500 gallons, horizontal cylindrical, carbon steel 5 ft. diameter x 23 ft. 6 in. long, 8 kWe 480 V immersion heater	1	EA	13,263		26.72	88	88	13,260	6,190		19,450
20	Soda Ash Storage Bin - 10,000 lb capacity, vertical cylindrical, cone top and hopper bottom, bottom discharge duct, slide gate valve Carbon steel, 5 ft. diameter x 10 ft. high, 8 ft ground clearance	1	EA		43,486						43,490	43,490
21	Quick Lime Storage Bin - 9,600 lb capacity, vertical cylindrical, cone top and hopper bottom, bottom discharge duct, slide gate valve Carbon steel, 5 ft. diameter x 10 ft. high, 8 ft ground clearance	1	EA		43,486						43,490	43,490
	Subtotal - Tanks								1,076,610	247,850	86,980	1,411,440
E	<u>HEAT EXCHANGERS</u>											
1	Feedwater Heaters - Horizontal, closed, integral desuperheater and drain cooler											
	Low pressure 1 - 8,309 ft^2	1	EA	135,497		38.13	110	110	135,500	7,740		143,240
	Low pressure 2 - 11,754 ft^2	1	EA	191,675		38.13	165	165	191,680	11,610		203,290
	Low pressure 3 - 12,264 ft^2	1	EA	199,992		38.13	165	165	199,990	11,610		211,600
	High pressure 1 - 12,691 ft^2	1	EA	344,925		38.13	176	176	344,930	12,380		357,310
	High pressure 2 - 21,476 ft^2	1	EA	583,690		38.13	297	297	583,690	20,890		604,580

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 20)

Code	Description	Qty	Unit	----- Unit Cost ------ Material	S/C	Labor $ Rate	MH Rate	Total MH	----- $ ----- Material	Labor	S/C	Total
2	Main Condenser - 2,000,000 lb/hr inlet steam, 2.5 in. HgA 222,000 gpm circulating water flow rate, 141,200 ft² heat transfer area	1	EA	3,377,120		38.13	968	968	3,377,120	68,100		3,445,220
3	Cooling Towers - Wet, mechanical draft, 135,000 gpm circ water flow rate Circulating water: 101 F to 80 F @ 104 F dry bulb / 68 F wet bulb 9 cells, 300 kWe 2 speed fan in each cell	9	EA	470,011		38.13	264	2,376	4,230,090	167,150		4,397,240
4	Gland Steam Condenser - Straight tube heat exchanger Steam on shell side, water on tube side, 2500 lb/hr steam at 3.0 psia 400 ft² surface area, carbon steel shell, stainless steel tubes	1	EA	8,697		38.13	44	44	8,700	3,100		11,800
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	Subtotal - Heat Exchangers								9,071,700	302,580	0	9,374,280
G	<u>PUMPS AND DRIVERS</u>											
1	Condensate - 2 x 100 %, 4025 gpm, 335 ft tdh, 114 °F, 450 bhp motor, 4.16 kV 1750 rpm, multi-stage vertical turbine, mounted in below-grade cans	2	EA	92,408		26.72	253	506	184,820	35,600		220,420
2	Feedwater - 2 x 100 %, 5285 gpm, 3590 ft tdh, 312 °F, 5500 bhp 4.16 kV motor, 1750 rpm, multi-stage horizontal turbine	2	EA	489,217		26.72	1155	2,310	978,430	162,510		1,140,940
3	Component Cooling Water - 2 x 100 %, 18300 gpm, 225 ft tdh, 1250 bhp, 4.16 kV Double suction, single state, horizontal split case, centrifugal Cast iron case and impeller	2	EA	59,793		26.72	418	836	119,590	58,810		178,400
4	Sludge Transfer - 2 x 100 %, 70 gpm, 20 ft tdh, 5 bhp motor, 480 V, 1100 rpm Centrifugal, vertical, split, rubber-lined, cast iron case, V belt drive, TEFC motor	2	EA	2,174		26.72	28	55	4,350	3,870		8,220
5	Sludge Disposal - 2 x 100 %, 25 gpm, 100 ft tdh, 7.5 bhp, 480 V motor Centrifugal, vertical, split, rubber-lined, cast iron case, V belt drive, TEFC motor	2	EA	3,261		26.72	28	55	6,520	3,870		10,390
6	Blowdown Makeup - 2 x 100 %, 18 gpm, 3600 ft tdh, 25 bhp, 480 V motor Positive displacement, variable speed drive	2	EA	3,805		26.72	83	165	7,610	11,610		19,220
7	Service Water - 2 x 100 %, 250 gpm, 350 ft tdh, 30 bhp, 480 V motor Double suction, single stage, horizontal split case centrifugal Cast iron case with 316 stainless steel shaft and impeller	2	EA	8,969		26.72	83	165	17,940	11,610		29,550
8	Circulating Water - 2 x 50 %, 110,000 gpm, 70 ft tdh, 2400 bhp motor 4.16 kV, 870 rpm, multi-stage vertical turbine, can type	2	EA	201,123		26.72	715	1,430	402,250	100,600		502,850
9	Turbine Oil Pit Sump - 25 gpm, 50 ft tdh, 3/4 bhp, 480 V, 1750 rpm Positive displacement, with level switch	2	EA	4,783		26.72	28	55	9,570	3,870		13,440
10	Oily Waste Sump - 100 gpm, 50 ft tdh, 2 bhp, 480 V, 1750 rpm Positive displacement, with level switch	2	EA	10,871		26.72	28	55	21,740	3,870		25,610

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 21)

Code	Description	Qty	Unit	Unit Cost Material	Unit Cost S/C	Labor $ Rate	MH Rate	Total MH	$ Material	$ Labor	$ S/C	$ Total
11	Fire Water - 1000 gpm, 300 ft tdh, 125 bhp motor, 480 V Single stage centrifugal, NFPA access and control panel	2	EA	35,876		26.72	253	506	71,750	35,600		107,350
12	Fire Water Pressure Maintenance - 20 gpm, 300 ft tdh, 5 bhp motor, 480 V Single stage centrifugal	1	EA	2,392		26.72	28	28	2,390	1,970		4,360
13	Supernatant Transfer - 5 gpm, 50 ft tdh, fractional hp, 480 V Single stage, vertical split case, cast iron case and impeller	2	EA	1,196		26.72	28	55	2,390	3,870		6,260
14	Soda Ash Injection - 1 gpm, 30 ft tdh, 0.1 bhp, 480 V	2	EA	598		26.72	28	55	1,200	3,870		5,070
15	Lime Injection - 1 gpm, 30 ft tdh, 0.1 bhp, 480 V	2	EA	598		26.72	28	55	1,200	3,870		5,070
16	Coagulant Transfer - 2 gpm, 30 ft tdh, 0.1 bhp, 480 V	2	EA	1,196		26.72	28	55	2,390	3,870		6,260
17	Acid Injection - 0 to 50 gpm, 60 psi, 1/2 bhp, 120 V Positive displacement, 316 stainless steel	2	EA	4,783		26.72	28	55	9,570	3,870		13,440
18	Coagulant Aid Charging - 0 to 5 gpm, 30 psi, fractional bhp, 120 V Positive displacement, 316 stainless steel	2	EA	4,783		26.72	28	55	9,570	3,870		13,440
19	Caustic Feed - 0 to 50 gpm, 60 psi, 3/4 bhp, 120 V Positive displacement, 316 stainless steel	2	EA	4,783		26.72	28	55	9,570	3,870		13,440
20	Ammonia Solution Feed - 0 to 10 gpm, 250 psi, 3/4 bhp, 120 V Positive displacement, 316 stainless steel	2	EA	5,979		26.72	28	55	11,960	3,870		15,830
21	Hydrazine Feed - 0 to 10 gpm, 250 psi, 3/4 bhp, 120 V Positive displacement, 316 stainless steel	2	EA	5,979		26.72	28	55	11,960	3,870		15,830
22	Sodium Phosphate Feed - 0 to 10 gpm, 1800 psi, 15 bhp, 480 V Positive displacement, 316 stainless steel	2	EA	8,697		26.72	83	165	17,390	11,610		29,000
23	Hydrazing Dispensing - 8 gpm, 15 cfm air drive at 90 psig, Reciprocating drive, stainless steel drum, 48 in. riser tube	1	EA	3,588		26.72	28	28	3,590	1,970		5,560
24	Ammonia Dispensing - 8 gpm, 15 cfm air drive at 90 psig, Reciprocating drive, stainless steel drum, 48 in. riser tube	1	EA	3,588		26.72	28	28	3,590	1,970		5,560
25	Diesel Generator Fuel Oil Supply - 2 gpm, 150 ft tdh, 1/4 bhp, 120 V Positive displacement	1	EA	1,087		26.72	28	28	1,090	1,970		3,060
	Subtotal - Pumps and Drivers								1,912,430	486,140	0	2,398,570

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 22)

Code	Description	Qty	Unit	Unit Cost Material	Unit Cost S/C	Labor $ Rate	MH Rate	Total MH	$ Material	$ Labor	$ S/C	$ Total
K	COMPRESSORS AND DRIVERS											
1	Air Compressors - 2 x 100 %, 2 stage, non-lubricated reciprocating	2	EA	92,408		26.72	176	352	184,820	24,760		209,580
	560 actual ft^3/min delivery, 110 psig, 150 bhp, 480 V											
	Inter- and after-coolers, carbon steel shell, stainless steel tubes											
	Cooling water - 20 gpm, 10 psi											
2	Vacuum Pumps - 1,000 actual ft^3/min, 300,000 ft total developed head	2	EA	48,922		26.72	176	352	97,840	24,760		122,600
	80 bhp motor, single stage, positive displacement with liquid seal rotor											
	Discharge with water trap silencer											
3	Gland Steam Condenser Air Exhauster - Horizontal shaft axial blower	2	EA	5,436		26.72	44	88	10,870	6,190		17,060
	500 ft^3/min, 5,000 ft total developed head, 7.5 bhp motor, 480 V											
	Subtotal - Compressors and Drivers								293,530	55,710	0	349,240
T	SPECIAL EQUIPMENT											
1	Turbine Generator Package	1	LT	54,737,965	244,609	38.13	10,397	10,397	54,737,970	731,430	244,610	55,714,010
	Steam Turbine - 2 cylinder (HP and IP/LP), downward exhaust											
	265 MWe, 1800 rpm, 1465 psia / 703 F / 703 F, 2.5 in. HgA exhaust											
	2,340,000 lb/hr main steam flow rate											
	Generator - 2 pole, air cooled, 294 MVA, 0.9 lagging power factor											
	13.8 kV, 12,300 A each phase											
	Exciter - Direct drive, solid state											
	Turbine turbine gear and motor											
	Automatic voltage and stability control panel											
	Generator gas control panel											
	Lube oil reservoir - 10,000 gallons, carbon steel tank											
	Lube oil coolers - Straight tube / straight shell, 300 gpm oil flow											
	Lube oil vapor extractor - 15 bhp, 175 cfm											
	Primary oil pumps - Vertical centrifugal, single stage pump											
	250 bhp, 480 V motor, mounted on oil reservoir											
	Emergency oil pumps - Vertical centrifugal, single stage pump											
	250 bhp, 125 V DC motor, mounted on oil reservoir											
	Turning gear oil pumps - Vertical centrifugal, single stage pump											
	50 bhp, 480 V motor, mounted on oil reservoir											
	Jacking oil pumps - Positive displacement, horizontal											
	50 bhp, 480 V motor, mounted on oil reservoir											
	Electro-hydraulic control unit - Skid mounted with oil reservoir											
	Seal oil pumps - 150 gpm, 200 ft total developed head, 25 bhp, 480 V											
	Cast iron case, carbon steel shaft and impeller, TEFC motor											
2	Turbine Crane - Step leg gantry with double girder bridge	1	EA	804,490		26.72	748	748	804,490	52,620		857,110
	90 ft center-to-center width, 110 ft. long, 80 ton main hook, 20 ton auxiliary											

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 23)

Code	Description	Qty	Unit	----- Unit Cost ------ Material	S/C	Labor $ Rate	MH Rate	Total MH	Material	Labor	S/C	Total
3	Shop and Warehouse Bridge Crane - 2 ton, single girder, top riding rail mounted conductor, pendant operating hoist 5 hp crane motor, 2 1/2 hp bridge motor	1	EA	21,526		26.72	176	176	21,530	12,380		33,910
4	Soda Ash Mixing Tank Agitator - Tank mounted, stainless steel 1/3 bhp motor drive, 120 V, 2 in. propeller	1	EA	1,087		26.72	22	22	1,090	1,550		2,640
5	Lime Paste Slaker - 200 lb/hr lime / water mixer (2:1 ratio) with classifier and grit discharge, 480 V motor drive	1	EA	3,805		26.72	44	44	3,810	3,100		6,910
	Subtotal - Special Equipment								55,568,890	801,080	244,610	56,614,580
P	PIPING AND INSTRUMENTATION											
1	Main Steam - 20 in., Sch 80, carbon steel	200	LF	361		42.68	3.40	680	72,210	50,930		123,140
	Welds	14	EA			42.68	22.10	316		23,670		23,670
	Main Steam - 14 in., Sch 80, carbon steel	180	LF	183		42.68	2.10	378	33,020	28,310		61,330
	Welds	13	EA			42.68	9.00	116		8,690		8,690
2	Hot Reheat Steam - 36 in., STD wall, carbon steel	200	LF	247		42.68	2.50	500	49,330	37,450		86,780
	Welds	14	EA			42.68	13.80	197		14,760		14,760
	Hot Reheat Steam - 18 in., STD wall, carbon steel	320	LF	122		42.68	1.78	570	39,050	42,690		81,740
	Welds	23	EA			42.68	6.82	156		11,680		11,680
3	Cold Reheat Steam - 42 in., STD wall, carbon steel	200	LF	288		42.68	2.80	560	57,630	41,940		99,570
	Welds	14	EA			42.68	16.00	229		17,150		17,150
	Cold Reheat Steam - 20 in., STD wall, carbon steel	320	LF	136		42.68	1.87	598	43,480	44,790		88,270
	Welds	23	EA			42.68	7.49	171		12,810		12,810
4	Condensate - 14 in., Sch 40, carbon steel	300	LF	110		42.68	1.54	462	32,900	34,600		67,500
	Welds	21	EA			42.68	5.18	111		8,310		8,310
5	Feedwater - 14 in., Sch 80, carbon steel	700	LF	183		42.68	2.10	1,470	128,420	110,100		238,520
	Welds	50	EA			42.68	9.00	450		33,700		33,700
	Feedwater - 8 in., Sch 80, carbon steel	240	LF	75		42.68	1.12	269	18,000	20,150		38,150
	Welds	17	EA			42.68	3.15	54		4,040		4,040
6	Circulating Water - 72 in., concrete lined carbon steel	900	LF	497		42.68	4.50	4,050	446,860	303,340		750,200
	Welds	64	EA			42.68	27.43	1,763		132,050		132,050
7	Feedwater Heater Extraction Steam - 10 in., Sch 40, carbon steel	360	LF	70		42.68	1.25	450	25,190	33,700		58,890
	Welds	36	EA			42.68	3.52	127		9,510		9,510
8	Feedwater Heater Drains - 4 in., Sch 40, carbon steel	480	LF	19		42.68	0.80	384	8,950	28,760		37,710
	Welds	60	EA			42.68	1.92	115		8,610		8,610
9	Process Water - 3 in., Sch 40, carbon steel	6,500	LF	13		42.68	0.70	4,550	85,120	340,790		425,910
	Welds	813	EA			42.68	1.60	1,300		97,370		97,370

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 24)

				----- Unit Cost ------		Labor	MH	Total	------------------------------ $ ------------------------------			
Code	Description	Qty	Unit	Material	S/C	$ Rate	Rate	MH	Material	Labor	S/C	Total
====	==	====	===	=======	======	=====	=====	=====	=======	=======	========	========
10	Service Water - 2 in., Sch 80, carbon steel	2,500	LF	9		42.68	0.70	1,750	21,700	131,070		152,770
	Welds	313	EA			42.68	1.60	500		37,450		37,450
11	Instrument Air - 2 in., Sch 80, carbon steel	1,600	LF	9		42.68	0.70	1,120	13,890	83,890		97,780
	Welds	200	EA			42.68	1.60	320		23,970		23,970
12	Service Air - 2 in., Sch 80, carbon steel	1,500	LF	9		42.68	0.70	1,050	13,020	78,640		91,660
	Welds	188	EA			42.68	1.60	300		22,470		22,470
13	Demineralized Water - 6 in., Sch 40, carbon steel	300	LF	33		42.68	0.86	258	9,840	19,320		29,160
	Welds	38	EA			42.68	2.40	90		6,740		6,740
14	Lubricating Oil - 2 in., Sch 80, carbon steel	400	LF	9		42.68	0.70	280	3,470	20,970		24,440
	Welds	50	EA			42.68	1.60	80		5,990		5,990
15	Chemical Feed - 1 in., Sch 80, stainless steel	900	LF	23		42.68	1.40	1,260	20,270	94,370		114,640
	Welds	113	EA			42.68	3.20	360		26,960		26,960
16	Fuel Oil - 1 in., Sch 80, carbon steel	200	LF	4		42.68	0.70	140	750	10,490		11,240
	Welds	25	EA			42.68	1.60	40		3,000		3,000
17	Nitrogen - 2 in., Sch 80, carbon steel	300	LF	9		42.68	0.70	210	2,600	15,730		18,330
	Welds	38	EA			42.68	1.60	60		4,490		4,490
18	Carbon Dioxide - 2 in., Sch 80, carbon steel	200	LF	9		42.68	0.70	140	1,740	10,490		12,230
	Welds	25	EA			42.68	1.60	40		3,000		3,000
19	Auxiliary Steam - 4 in., Sch 40, carbon steel	1,800	LF	19		42.68	0.80	1,440	33,570	107,860		141,430
	Welds	225	EA			42.68	1.92	432		32,360		32,360
20	Miscellaneous Process - 2 in., Sch 80, carbon steel	2,500	LF	9		42.68	0.70	1,750	21,700	131,070		152,770
	Welds	313	EA			42.68	1.60	500		37,450		37,450
21	Pneumatic Tubing	22,000	FT	0.38		36.85	0.055	1,210	8,371	83,570		91,941
22	Raceway for Pneumatic Tubing	2,750	FT	1.36		36.85	0.165	454	3,737	31,360		35,097
23	Loop Checks	900	EA			36.85	2.75	2,475		170,950		170,950
24	Calibration and Testing	600	EA			36.85	2.97	1,782		123,080		123,080
25	Valves (150% of piping material)	1	LT	1,774,065					1,774,070			1,774,070
26	Instrumentation (35% of piping + valves; 45 MH/$1000 of instrumentation)	1	LT	1,039,111		42.68	46,760	46,760		3,502,320		3,502,320

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 25)

				----- Unit Cost ------		Labor	MH	Total	----------------------------- $ -------------------------------			
Code	Description	Qty	Unit	Material	S/C	$ Rate	Rate	MH	Material	Labor	S/C	Total
====	===	====	===	=======	======	=====	=====	=====	=======	=======	========	========
27	Miscellaneous Piping and Operations											
	Hangers and supports (20% of installation manhours; $4/ft for material)	1	LT	208,159		42.68	16,965	16,965	208,160	1,270,680		1,478,840
	Waste allowance (10% of piping material)	1	LT	296,889					296,890			296,890
	Testing and inspection (7.5% of installation manhours)	1	LT			42.68	6,362	6,362		476,510		476,510
	Material handling (5% of installation manhours)	1	LT			42.68	4,241	4,241		317,650		317,650
	Freight (3% of material)	1	LT	89,067					89,070			89,070
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	Subtotal - Piping and Instrumentation								3,563,008	8,383,800	0	11,946,808
M	STRUCTURAL STEEL											
1	Structural Steel - Supports, Pipe Racks, Cable Trays	125	T	1,631					203,840			203,840
2	Gratings and Ladders	7	T	2,174					15,220			15,220
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	Subtotal - Structural Steel								219,060	0	0	219,060
N	INSULATION											
1	Equipment											
	Feedwater Pumps	300	SF	3.33		26.72	0.51	152	998	8,960		9,958
	Condenser Air Ejectors	60	SF	3.33		26.72	0.51	30	200	1,770		1,970
	Feedwater Heaters	2,400	SF	6.13		26.72	0.62	1,500	14,711	88,410		103,121
	Deaerator	1,500	SF	6.13		26.72	0.62	937	9,194	55,230		64,424
	Miscellaneous Equipment	2,000	SF	6.13		26.72	0.62	1,250	12,259	73,670		85,929
2	Piping											
	Main Steam - 20 in. x 6 in.; 1.58 fitting factor	316	ELF	103		26.72	1.27	402	32,569	23,690		56,259
	Hot Reheat Steam - 36 in. x 6 in.; 1.58 fitting factor	316	ELF	160		26.72	2.06	650	50,596	38,310		88,906
	Cold Reheat Steam - 42 in. x 4 in.; 1.58 fitting factor	316	ELF	118		26.72	1.90	601	37,147	35,420		72,567
	Feedwater - 14 in. x 4 in.; 1.58 fitting factor	1,106	ELF	49		26.72	0.83	915	54,503	53,930		108,433
	Feedwater Heater Extraction Steam - 10 in. x 4 in.; 1.93 fitting factor	695	ELF	39		26.72	0.68	475	27,185	28,000		55,185
	Feedwater Heater Drains - 4 in. x 4 in.; 1.93 fitting factor	926	ELF	24		26.72	0.48	447	21,907	26,350		48,257
	Auxiliary Steam - 4 in. x 4 in.; 1.93 fitting factor	3,474	ELF	24		26.72	0.48	1,675	82,153	98,720		180,873
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	Subtotal - Insulation								343,422	532,460	0	875,882
P	ELECTRICAL											
1	Power Distribution											
	Main Transformer - 13.8 / 115 kV, 275 / 305 MVA, OA, 55 / 65 C	1	EA	1,304,579		29.42	1,056	1,056	1,304,580	65,090		1,369,670
	Generator Main Bus - 12,300 A, 13.8 kV, 3 phase, non-segregated	90	LF	652		29.42	13	1,188	58,710	73,230		131,940
	Auxiliary Transformer - 115 / 4.16 kV, 50 / 55 MVA, OA, 55 / 65 C	1	EA	706,647		29.42	440	440	706,650	27,120		733,770
	Load Center Transformer - 4160 / 480 V, 1.0 / 1.12 MVA, AA, 55 / 65 C	2	EA	71,752		29.42	99	198	143,500	12,200		155,700
	Load Center Transformer - 4160 / 480 V, 1.0 / 1.12 MVA, OA, 55 / 65 C	6	EA	71,752		29.42	99	594	430,510	36,610		467,120
	Indoor Transition Section and Auxiliary Cubicle	2	EA	21,743		29.42			43,490			43,490
	Outdoor Transition Section and Auxiliary Cubicle	6	EA	26,092		29.42			156,550			156,550

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 26)

Code	Description	Qty	Unit	Unit Cost Material	Unit Cost S/C	Labor $ Rate	MH Rate	Total MH	$ Material	$ Labor	$ S/C	$ Total
	Metalclad Switchgear - 4160 V											
	2,000 A air circuit breaker, indoor (480 V transformers)	1	EA	27,179		29.42	40	40	27,180	2,470		29,650
	400 A air circuit breaker, indoor (Heat transport fluid pumps)	6	EA	14,133		29.42	40	238	84,800	14,670		99,470
	600 A air circuit breaker, indoor (Feedwater pump)	2	EA	16,307		29.42	40	79	32,610	4,870		37,480
	300 A air circuit breaker, indoor (Circulating water pumps)	2	EA	13,046		29.42	40	79	26,090	4,870		30,960
	200 A air circuit breaker, indoor (Nitrate salt pumps)	6	EA	9,784		29.42	40	238	58,710	14,670		73,380
	Air Circuit Breakers - 480 V											
	Indoor, 1600 A	2	EA	21,743		29.42	15	31	43,490	1,910		45,400
	Indoor, 800 A	10	EA	15,220		29.42	11	110	152,200	6,780		158,980
	Outdoor, 1600 A	6	EA	21,743		29.42	19	112	130,460	6,900		137,360
	Outdoor, 800 A	27	EA	15,220		29.42	13	356	410,940	21,940		432,880
	Motor Control Centers - 480 V											
	Indoor	3	EA	21,743		29.42	176	528	65,230	32,550		97,780
	Outdoor	14	EA	27,179		29.42	220	3,080	380,500	189,850		570,350
	Motor Control Center - 125 V DC	1	EA	21,743		29.42	176	176	21,740	10,850		32,590
	Distribution Panels											
	480 V, 3 phase	3	EA	1,087		29.42	13	40	3,260	2,470		5,730
	208 / 120 V, single phase	9	EA	870		29.42	13	119	7,830	7,340		15,170
	125 V DC	1	EA	1,087		29.42	13	13	1,090	800		1,890
	480 V Power Receptables	60	EA	109		29.42	1.94	116	6,520	7,150		13,670
	Local Control Stations	50	EA	163		29.42	2.90	145	8,150	8,940		17,090
	480-208/120V Dry Type Transformers											
	9 kVA	5	EA	1,957		29.42	7.9	40	9,780	2,470		12,250
	15 kVA	2	EA	2,718		29.42	13	26	5,440	1,600		7,040
	30 kVA	1	EA	3,261		29.42	26	26	3,260	1,600		4,860
	45 kVA	1	EA	3,805		29.42	40	40	3,810	2,470		6,280
	Duplex Receptables, 120 V	100	EA	9		29.42	0.97	97	870	5,980		6,850
	Switches, 120 V	80	EA	9		29.42	0.97	77	700	4,750		5,450
	Relay and Meter Boards	10	LF	8,697		29.42	40	396	86,970	24,410		111,380
	Battery and Racks, 60 Cells, 125 V DC	1	EA	32,614		29.42	176	176	32,610	10,850		43,460
	Battery Charger, 125 V DC	2	EA	21,743		29.42	44	88	43,490	5,420		48,910
	Uninterruptible Power Supply, 100 kVA, 0.5 hours	1	LT	108,715		29.42	440	440	108,710	27,120		135,830
	Emergency Diesel-Generator, 1000 kVA	1	EA	271,787		29.42	616	616	271,790	37,970		309,760
	Telephone Switchboard and Equipment	1	LT	86,972		29.42	880	880	86,970	54,240		141,210
	Plant Intercom	1	LT	27,179		29.42	880	880	27,180	54,240		81,420
	Security System	1	LT	11,959		29.42	440	440	11,960	27,120		39,080
	Fire Detection System	1	LT	38,050		29.42	352	352	38,050	21,700		59,750
	Lighting Fixtures - Low pressure sodium	100	EA	381		29.42	2.6	264	38,050	16,270		54,320
	Roadway Lights with 30 ft. Poles	60	EA	815		29.42	26	1,584	48,920	97,640		146,560
	Emergency Lighting Fixtures with 2 Lamps and Battery	24	EA	435		29.42	2.6	63	10,440	3,880		14,320
	Lighting Transformer, 30 kVA, 3 phase 480 / 277 V, Indoor	2	EA	3,805		29.42	26	53	7,610	3,270		10,880
	Lighting Transformer, 30 kVA, 3 phase, 480 / 277 V, Outdoor	3	EA	3,805		29.42	26	79	11,420	4,870		16,290
	Lighting Panel, 480 / 277 V, 3 phase, 24 circuits, Indoor	2	EA	2,935		29.42	26	53	5,870	3,270		9,140
	Lighting Panel, 480 / 277 V, 3 phase, 24 circuits, Outdoor	3	EA	3,588		29.42	26	79	10,760	4,870		15,630

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 27)

				----- Unit Cost ------		Labor	MH	Total	---------------- $ ----------------			
Code	Description	Qty	Unit	Material	S/C	$ Rate	Rate	MH	Material	Labor	S/C	Total
====	===	====	===	=======	======	=====	=====	=====	=======	=======	========	========
2	Bulk Materials											
	Cable Trays - Separate power and instrumentation, with supports and covers	8,000	LF	12		29.42	0.41	3,318	95,930	204,520		300,450
	Rigid Metal Conduit - Various sizes	30,000	LF	4.59		29.42	0.30	9,102	137,610	561,050		698,660
	Nonmetallic Conduit - Various sizes	40,000	LF	2.17		29.42	0.11	4,400	86,970	271,220		358,190
	Power Cable - 600 V, 1/C #6 and larger	75,000	LF	1.23		29.42	0.012	897	92,140	55,290		147,430
	Power Cable - 600 V, multi-conductor, #8 and smaller	450,000	LF	0.17		29.42	0.004	1,848	78,270	113,910		192,180
	Power Cable - 1/C, 4.16 kV	60,000	LF	3.32		29.42	0.013	752	198,950	46,350		245,300
	Terminations - 480 V and instrumentation	18,000	EA	1.16		29.42	0.08	1,485	20,940	91,540		112,480
	Terminations - 4.16 kV	200	EA	1.75		29.42	0.12	24	350	1,480		1,830
	Conduit - Lighting	2,000	LF	2.97		29.42	0.26	519	5,950	31,990		37,940
	Conduit - Communications	1,000	LF	2.97		29.42	0.26	259	2,970	15,960		18,930
	Instrument and Control Wiring											
	7 conductor, 14 gauge	50,000	FT	1.59		29.42	0.015	770	79,362	47,460		126,822
	Twisted pair, 16 gauge	80,000	FT	1.11		29.42	0.012	977	88,711	60,210		148,921
	Twisted pair, 16 gauge, thermocouple	100,000	FT	1.11		29.42	0.012	1,221	110,889	75,260		186,149
	25 pair, 16 gauge	20,000	FT	7.89		29.42	0.052	1,036	157,854	63,870		221,724
	25 conductor, 14 gauge	30,000	FT	4.13		29.42	0.034	1,023	123,935	63,060		186,995
	Terminations	2,000	EA	17.97		29.42	0.715	1,430	35,941	88,140		124,081
	Termination boxes	25	EA	435		29.42	11.0	275	10,871	16,950		27,821
	Armored cable connections	100	EA	54		29.42	1.1	110	5,436	6,780		12,216
	Lighting Wiring - 1 C THHN	12,000	LF	0.15		29.42	0.010	119	1,830	7,340		9,170
	Lighting Wiring - Metalclad cable	4,000	LF	1.30		29.42	0.18	704	5,220	43,390		48,610
	Communications Cable - Multiconductor	2,000	LF	1.11		29.42	0.015	31	2,220	1,910		4,130
	Communications Cable - Metalclad	46,000	LF	1.30		29.42	0.18	8,096	60,010	499,040		559,050
	Grounding - Wire, rods, cadwelds, and pads	80,000	LF	2.17		29.42	0.13	10,560	173,940	650,920		824,860
	Lightning Protection (allowance)	1	LT	10,871		29.42	880	880	10,870	54,240		65,110
	Cathodic Protection (allowance)	1	LT		108,715						108,710	108,710
	Heat Tracing - Freeze protection for water systems	1	LT	38,050		29.42	708	708	38,050	43,640		81,690
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	Subtotal - Electrical								6,794,670	4,084,810	108,710	10,988,190
Q	<u>CONCRETE WORK</u>											
1	Turbine-Generator Foundation											
	Concrete	650	CY	82		26.72	1.65	1,073	53,000	63,240		116,240
	Forms	5,200	SF	1.63		26.72	0.39	2,002	8,480	118,000		126,480
	Reinforcing Steel	39	T	870		26.72	22	858	33,919	50,570		84,489
	Embedded Metal	9,750	LB	1.63		26.72	w/ forms		15,900			15,900
2	Cooling Tower Foundation											
	Concrete	250	CY	82		26.72	1.65	413	20,380	24,340		44,720
	Forms	15,500	SF	1.63		26.72	0.39	5,968	25,280	351,750		377,030
	Reinforcing Steel	30	T	870		26.72	22	660	26,092	38,900		64,992
	Embedded Metal	1,000	LB	1.63		26.72	w/ forms		1,631			1,631

250 MWe Parabolic Trough Power Plant Total Field Cost Estimate (Sheet 28)

Code	Description	Qty	Unit	----- Unit Cost ------ Material	S/C	Labor $ Rate	MH Rate	Total MH	------ $ ------ Material	Labor	S/C	Total
3	Footings and Foundations											
	Concrete	1,500	CY	82		26.72	1.65	2,475	122,300	145,880		268,180
	Forms	7,500	SF	1.63		26.72	0.39	2,888	12,230	170,220		182,450
	Reinforcing Steel	90	T	870		26.72	22	1,980	78,275	116,700		194,975
	Embedded Metal	7,500	LB	1.63		26.72	w/ forms		12,230			12,230
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	Subtotal - Concrete Work								409,716	1,079,600	0	1,489,316
S	<u>SITEWORK</u>											
1	Turbine-Generator Foundation											
	Excavation	813	CY			26.72	0.55	447		26,340		26,340
	Backfill and Compaction	390	CY	9		26.72	0.99	386	3,392	22,760		26,152
2	Cooling Tower Foundation											
	Excavation	500	CY			26.72	0.55	275		16,210		16,210
	Backfill and Compaction	333	CY	9		26.72	0.99	330	2,899	19,450		22,349
3	Footings and Foundations											
	Excavation	1,875	CY			26.72	0.55	1,031		60,780		60,780
	Backfill and Compaction	469	CY	9		26.72	0.99	464	4,077	27,350		31,427
4	Circulating Water Pipe											
	Excavation	2,700	CY			26.72	0.55	1,485		87,530		87,530
	Backfill and Compaction	900	CY	9		26.72	0.99	891	7,827	52,520		60,347
5	Fuel Oil Tank											
	Excavation	150	CY			26.72	0.55	83		4,860		4,860
	Backfill and Compaction	100	CY	9		26.72	0.99	99	870	5,840		6,710
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	Subtotal - Sitework								19,065	323,640	0	342,705
									--------------	-------------	-----------	--------------
	Subotal								79,386,791	16,334,820	440,300	96,161,911
	Sales Tax								5,874,623			5,874,623
									--------------	-------------	-----------	--------------
6	TOTAL - ELECTRIC POWER GENERATION SYSTEM								85,261,414	16,334,820	440,300	102,036,534
7	**<u>MASTER CONTROL SYSTEM</u>**											
1	Distributed Control System 2,750 I/O Points, 4 operator stations, 6 programmable logic controllers DCS and PLC software	1	LT			36.85	1,760	1,760	2,000,000	121,560		2,121,560
	Sales Tax								148,000			148,000
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7	TOTAL - MASTER CONTROL SYSTEM								2,148,000	121,560		2,269,560

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. **REPORT DATE** *(DD-MM-YYYY)*	2. **REPORT TYPE**	3. **DATES COVERED** *(From - To)*
July 2006	Subcontract Report	January 20, 2005 – December 31, 2005

4. TITLE AND SUBTITLE
Nexant Parabolic Trough Solar Power Plant Systems Analysis: Task 1: Preferred Plant Size

5a. CONTRACT NUMBER
DE-AC36-99-GO10337

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
B. Kelly

5d. PROJECT NUMBER
NREL/SR-550-40162

5e. TASK NUMBER
CP06.1301

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Nexant, Inc.
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8. PERFORMING ORGANIZATION REPORT NUMBER
LDC-5-55014-01

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393

10. SPONSOR/MONITOR'S ACRONYM(S)
NREL

11. SPONSORING/MONITORING AGENCY REPORT NUMBER
NREL/SR-550-40162

12. DISTRIBUTION AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

13. SUPPLEMENTARY NOTES
NREL Technical Monitor: H. Price

14. ABSTRACT *(Maximum 200 Words)*
Subcontract report by Nexant, Inc., regarding analysis of plant size of solar parabolic trough plants.

15. SUBJECT TERMS
concentrating solar power; solar parabolic trough; solar; solar thermal electricity

16. **SECURITY CLASSIFICATION OF:**			17. **LIMITATION OF ABSTRACT**	18. **NUMBER OF PAGES**	19a. **NAME OF RESPONSIBLE PERSON**
a. **REPORT**	b. **ABSTRACT**	c. **THIS PAGE**			
Unclassified	Unclassified	Unclassified	UL		19b. **TELEPONE NUMBER** (*Include area code*)