MASTER

19.1866
DOE/ET/20567-1/3

**SOLAR CENTRAL RECEIVER HYBRID POWER SYSTEMS SODIUM-COOLED
RECEIVER CONCEPT. FINAL REPORT**

Volume 3. Appendices

January 1980

Work Performed Under Contract No. AC03-78ET20567

**Rockwell International
Energy Systems Group
Canoga Park, California**

U.S. Department of Energy

Solar Energy

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DISCLAIMER

"This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof."

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Paper Copy \$30.00
Microfiche \$3.50

SOLAR CENTRAL RECEIVER HYBRID POWER SYSTEMS SODIUM-COOLED RECEIVER CONCEPT FINAL REPORT

VOLUME III APPENDICES

JANUARY 1980

**PREPARED FOR THE
U.S. DEPARTMENT OF ENERGY
AS PART OF**

CONTRACT NO. DE-AC03-78ET20567 (ET-78-C-03-2233)

Rockwell International
Energy Systems Group

MCDONNELL DOUGLAS

Salt River Project
WATER & POWER

Babcock & Wilcox

mg

CONTENTS

	Page
Appendices	
A. Selection of Fuel and Solar Multiple	A-1
B. Selection of Parallel vs Series Configuration	B-1
C. Steam Cycle Optimization Study (N001TSR000-003)	C-1
D. Tower Analysis and Receiver Mass Distribution	D-1
E. 0.8 Solar Multiple Design Data Sheets	E-1
F. 1.4 Solar Multiple Design Data Sheets	F-1
G. Electric Power Generation Subsystem P&I Diagram	G-1
H. 0.8 Solar Multiple P&ID	H-1
I. 1.4 Solar Multiple P&ID	I-1
J. System Response to Loss of P-1 Pump and Loss of Sun Transients . . .	J-1
K. 0.8 and 1.4 Solar Multiple STEAEC Input Data	K-1
L. Plume-Solar Insolation Study	L-1
M. 1.44 Solar Multiple Preferred Commercial Plant Design Data Sheets .	M-1
N. 1.44 Solar Multiple Preferred Commercial Plant P&ID	N-1
O. 0.8 Solar Multiple 1st Plant Cost Data	O-1
P. 0.8 Solar Multiple N th Plant Cost Data	P-1
Q. 1.4 Solar Multiple 1 st Plant Cost Data	Q-1
R. 1.4 Solar Multiple N th Plant Cost Data	R-1
S. 1.44 Solar Multiple Preferred Commercial Plant Cost Data	S-1
T. 1.4 Solar Multiple Operation and Maintenance Cost Data	T-1

APPENDIX A

SELECTION OF FUEL AND SOLAR MULTIPLE

ESG-79-30, Vol III

I. INTRODUCTION

Two of the primary baseline selection decisions to be made during the conceptual design of the 100 MWe Solar Central Receiver/Fossil Hybrid Power System are: (1) which fossil fuel to use to fire the sodium heater, and (2) what is the optimum solar multiple for the selected fuel. A diagram of the general configuration of the hybrid power system is shown in Figure A-1.

The turndown ratio of the sodium heater (rated power/minimum operating power) is determined primarily by the fuel being fired. When the heater is at minimum power, the difference between the steam generator power and heater power is the required receiver power.

Once the fuel is known and the turndown specified, the economic effects of varying solar multiple can be determined and an optimum solar multiple selected. (For a parallel heater/receiver configuration, 1-1/turndown ratio is the point of departure for solar multiple selection trade studies.) Selection of the solar multiple in conjunction with the steam generator power determines the size of the receiver and receiver sodium components in terms of required power and indicates the size of the thermal storage subsystem.

The purpose of these trade studies is to select a fossil fuel and receiver size (power) for the 100 MWe conceptual design of the Solar Central Receiver Hybrid Power System. These parameters form the basis of other ongoing trade studies.

II. DESIGN BASIS FOR COMPARISON STUDY

The parallel receiver/heater configuration has been selected as baseline for the hybrid system. (A-1) In this configuration, the heater is required to be at temperature during sunlight hours in order to be capable of rapidly supplementing meteorological induced shortfalls in receiver power. This requirement means that either the receiver power be large enough such that the heater can be kept warm by solar heated sodium or that fuel be burned to keep the heater at temperature. Only the latter case is considered in this study. Depending on the fuel selected, the minimum heater power required to maintain combustion stability and sodium temperatures concurrently, ranges from 10 to 20% of full power. Full heater power is currently set at the steam generator power level of 160 Mwt.

The sodium inlet temperature to the steam generator is currently fixed at 1100°F and the temperature drop (ΔT) across the steam generator is maintained constant at 550°F which establishes the steam generator outlet temperature at 550°F. The sodium heater and receiver outlet temperature of 1100°F and the ΔT of 550°F were established as the optimum design points as a result of previous solar design studies. (A-2) Based on the foregoing, the receiver and heater, connected in parallel, are designed to furnish the required thermal energy with a constant sodium inlet and outlet temperature of 550°F and 1100°F, respectively.

Variations in the solar receiver thermal energy output, because of the diurnal variation in absorbed thermal power, will be made up by the fossil-fired sodium heater to provide a constant net electrical plant output of 100 MW. As the receiver output drops, the heater output is increased. Load changes are made by varying the sodium flow through the components. Changes in the seasons, time of day, and weather patterns all affect the solar heat input which will require adjustment in the

Rockwell International
Energy Systems Group

Figure A-2. Storage Capacity vs Solar Multiplier

fossil-fired sodium heater thermal input to maintain a fixed plant output. At some specified minimum load in the solar receiver, the receiver will be shut down and all the power will be generated by the sodium heater.

If oil or either of the cadadate gases are used as fossil fuels in the hybrid plant, the projected minimum heater power is 10% of full power. The projected minimum power of a coal-fired sodium furnace is 20%.^(A-3) This means that as a point of departure, the power provided by the receiver at peak design conditions would be 90% for an oil or gas system, and 80% for a coal system.

There is no technical restriction on the amount of total power the receiver can contribute to the system. Consequently, the receiver can contribute more or less than the foregoing percentages of total required steam generator power. As a minimum, however, a fossil fuel displacement of at least 50% at design operating conditions should be utilized for the plant to be considered a true hybrid. This sets the minimum receiver power rating at 50% of the steam generator rating. As a maximum, the design receiver power has been limited to 266% of the required steam generator power. This would effectively supply the steam generator 100% power all day and night if storage facilities were available. Thus, it can be seen that for receiver powers equal to or less than the point of departure, no storage is required. For higher powers, storage is required. A convenient single factor which describes the receiver power capability relative to the turbine requirements at name plate rating and simultaneously indicates the relative magnitude of storage is the Solar Multiple. Selecting a Solar Multiple defines the peak design solar/fossil spit of the plant and indicates the magnitude of storage. Figure A-2 shows the relation between Solar Multiple and hours of storage.

It is also possible to increase the total solar contribution to the plant by increasing the size of the heliostat field without adding storage. This will increase the collector field to receiver power ratio (FRPR) for a given receiver power. An investigation of this parameter is currently being conducted as part of the field optimization study and is, therefore, excluded from the scope of this study.

III. TRADE STUDY ASSUMPTIONS

The technical trade study assumptions and brief justifications are shown in Table A-1. The economic assumptions used in this trade study are shown in Table A-2.

The heater standby turndown requirements shown in Table A-2 are based on two operating philosophies. The first philosophy indicates that the heater be at temperature in order for the plant to be "available." The second philosophy does not require the heater to be at temperature in order to be available. This philosophy requires results in lower fuel costs and lower overall busbar costs and is supported by the utilities who do not like to start a plant up unless it will produce electricity.^(A-4) (In either case, the results of this trade study were unchanged.)

It was also assumed that there were no significant variations in technical reliability with fuel or solar multiple.

TABLE A-2
TECHNICAL ASSUMPTIONS

	<u>Notes</u>
1. Net Plant Rating = 100 MWe	See Reference A-5
2. Heater/Receiver Configuration = Parallel	See Reference A-1
3. Plant Availability = 90% including solar variation	See Reference A-5
4. Heater Standby Turndown Rating oil = 10% and 0% coal = 20% and 0%	See Preceding Discussion
5. Plant Performance Requirements	As per Reference A-5
6. Plant Capacity Factor Range = 5-95%	
7. Oil and Gas Base Turndown = 10 to 1	See Reference A-3
8. Coal Turndown = 5 to 1	See Reference A-3
9. Standby Turndown Heat Source = fuel	
10. Number of cloudy days per year = 35	See Reference A-6

TABLE A-3
ECONOMIC ASSUMPTIONS*

Discount Rate = 10%

Economic Life = 30 years

Fixed Charge Rate = 18%

Annual Capital Escalation Rate = 10%

Startup Year = 1990

Annual Fuel Escalation Rates = 6, 8, 10, and 15%

Oil Cost = \$2.00/MMBtu (1978 \$)

Coal Cost = \$1.00/MMBtu (1978 \$)

Natural Gas Cost = \$2.10/MMBtu (1978 \$)
(See Reference A-7)

Syngas Cost = \$3.75/MMBtu (1978 \$)
(See Reference A-7)

*All assumptions as per Reference A-5 except as noted.

IV. FOSSIL FUEL SELECTION

A. NON-ECONOMIC CONSIDERATIONS

The non-economic advantages and disadvantages of each fuel alternative are shown in Table A-3. The most abundant of the alternatives is coal. This fact is reflected in its low fuel cost. Coal is also the most available fuel. While it is recognized that its availability is subject to labor negotiations, last winter's coal strike did not seem to seriously impact the operation of western coal-fired plants in the major solar market areas. Oil availability is subject to the decisions of foreign suppliers. Natural gas is expected to be unavailable to new power plants as a result of fuel management regulations. "Syngas" is and will continue to be unavailable so long as natural gas prices remain regulated at low levels.

TABLE A-3
FUEL SELECTION NON-ECONOMIC CONSIDERATIONS

	Coal	Oil	Natural Gas	Syngas
Abundance	+	-	-	+
Availability	+	-	-	-
Convertibility	+	-	-	-
Freedom from Usage Restrictions	+	-	-	-
Ease of Handling	-	+	+	0
Lack of Flue Gas Cleanup	-	-	+	0
Mirror Fly Ash Precipitation	-	0	+	0
Plant Location Flexibility	-	+	+	0

- + Advantage
- Disadvantage
- No significant effect

Coal and syngas are the only fuel alternatives expected to remain or become available with reasonable certainty. A number of utilities expect that oil would not be used in power plants.^(A-4) The use of natural gas in new power plants is currently prohibited in many western states.

Oil and natural gas are the easiest fuels to handle of the two alternatives. Coal is the most difficult. The handling problems of syngas depend upon whether the gas is manufactured onsite. If it is manufactured onsite from coal, then the handling difficulties would be the same as those for coal. If, however, syngas is purchased from an outside supplier, the handling difficulties would be similar to those of natural gas.

Both coal and oil are expected to require flue gas scrubbers and electrostatic precipitators or equivalent SO_2 removal and particulate control equipment. This problem is critical in that it impacts heliostat fly ash deposition rates. Stearns-Roger has indicated that with properly operating precipitators and correct fuel selection, the deposition rate should be manageable. It is not known whether fly ash deposition will be a serious problem with oil firing at this time. Firing natural gas eliminates the scrubber and precipitator requirements as well as the fly ash problem. The precipitator and scrubber requirements as well as fly ash deposition resulting from syngas firing depend upon syngas plant design and location.

Another non-economic fuel selection criterion is plant site flexibility. Coal is the least flexible alternative as reflected in increasing transportation costs as a function of distance from mine mouth. Oil and natural gas have the most flexibility with regard to site location. The site location flexibility of syngas will depend upon the syngas plant location.

It is probable that gas may be unavailable at any price as a result of fuel management decisions. Syngas is, at this time, high enough in cost to be ruled out from an economic consideration. Since oil is more abundant than natural gas, the final economic choice is between oil and coal.

A final non-economic consideration is the capability of fuel conversion. A coal heater is the only heater that, once selected, can be converted to other fuels.

RUN DATE IS 3/7/79
 FUEL IS COAL STANDBY TURNDOWN = 0.0 %
 PLANT TYPE IS HYBRID 1

SYSTEM LIFE = 30.0 YEARS
 INITIAL YEAR OF OPERATION = 1990.0
 CAPITAL COST = 128.3 MILLION
 INITIAL ANNUAL FIXED O&M COST = 1.3 MILLION
 FIXED CHARGE RATE = 18.0 %
 ANNUAL CAPITAL ESCALATION RATE = 10.0 %
 ANNUAL O&M ESCALATION RATE = 8%
 DISCOUNT RATE = 10.0 %
 FUEL = 8.9 CF- 2.0 MILLION/YEAR (1978 \$)
 FUEL COST = 1.0 \$/MMBTU (1978 \$)
 FUEL ANNUAL ESCALATION = 6,8,10 AND 15%
 GENERAL ESCALATION = 10.00 %

SOLAR MULTIPLE = .80
 54.75 CLOUDY DAYS/YEAR

CF= .1000
 CF= .2000
 CF= .3000
 CF= .4000
 CF= .5000
 CF= .6000
 CF= .7000
 CF= .8000
 CF= .9000

BUSBAR ENERGY COSTS, (MILS/KWH, 1978 \$)

FUEL

0.0	0.0	3.2	5.5	6.8	7.7	8.4	8.9	9.3
0.0	0.0	5.1	8.8	11.0	12.5	13.5	14.3	14.9
0.0	0.0	8.3	14.4	18.0	20.4	22.1	23.4	24.4
0.0	0.0	30.4	52.4	65.7	74.5	80.8	85.5	89.2

FUEL+O&M

21.2	13.6	14.2	15.2	15.8	16.2	16.5	16.7	16.9
21.2	13.6	16.1	18.5	20.0	21.0	21.6	22.2	22.6
21.2	13.6	19.4	24.1	27.0	28.9	30.2	31.3	32.1
21.2	13.6	41.4	62.2	74.7	83.0	88.9	93.4	96.8

TOTAL BUSBAR ENERGY COSTS

337.5	171.7	119.6	94.3	79.1	69.0	61.7	56.3	52.1
337.5	171.7	121.6	97.6	83.3	73.7	66.0	61.7	57.7
337.5	171.7	124.8	103.2	90.2	81.6	75.4	70.8	67.2
337.5	171.7	146.9	141.3	137.9	135.7	134.1	132.9	132.0

Figure A-3. Sample Output

B. ECONOMIC CONSIDERATIONS

The economic comparisons of oil and coal for various fuel escalation rates in the range of 6 to 15% were made, in terms of busbar energy costs vs capacity factor, using the JPL methodology.^(A-8) The economic assumptions used are listed in Table A-2. The methodology was programmed into a computer code for use on a Hewlett Packard 9845 desk top computer. The program generates fuel, O&M plus fuel, and the total busbar energy costs as a function of capacity factor and fuel escalation if given the capital cost, standby turndown heater power requirement, solar multiple, and number of cloudy days per year. A sample output of the code is shown in Figure A-3.

The technical and economic parameters of each case are followed by the busbar costs arranged in rows of ascending capacity factor, from left to right, and columns of ascending fuel escalation from top to bottom. A fuel algorithm based on a standby turndown rate, fuel cost, and solar multiple is also shown in 1978 dollars.

The results of the fuel selection trade study were plotted by the same computer and are shown in Figures A-4 through A-9. Figures A-4 and A-5 show the busbar energy cost breakdowns vs capacity factor for coal and oil-fired system, respectively. Figures A-6 through A-9 show the total busbar energy costs for full escalation of 6, 8, 10, and 15%, respectively.

The capital costs, solar multiples, and fuel escalation rates shown in Figures A-4 and A-5 were considered points of departure for the fuel selection and solar multiple trade study.

As shown in Figures A-6 through A-9, coal is a more cost effective fuel, at any fuel escalation rate, above capacity factors of 55-60%. Furthermore, at an escalation rate equal to the historical rate of the last five years, 10% coal is superior to oil at capacity factors of 42% or higher.

Figure A-4. Coal Fired Hybrid Baseline Energy Costs

Figure A-5. Oil Fired Hybrid Baseline Energy Costs

Figure A-6. Oil and Coal Hybrid Busbar Energy Costs

Figure A-7. Oil and Coal Hybrid Busbar Energy Costs

Figure A-8. Oil and Coal Hybrid Busbar Energy Costs

Figure A-9. Oil and Coal Hybrid Busbar Energy Costs

As a result of the lower fuel costs of coal, the incremental fuel cost of electricity from a coal plant will also be less than that of an oil plant, as shown in Figures A-4 and A-5. Consequently, a dispatcher would be reasonably expected to select a coal hybrid over an oil hybrid if two otherwise equivalent plants existed. This would result in the coal hybrid attaining a relatively higher capacity factor. It can be concluded, therefore, that from an economic standpoint, coal should be the baseline fuel for the hybrid system.

Figure A-10. Coal Solar Multiple Trade Study

Figure A-11. Coal Solar Multiple Trade Study

V. SOLAR MULTIPLE TRADE STUDIES

Using the same computer program, the busbar energy costs of coal and oil fired hybrid plants as functions of capacity factor and fuel escalation rates were generated for solar multiples in the range of 0.5 to 2.15. The results are shown for coal with solar multiples of 0.5, 0.8, and 1.5 in Figures A-10, A-11, and A-12 for fuel escalation rates of 6, 10, and 15%, respectively. Also shown are the capital costs of each plants in millions (1978 dollars). All plant capital costs were generated by estimates of heater costs provided by Babcock and Wilcox and balance of plant component costs determined by scaling the costs from previous solar studies.

For coal with low fuel escalation rates, Figure A-10 shows that a low solar multiple is cost effective due to the relatively low cost of fuel. Increasing the fuel escalation rate to a more reasonable rate of 10% decreases the cost effectiveness of the low solar multiple. In fact, it can be shown that the difference in incremental fuel costs would cause a plant with a solar multiple of 0.8 to be used at a higher capacity than a plant with a solar multiple of 0.5. Consequently, the total busbar energy costs of 0.8 solar multiple plant would be less than those of the 0.5 solar multiple plant. At a 10% fuel escalation rate, the 1.5 solar multiple is still not competitive.

At very high fuel escalation rates (15%), the high solar multiple plant is clearly most cost effective as shown in Figure A-12.

On the basis of the foregoing trade study, the optimum solar multiple appears to be 0.8 for coal.

A similar trade study for oil showed that the optimum solar multiple at a fuel escalation rate of 10% was greater than 1.5 due to the high

Figure A-12. Coal Solar Multiple Trade Study

Figure A-13. Coal Solar Multiple Trade Study

cost of fuel. In this case, the margin of superiority of the 1.5 solar multiple was not large. However, the incremental fuel cost drives the solar multiple up. The results of this study are shown in Figure A-13 for a fuel escalation rate of 10%.

VI. SUMMARY AND CONCLUSIONS

Based on economic and noneconomic considerations, coal has been shown to be the superior fossil fuel candidate. It is, therefore, recommended that coal be selected as the baseline fuel for the solar central receiver hybrid power system. The option of heater conversion to oil or gas operation should, however, be left open to mitigate the effects of the uncertainty of the study.

Based on the results of the solar multiple trade study, the fossil to solar power ratio at plant design conditions should be 80/20. The solar multiple associated with this ratio is 0.8 and the required receiver power is 208 MWt at current design conditions. Unless required by transient considerations, storage of solar energy has not been shown cost effective. It is, therefore, recommended that thermal storage facilities not be included in the baseline conceptual design.

VII. REFERENCES

- A-1. Auleta, J. J., "Selection of Parallel vs Series Configuration," NO01TSR000001, January 15, 1979, Energy Systems Group, Canoga Park, California
- A-2. Gabler, M. J., "Steam Generator System Conceptual Design," N272TI000002, March 9, 1978, Energy Systems Group, Canoga Park, California
- A-3. Personal Communication, W. W. Willcox, Energy Systems Group, and John Slavens, Babcock & Wilcox, January 5, 1979
- A-4. Personal Communication, L. E. Glasgow, Energy Systems Group, and R. F. Durning, Salt River Project, November 29, 1978
- A-5. "Solar Central Receiver Hybrid Power Systems Requirements Definition," Revision C, Sandia Livermore Laboratories, November 6, 1978
- A-6. "Solar Central Receiver Hybrid Power System, Volume 1, A Technical Proposal to U.S. Department of Energy, San Francisco Operations Office," Pages 2-90, AI-78-26P, June 19, 1978, Energy Systems Group, Canoga Park, California
- A-7. Personal Communication, W. W. Willcox, Energy Systems Group, and E. Kinderman, SRI International, December 11, 1978
- A-8. Doane, J. W., et al., "The Cost of Energy from Utility-Owned Solar Electric Systems," ERDA/JPL-1012-76/3, NTTS

APPENDIX B
SELECTION OF PARALLEL VS SERIES CONFIGURATION

ESG-79-30, Vol III

B-1

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

I. INTRODUCTION

Several alternatives exist for piping the solar receiver and fossil-fired sodium heater into the sodium process system for the solar central receiver hybrid power system conceptual design study. These two components can be connected either in parallel or series. Two options also exist for the series connection. The solar receiver can be connected in series either upstream or downstream of the heater.

A study was made to compare the relative merits of these alternatives in order to make a selection to be used as the baseline design for the ongoing study work. The following is a discussion of this study whereby advantages and disadvantages are presented for comparison among the various options.

II. DESIGN BASIS FOR COMPARISON STUDY

At full power, both the solar receiver and fossil-fired sodium heater are designed to furnish 260 MW of thermal energy to the steam generator. Steam, which is generated at 1000°F in the steam generator, passes through the turbine generator to develop the 100 MWe net plant output.

The sodium inlet temperature to the steam generator is fixed at 1100°F and the temperature drop (ΔT) across the steam generator is maintained constant at 550°F, which establishes the steam generator outlet temperature at 550°F. The sodium outlet temperature of 1100°F and the ΔT of 550°F were established as the optimum design points as a result of previous solar design studies. Based on the foregoing, the receiver and heater, connected either in series or parallel, are designed to furnish the required thermal energy with a constant sodium inlet and outlet temperature of 550°F and 1100°F, respectively. In the series configuration, the sodium enters the downstream component at 550°F and leaves the upstream component at 1100°F.

Variations in the solar receiver thermal energy output, because of the diurnal variation in absorbed thermal power, will be made up by the fossil-fired sodium heater to provide a constant net electrical plant output of 100 MW. As the receiver output drops, the heater output is increased. In the series arrangement, load changes are adjusted by varying the temperature rise across the components. Conversely, with the parallel arrangement, load changes are made by varying the sodium flow through the components. Changes in the seasons, time of day, and weather patterns all affect the solar heat input, which will require adjustment in the fossil-fired sodium heater thermal input to maintain a fixed plant output. At some specified minimum load in the solar receiver, the receiver will be shut down and all the power will be generated by the sodium heater. For the baseline reference design, the receiver is sized to develop full power at noon during the summer solstice.

III. SERIES CONFIGURATION

The two options that exist for designing the plant with a series configuration for the heater and receiver are shown in Figures B-1 and B-2. In Figure B-1, the receiver is piped upstream of the heater, whereas in Figure B-2 the receiver is connected downstream. In either case, for full-load operation, the sodium flow rate through the two components is maintained constant at 5.4×10^6 lb/h and the temperature rise across each component is varied in direct proportion to its load. This is illustrated in Tables B-1 and B-2.

As an example, Table B-1 shows that the receiver operating at 75% power the $\Delta T = 413^\circ\text{F}$ and the heater operates at 25% power with a $\Delta T = 137^\circ\text{F}$. The total ΔT across the two series connected components is 550°F with a flow rate of 5.4×10^6 lb/h at full load. Either component may be required to operate at full power by itself and, therefore, both components must be designed for the full 550°F temperature rise which is the same temperature design conditions for these components when they are connected in parallel.

The life of sodium systems is determined by the number and magnitude of the thermal and mechanical stress cycles they receive. For a very good approximation the design life is simply the number of thermal cycles. The integral of the damage factor is very uncertain which leads to large design margins. For this reason, sodium systems are generally designed to minimize the number of thermal cycles, unless there is a compelling economic or technical reason to do otherwise.

With the series arrangement, components are subjected to more thermal cycling than with the parallel arrangement, since the sodium flow is fixed and the temperatures are varied with the load. In addition, more severe temperature transients are generated in the heater and receiver when connected in series.

Figure B-1. Simplified Diagram — Solar Hybrid Plant Series Configuration
Solar Receiver Followed by Fossil Heater

Figure B-2. Simplified Diagram — Solar Hybrid Plant Series Configuration
Fossil Heater Followed by Solar Receiver

TABLE B-1

SODIUM TEMPERATURE RISE VS % LOAD FOR SERIES CONFIGURATION
SOLAR RECEIVER FOLLOWED BY FOSSIL HEATER
CONSTANT FLOW OF 5.4×10^6 lb/h

Solar Receiver			Fossil Fired Heater		
% Load	Temperature Rise		% Load	Temperature Rise	
	$T_{IN} - T_{OUT}$ $_{OF}$	ΔT $_{OF}$		$T_{IN} - T_{OUT}$ $_{OF}$	ΔT $_{OF}$
100	550 - 1100	550	0	0	0
75	550 - 963	413	25	963 - 1100	137
50	550 - 825	275	50	825 - 1100	275
25	550 - 687	137	75	687 - 1100	413
0	0	0	100	550 - 1100	550

TABLE B-2

SODIUM TEMPERATURE RISE VS % LOAD FOR SERIES CONFIGURATION
FOSSIL HEATER FOLLOWED BY SOLAR RECEIVER
CONSTANT FLOW OF 5.4×10^6 lb/h

Fossil Fired Heater			Solar Receiver		
% Load	Temperature Rise		% Load	Temperature Rise	
	$T_{IN} - T_{OUT}$ $_{OF}$	ΔT $_{OF}$		$T_{IN} - T_{OUT}$ $_{OF}$	ΔT $_{OF}$
100	550 - 1100	550	0	0	0
75	550 - 963	413	25	963 - 1100	137
50	550 - 825	275	50	825 - 1100	275
25	550 - 687	137	75	687 - 1100	413
0	0	0	100	550 - 1100	550

For example, if the receiver power output drops due to cloud cover, the temperature collapse in the receiver creates severe temperature shocks to the series connected components. Thus, it will require more extensive design analysis and possibly the installation of thermal liners to mitigate the thermal shock and extend the life of the components when they are connected in series rather than in parallel. The reliability of the components is severely affected by the number of thermal cycles. When the receiver is connected downstream of the heater, the temperature collapse due to cloud cover will create a severe thermal shock in the hot storage tank which may be carried over to the steam generators.

One scheme evaluated for reducing the receiver cost was to consider lowering the receiver design outlet temperature to 800°F, thereby permitting the use of carbon or 2-1/4 Cr - 1 Mo low alloy steel instead of stainless steel which is required for the 1100°F operation. In order to limit the receiver temperature to 800°F for the series arrangement, the receiver must be piped ahead of the heater and be limited to approximately 50% of the total plant output. Use of carbon or 2-1/4 Cr - 1 Mo steel results in lower tube wall stresses in the receiver because of the lower coefficient of thermal expansion for these steels. However, this stress reduction is offset by the reduction in allowable stress for the lower grade steels. Thus, it was determined that the receiver size could not be reduced by lowering the design temperatures and using lower grade materials. Material cost plus the added heat treatment cost for the 2-1/4 Cr - 1 Mo were equivalent to the stainless steel costs. Carbon steel was not considered cost effective because of the significantly lower allowable stress at 800°F than stainless steel at 1100°F.

For this scheme, the efficiency of the receiver is improved by about 2% because of the lower average operating temperature. However, whatever cost savings this results in is more than offset by the additional cost for a thermal buffering system required to effect rapid load changes

from receiver to heater. It was estimated that approximately 1/4 hour of thermal storage is required for this temperature buffering. It was concluded that this scheme of low-temperature receiver operation in series is not cost effective when compared to the parallel operation.

Following are the advantages and disadvantages of the two series configurations when compared to the parallel configuration.

A. ADVANTAGES - Receiver followed by Heater (Figure B-1)

- 1) Good sodium distribution at all loads because of constant flow rate
- 2) High solar receiver efficiency at part loads because of low average temperature
- 3) High-temperature flue gas available for air preheating

B. DISADVANTAGES - Receiver followed by Heater (Figure B-1)

- 1) Large thermal fatigue effects because of ΔT variations with load resulting in lower component reliability
- 2) High exit gas temperature at low heater loads
- 3) Bypass piping and valves required for single component operation
- 4) Lag in thermal equilibrium may lead to instability for fast load changes in heater
- 5) Heat loss always present on the idle unit unless it is bypassed
- 6) Heater inlet must be designed for approximately 1000°F
- 7) Stainless steel piping and valves required between receiver and heater, whereas carbon steel can be used for parallel configuration
- 8) System more difficult to control than parallel arrangement
- 9) Requires thermal storage to offset load changes

C. ADVANTAGES - Heater followed by Receiver (Figure B-2)

- 1) Good sodium distribution at all loads because of constant flow rate
- 2) Favorable heater efficiency at all loads

D. DISADVANTAGES - Heater followed by Receiver (Figure B-2)

- 1) Large thermal fatigue effects because of ΔT variations with load resulting in lower component reliability
- 2) Lower solar receiver efficiency at lower loads because of higher average temperatures
- 3) Bypass piping and valves required for single component operation
- 4) Lag in thermal equilibrium may lead to instability for fast load changes in heater
- 5) Heat loss always present on the idle unit unless it is bypassed
- 6) Receiver inlet must be designed for approximately 1000°F
- 7) Stainless steel riser piping and valves required between heater and receiver, whereas carbon steel can be used for parallel configuration
- 8) Average heat losses greater than when receiver is followed by heater
- 9) More difficult to control than parallel arrangement
- 10) Requires thermal storage to offset load changes

IV. PARALLEL CONFIGURATION

Figure B-3 shows a simplified diagram of the hybrid plant with the solar receiver and fossil-fired heater connected for parallel operation. In this configuration, either component may be operated by itself up to 100% full load, or else the total plant load may be split between the two heat sources.

For the parallel mode of operation, the sodium flow must be proportioned between the receiver and heater in order to maintain the temperature rise across the units constant at 550°F with a fixed outlet temperature of 1100°F. For example, in order to provide a total of 260 MWt power to the steam generator the sodium flow rate is fixed at 5.4×10^6 lb/h for a temperature rise (ΔT) of 550°F. Sodium enters the receiver and heater at 550°F and is heated to 1100°F. If the receiver is operating at 75% of full load, the flow is adjusted to approximately 4.1×10^6 lb/h. The balance of the sodium flow (i.e., 1.3×10^6 lb/h) is circulated to the heater to provide the 25% balance of the load.

Following are the advantages of the parallel configuration.

A. ADVANTAGES - Parallel configuration

- 1) System is able to respond more rapidly to load changes than series arrangement
- 2) Components experience small thermal fatigue effects since the axial ΔT remains approximately fixed at all loads
- 3) Easier to control than series arrangement
- 4) Thermal buffering is not required

In comparing the parallel arrangement with the series arrangement, no disadvantages of the parallel arrangement were identified.

Figure B-3. Simplified Diagram — Solar Hybrid Plant Parallel Configuration

V. SODIUM HEATER TEMPERATURES

To illustrate how the flue gas outlet temperature varies, estimates of temperature variation in the sodium heater with power level were made for the parallel and series configurations. Test data from the ETEC 35 Mwt SCTI sodium heater (H-1) were used as the basis for estimating the temperature conditions for the solar hybrid plant sodium heater. Flue gas outlet temperatures, assuming no air preheating, were estimated for 100% full power, 75% part load, and 50% part load. These are shown in Figure B-4. Calculations were based on assuming a constant UA and a fixed flue gas inlet temperature of 3400°F. The LMTD was assumed to vary directly with power level. The flue gas outlet temperatures were calculated from the LMTD. As shown, the highest flue gas outlet temperatures occur with the sodium heater installed in series downstream from the receiver.

Figure B-4. Sodium Heater Temperatures

VI. ECONOMIC CONSIDERATIONS

An assessment of the economic factors which influence the choice between the series and parallel configurations was made. The economics favor the parallel arrangement for the following reasons:

1. Stainless steel piping will be required for the piping connecting the receiver to the heater when connected in series. In the case where the receiver is downstream of the heater (Figure 2), this piping is the riser piping in the solar receiver tower.

Replacing the carbon steel piping and valves, which can be used for parallel operation, with stainless steel piping and valves is estimated to cost an additional \$160,000 in 1978 dollars.

2. Stainless steel piping and valves are also required for the bypass piping for the series arrangement.

It is estimated that this additional piping and valving will cost an additional \$700,000 in 1978 dollars.

3. Average heat losses for the series configuration are greater than for the parallel configuration when the receiver is installed downstream of the heater. The higher average receiver-operating temperature results in the larger heat losses which are made up by increasing the power output of the heater.

It is estimated that heat losses equal to about 2 MW of thermal energy must be provided by the heater. Assuming a coal-fired heater, additional annual fuel costs of \$47,000 per year are estimated based on a fuel escalation rate of 10%. This is equivalent to a present worth of \$450,000 in 1978 dollars.

4. Rapid load changes between the receiver and heater when connected in series will require thermal storage. This is because the receiver can change load at 1% per second, whereas the heater is limited to a temperature change of 10°F per minute, which is equivalent to a load change of 1.8% per minute. Storage of about 1/4 hr will be required in this case to provide the necessary thermal power to maintain constant output during the transfer of the load from the receiver to the heater.

It is estimated that 1/4 hr of thermal storage is equivalent to approximately \$1.6M in 1978 dollars.

5. Larger number of thermal cycles will require more expensive design analyses and design requirements to mitigate thermal stresses for the series connected components.

It is estimated that the engineering design and analysis costs for the series connected components could result in increased costs of up to 30%. The life and reliability of these components will be severely impaired by the continuous thermal cycling with load changes. This is a one-time nonrecurring cost for the hybrid plant.

Table B-3 presents a summary of the estimated additional capital price required for the series configuration and indicates that an additional price of 2.9 million dollars would be required for the series configuration when compared to the parallel configuration. In addition, \$900,000 of nonrecurring capital price would be required for the design and analyses associated with the thermal cycling problem.

TABLE B-3
ESTIMATED ADDITIONAL CAPITAL PRICE
REQUIRED FOR SERIES CONFIGURATION

<u>Item</u>	<u>Capital Price \$1000 (1978)</u>
1. Replace carbon steel piping and valves with stainless steel	160
2. Install stainless steel piping and valves for bypass	700
3. Make up for heat losses using coal-fired sodium heater	450
4. Provide 1/4 hr of thermal storage for rapid load changes	1,600
Subtotal	2,910
5. Additional design and analyses for thermal cycling*	900
TOTAL	3,810

*Nonrecurring price

VII. SUMMARY AND CONCLUSIONS

Based on the foregoing, it was concluded that the parallel configuration for the solar receiver and the fossil-fired sodium heater is the preferred arrangement for the baseline hybrid plant. This configuration offers the following major technical advantages over the series arrangements:

- 1) Thermal cycling of components is minimized, because load changes are effected by variation in flow rate and not temperature rise, since outlet temperature from heater and receiver is maintained constant at all loads
- 2) Sodium system is easier to control by varying flow rate
- 3) Carbon steel can be utilized for sodium riser and inlet piping to receiver
- 4) Thermal storage may not be a requirement for this mode of operation

Based on the economic factors previously discussed, the parallel configuration is also the most cost effective and, therefore, is the recommended choice for the reference solar central receiver hybrid plant conceptual design.

APPENDIX C

STEAM CYCLE OPTIMIZATION STUDY (N001TSR000-003)

ESG-79-30, Vol III

C-1

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

SUPPORTING DOCUMENT		NUMBER N001TSR000-003	REV LTR/CHG NO. SEE SUMMARY OF CHG
PROGRAM TITLE Solar Central Receiver Hybrid Power System		DOCUMENT TYPE Trade Study Report	
DOCUMENT TITLE Steam Cycle Optimization Study		KEY NOUNS Solar, Hybrid, Steam Cycle	
		ORIGINAL ISSUE DATE	
PREPARED BY/DATE J. J. Auleta <i>[Signature]</i>		DEPT 731	MAIL ADDR JB10
IR&D PROGRAM? YES ☐ NO ☒ IF YES, ENTER TPA NO.		GO NO. 09315	S/A NO. 14000
		PAGE 1 OF 26 TOTAL PAGES	
		REL DATE 4-4-79 <i>sw</i>	
SECURITY CLASSIFICATION			
(CHECK ONE BOX ONLY)			
UNCL ☒ DOE ☐ DOD ☐			
CONF. ☐			
SECRET ☐			
(CHECK ONE BOX ONLY)			
RESTRICTED DATA ☐			
DEFENSE INFO. ☐			
APPROVALS B. Katz <i>[Signature]</i> 3/16/79 T. H. Springer <i>[Signature]</i> 3/26/79 S. J. Stachura <i>[Signature]</i> 4/4/79		AUTHORIZED CLASSIFIER DATE	
DISTRIBUTION		ABSTRACT	
*	NAME	MAIL ADDR	
	E. B. Ash	LA24	Seventeen steam cycles were compared to select an optimum cycle for the solar hybrid 100-MWe conceptual design study. Turbine steam conditions considered were 1815 psia, 2415, and 3515 psia with single and double reheats at 1000°F and 1050°F. HARP (Heater Above Reheat Point) cycles at 1815 and 2415 psia were also compared. The basis of comparison was total annual costs, consisting of major equipment first costs and annualized fuel costs, all in terms of differentials. Results show that the most cost-effective steam cycle is the 1815 psia, 1000°F/1000°F, single reheat cycle with HARP and, therefore, this cycle has been selected for the conceptual design study.
*	L. E. Glasgow	LB39	
*	T. L. Johnson	LA19	
	B. Katz	LA19	
	M. P. Moriarty	LA19	
*	T. H. Springer(3)	LA13	
	S. J. Stachura	JB10	
*	W. W. Willcox	LA19	
*	W. B. Thomson	LA19	
	A. Z. Frangos	LA19	
731-B.284/jbv/clh			
* COMPLETE DOCUMENT NO ASTERISK, TITLE PAGE/SUMMARY OF CHANGE PAGE ONLY			
RESERVED FOR PROPRIETARY/LEGAL NOTICES			

CONTENTS

	<u>Page</u>
I. INTRODUCTION.....	4
II. GENERAL APPROACH.....	4
III. STEAM CYCLES STUDIED.....	5
IV. MAJOR COMPONENTS.....	7
V. SODIUM TEMPERATURES.....	9
VI. STEAM GENERATOR.....	9
VII. PLANT CAPITAL COSTS.....	10
VIII. ADDED PUMP AND MOTOR COST.....	12
IX. PIPING AND VALVE COSTS.....	13
X. FUEL SAVINGS.....	13
XI. SUMMARY AND CONCLUSIONS.....	13
APPENDICES.....	17
A. Summary Data Sheets - Estimated Differential Costs.....	16
B. Estimated Turbine-Generator Performance and Cost Data.....	22

FIGURES

<u>Figure</u>	<u>Page</u>
C-1. Typical Schematic - Solar Hybrid Generating System.....	8
C-2. Temperature vs Enthalpy Diagram Illustrating Temperature "Pinch Point" for Base Case.....	11
C-3. Differential Annual Costs.....	15

TABLES

<u>Table</u>	<u>Page</u>
C-1. Steam Cycle Conditions Studied.....	6
C-2. Differential Costs - Steam Cycle Optimization Study.....	14

I. INTRODUCTION

This report presents the results of a study conducted to select a turbine steam cycle that will give the most cost effective arrangement for the solar central receiver hybrid power system conceptual design. Seventeen steam cycles were analyzed and annualized capital and fuel costs for plants designed for each of these cycles were calculated and compared for minimum costs. A discussion and results of the cost study follows.

II. GENERAL APPROACH

Thermal energy generated in the hybrid plant is transferred from the sodium receiver and fossil fired sodium heater to the steam generator equipment by means of the high temperature sodium. The properties of sodium offer the capability of generating steam at high temperatures. In addition to this advantage, sodium also enables low system operating pressures.

The thermal energy transferred to the steam generator is used to generate steam for the turbine generator. Potential energy of the steam is transformed into mechanical energy in the turbine. The efficiency of this conversion process is a function of the temperature difference between the steam entering and leaving the turbine. Improvements in steam cycle efficiency may be obtained by raising the steam throttle pressure and temperature; reheating the steam in one or more steps during its expansion; and regenerative or feed-heating cycle, where steam is withdrawn from the turbine at various points to supply heat to the feedwater. The economical limit of the cycle for a particular plant may be determined by a study of relative costs and savings.

Seventeen steam cycles were selected for comparison and analysis for the hybrid plant. The basis of comparison was total annual costs, consisting of major equipment first cost and annualized fuel costs all in terms of differentials.

The major component in the sodium portion of the plant that is affected by the steam cycle conditions is the steam generators. For each of the seventeen cases studied, a differential capital cost for the steam generating equipment was determined. Differential capital costs for the turbine-generation equipment were furnished by Stearns-Roger. The remaining differential capital costs of the hybrid plant were calculated based on the assumption that these costs vary directly with thermal power to the 0.7 power for a fixed net plant electrical output. The total differential plant capital costs were subsequently determined and converted to an annual cost basis based on an 18% fixed charge rate. Finally, annual fuel savings costs were calculated and subtracted from the annual capital costs to arrive at the optimum steam cycle configuration.

Following is a detailed discussion of the procedure followed.

III. STEAM CYCLES STUDIED

The study effort was based on an economic analysis of three standard steam pressure conditions common to the power industry. These pressures were 1815, 2415, and a supercritical pressure of 3515 psia. Steam temperatures of 1000° and 1050°F were studied. Steam cycles with both single reheat and double reheat were considered, including single reheat cycles with HARP (Heater Above Reheat Point). A tabulation of the specific cases studied is given in Table C-1. Also included are the gross cycle efficiencies and final feedwater temperatures for each of the cases studied.

TABLE C-1
STEAM CYCLE CONDITIONS STUDIED

Case No.	Type Cycle	Gross Cycle Eff.	Throttle Pressure	Temperature	1st Reheat		2nd Reheat		No. FW Heaters	Final FW Temperature
					Pressure	Temperature	Pressure	Temperature		
			psia	°F	psia	°F	psia	°F		°F
1*	Single-Reheat	43.2	1815	1000	407	1000	-	-	6	453.6
2		43.8	1815	1050	407	1050	-	-	6	453.6
3		43.9	1815	1050	407	1050	-	-	7	453.6
4		44.2	2415	1000	542	1000	-	-	6	483
5		44.3	2415	1000	542	1000	-	-	7	483
6		45.0	2415	1050	542	1050	-	-	7	483
7	Single-Reheat with HARP	43.5	1815	1000	297	1000	-	-	6 HARP	483.5
8		43.6	1815	1000	328	1000	-	-	7 HARP	483.5
9		44.1	1815	1050	298	1050	-	-	6 HARP	483.5
10		44.2	1815	1050	328	1050	-	-	7 HARP	483.5
11		44.6	2415	1000	433	1000	-	-	7 HARP	514.8
12		45.3	2415	1050	433	1050	-	-	7 HARP	514.8
13	Double-Reheat	44.2	1815	1000	407	1000	136	1000	7 (2 RH)	453.6
14		45.2	2415	1000	542	1000	178	1000	7 (2 RH)	483
15		45.9	2415	1050	542	1050	178	1050	7 (2 RH)	483
16		45.4	3515	1000	906	1000	330	1000	8 (2 RH)	547
17		46.0	3515	1050	906	1050	330	1050	8 (2 RH)	547

*Base Case

731-B.284/jbv

Stearns-Roger prepared heat balances and furnished ESG with estimated turbine-generator performance and cost data for the seventeen cases listed in Table 1 (ESG Letter 125 ESG, January 4, 1979).

The turbine-generator cost included the turbine, generator, accessories, and installation labor. The turbine accessories included the excitation system, lube system, inlet valves, steam seal system, electro-hydraulic speed governing system, insulation and lagging, and generator H_2 and CO_2 manifolds, etc. Not included were the turbine-generator foundation, extraction piping, drain systems, condenser, heat rejection equipment, pumps, condensate piping, electrical work, etc., which were considered a standoff for the alternates considered. Feedwater heater cost was included as an incremental cost over the base 1815 psia, 1000°F/1000°F 6 feedwater heater cycle (Case 1). Likewise, the main steam, reheat and feedwater piping costs for the various cases were shown as an incremental cost over the base cycle.

IV. MAJOR COMPONENTS

The major components of the hybrid plant considered in this steam cycle study are shown schematically in Figure C-1. In addition, sodium-steam side operating temperatures and pressures are shown for the base case.

The economics pertaining to the steam cycle are based on comparing savings in cost because of the more efficient high pressure steam cycles with the added cost to the steam generating components. The cost of the remaining equipment and piping in the receiver subsystem are virtually independent of the steam pressure. However, these costs are less than the cost for the reference base case since the improvement in cycle efficiency results in a lower thermal power requirement for the solar collector, receiver, and sodium heater.

Figure C-1. Typical Schematic — Solar Hybrid Generating System

V. SODIUM TEMPERATURES

An upper temperature limit of 1100°F has been established for the sodium temperature based on the ASME Section VIII Code allowable stress values for 304 stainless steel. Limiting the temperature to 1100°F allows a margin for the peak metal temperature of the receiver which is in the range of 1250°F. Allowable stress values above this temperature drop off quite rapidly. A steam generator inlet sodium temperature of 1100°F permits the use of steam temperatures in the range of 1000° to 1050°F which are common to the power industry.

The lower sodium temperature limit is a function of the steam pressure selected for the turbine plant. With a fixed inlet temperature of 1100°F, the lower the sodium temperature out of the steam generator, the larger is the sodium temperature drop (ΔT) across the component. Since the sodium flowrate is inversely proportional to the ΔT , any increase in the ΔT results in a decrease in flowrate. For a constant thermal output, this decreased flowrate results in lower pumping power costs. Correspondingly, as the sodium ΔT is increased, the Log Mean Temperature Difference (LMTD) across the steam generator decreases, resulting in a more expensive steam generator. The incremental increase in the steam generator cost must be more than offset by the incremental savings in pumping cost to justify the use of the larger ΔT .

For this study, the sodium ΔT was varied between 500°F and 550°F. Cases 11, 12, 16, and 17 were based on a ΔT of 500°F and the remaining cases were based on a ΔT of 550°F. The supercritical pressure cases and the 2415 psia single reheat cycles with HARP require a higher sodium outlet temperature because of the temperature "pinch point" in the steam generator.

VI. STEAM GENERATOR

The steam generator selected for the hybrid plant is the same type as the one selected for the ACR study; i.e., separate evaporator, superheater, and reheater units. The evaporator is constructed of

2-1/4 Cr - 1 Mo, and the superheater and reheaters of 304 stainless steel. For the 3515 psia supercritical steam conditions, the steam generator is also divided into three sections; a low temperature section that admits feedwater and produces slightly superheated steam, a high temperature section that superheats to the final steam temperature, and a separate reheater unit. The sodium side of the reheater(s) is connected in parallel with the sodium side of the superheater as shown in Figure 1.

Steam generator differential costs were developed from cost data developed for the ACR study. The steam generators are to be designed and built to Section VIII, Division 1 of the ASME Code.

As previously mentioned, Cases 11, 12, 16, and 17 require that the sodium outlet temperature from the steam generators be increased from 550°F to 600°F in order to increase the "pinch point" in the component. The temperature approach "pinch point" is illustrated in Figure C-2.

VII. PLANT CAPITAL COSTS

As the cycle efficiency of the plant increases because of the higher steam pressures, temperatures, and number of feedwater heaters, the thermal power of the plant decreases for a fixed net plant electrical output. The cost differential for this reduction in thermal output was computed in the following manner for the cases studied.

First, the estimated overall plant capital cost for the base Case 1 was adjusted by subtracting the steam generator and turbine-generator plant costs. It was assumed that the remaining plant capital cost would vary with power level as follows:

- 1) Sodium heater capital cost varies with thermal power as the 0.85 power. This heater represents 14% of the total plant cost.
- 2) Solar collector costs varies directly with power as the 0.9 power and represents 25% of the total plant cost.

Figure C-2. Temperature vs Enthalpy Diagram Illustrating Temperature "Pinch Point" for Base Case

- 3) The sodium receiver and balance of the hybrid plant costs, varies directly with thermal power as the 0.6 power.

It was subsequently determined that a simplified cost model of this capital cost variation could be represented by varying these costs directly with thermal power raised to the 0.7 power. Thus, adjustments in plant capital costs were computed based on the following equation:

$$\text{Cost}_1 = \text{Cost}_B \left(\frac{P_1}{P_B} \right)^{.7}$$

where:

Cost 1 = Capital cost for case being studied

Cost B = Base Case 1 capital cost excluding steam generator and turbine generator costs

P_1 = Thermal power of case being studied

P_B = Thermal power of base case

VIII. ADDED PUMP AND MOTOR COST

For those cases where the sodium ΔT was reduced to 500°F, it was necessary to add an additional capital cost to account for the increase in pumping power requirements. For example, decreasing the sodium ΔT from 550°F to 500°F results in a 10% increase in sodium flowrate. Assuming the same size sodium piping, this 10% increase in flowrate results in a 30% increase in horsepower since the pumping power increases as the cube of the flow rate. Additional capital costs for the pump and motor were based on a cost of \$1000 per HP.

In addition to the capital cost for the pumping equipment, it was estimated that the additional power required to be supplied by the auxiliary power would be equivalent to a capital cost of \$1132/KWe. Both of these pumping costs were then added to the capital cost for Cases 11, 12, 16, and 17.

IX. PIPING AND VALVE COSTS

For the double reheat steam cycle cases (13 through 17), differential capital costs were added to account for the additional sodium piping and valving required for the second sodium reheater.

X. FUEL SAVINGS

As the steam cycle efficiency is increased, less thermal power is required to produce the same net electrical output. Thus, a fuel savings is realized for the improvements in efficiency. For this study, it was estimated that this annual fuel savings was equal to \$71,000 per Mwt per year. This number was calculated based on a fuel energy cost of 23.3 mills/KW hr, plant capacity factor of 90%, and a thermal power to electrical power ratio of 2.6 Mwt per MWe.

XI. SUMMARY AND CONCLUSIONS

Table C-2 presents a summary of the differential capital costs and annualized fuel costs for the seventeen steam cycle cases studied. Total annual differential costs are also plotted on a bar chart shown in Figure C-3. As shown in Figure C-3, the most cost effective steam cycle is Case 7 which is the 1815 psia single reheat cycle with HARP

Therefore, it is concluded that the optimum steam cycle conditions to be used in the hybrid plant conceptual design study is the 1815 psia single reheat cycle with steam temperatures of 1000°F/1000°F and six feedwater heaters using HARP.

TABLE C-2
DIFFERENTIAL COSTS — STEAM CYCLE OPTIMIZATION STUDY

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Sodium ΔT ($^{\circ}F$)	550										500	500	590			500	500
Throttle Pressure (psia)	1915			2415			1815				2415		1815	2415		3515	
Throttle Temperature ($^{\circ}F$)	1000	1050	1050	1000	1000	1050	1000	1000	1050	1050	1000	1050	1000	1000	1050	1000	1050
1st Reheat Pressure (psia)	407			542			297	328	298	328	433		407	542		906	
1st Reheat Temperature ($^{\circ}F$)	1000	1050	1050	1000	1000	1050	1000	1000	1050	1050	1000	1050	1000	1000	1050	1000	1050
2nd Reheat Pressure (psia)	N/A												136	178		330	
2nd Reheat Temperature ($^{\circ}F$)	N/A												1000	1000	1050	1000	1050
Number of F.W. Heaters	6	6	7	6	7	7	HARP* 6	HARP 7	HARP 6	HARP 7	HARP 7	HARP 7	2RH 7	2RH 7	2RH 7	2RH 8	2RH 8
Final F.W. Temperature ($^{\circ}F$)	483.6			483			483.5				514.8		453.6	483		547	
Gross Cycle Efficiency (%)	43.2	43.8	43.9	44.2	44.3	45.0	43.5	43.6	44.1	44.2	44.6	45.3	44.2	45.2	45.9	45.4	46.0
Thermal Power (Mwt)	259.3	255.7	255.1	253.4	252.8	248.9	247.5	256.9	254.0	253.4	251.1	247.2	253.4	247.8	244.0	246.7	243.5
Capital Cost Δ's (\$-10⁶)																	
Steam Generators	Base	+1.33	+1.35	+0.54	+0.48	+2.00	+0.45	+0.39	+1.58	+1.66	-0.50	+0.75	+1.67	+2.39	+6.18	+3.28	+6.22
Added Pumping Power	Base										+1.42	+1.42				+1.42	+1.42
Added Sodium Piping and Valves	Base												+0.20	+0.20	+0.20	+0.20	+0.20
Turbine Generator Plant	Base	+1.16	+1.26	+0.61	+0.71	+1.90	+0.05	+0.15	+1.21	+1.31	+0.76	+1.95	+2.55	+3.16	+4.98	+4.08	+6.13
Savings Plant Capital Cost [$(P_1/P_2)^{0.7} \times 110 \times 10^6$]	Base	-1.07	-1.25	-1.76	-1.94	-3.11	-0.54	-0.71	-1.58	-1.76	-2.45	-3.62	-1.76	-3.44	-4.58	-3.77	-4.74
Total Capital Cost - Δ	Base	+1.42	+1.36	-0.61	-0.75	+0.79	-0.04	-0.17	+1.21	+1.21	-0.77	+0.50	+2.66	+2.31	+6.78	+5.21	+9.23
Annual Costs (\$/year)																	
Capital at 18% FC	Base	+0.25	+0.25	-0.11	-0.14	+0.14	-	-0.03	+0.22	+0.22	-0.14	+0.09	+0.48	+0.42	+1.22	+0.94	+1.66
Fuel Savings at \$71,000/Mwt-year	Base	-0.25	-0.30	-0.42	-0.46	-0.74	-0.84	-0.17	-0.38	-0.42	-0.56	-0.86	-0.42	-0.82	-1.09	-0.89	-1.12
Total Annual Cost Δ	Base	0	-0.05	-0.53	-0.60	-0.60	-0.84	-0.20	-0.16	-0.20	-0.72	-0.77	+0.04	-0.40	+0.13	+0.05	+0.54

*HARP (Heater above reheat point)

Figure C-3. Differential Annual Costs

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

APPENDIX A
SUMMARY DATA SHEETS -
ESTIMATED DIFFERENTIAL COSTS

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * BEAM PROPERTY TABLE * * * * *

MEMB	JA	JB	LENGTH	MODULUS OF ELASTICITY	POISSON'S RATIO	MATERIAL DAMP. RATIO	AREA	MOMENT OF INERTIA	SHEAR SHAPE FACTOR
1	1	2	1.209785D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.401755D 02	4.177784D 04	5.171497D-01
2	2	3	2.433205D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.366515D 02	3.942011D 04	5.171539D-01
3	3	4	2.433200D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.320086D 02	3.642572D 04	5.171599D-01
4	4	5	2.433194D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.274393D 02	3.360266D 04	5.171662D-01
5	5	6	2.433198D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.229438D 02	3.094446D 04	5.171729D-01
6	6	7	2.433182D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.185220D 02	2.844455D 04	5.171800D-01
7	7	8	2.433175D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.141738D 02	2.609682D 04	5.171875D-01
8	8	9	2.433168D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.098994D 02	2.389504D 04	5.171955D-01
9	9	10	2.433160D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.056987D 02	2.183319D 04	5.172040D-01
10	10	11	2.433152D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.015717D 02	1.990535D 04	5.172131D-01
11	11	12	2.433143D 01	5.247600D 05	1.500000D-01	7.000000D-02	9.751841D 01	1.810572D 04	5.172280D-01
12	12	13	2.433133D 01	5.247600D 05	1.500000D-01	7.000000D-02	9.353883D 01	1.642655D 04	5.172332D-01
13	13	14	2.433122D 01	5.247600D 05	1.500000D-01	7.000000D-02	8.963296D 01	1.486858D 04	5.172443D-01
14	14	15	2.433111D 01	5.247600D 05	1.500000D-01	7.000000D-02	8.580680D 01	1.342010D 04	5.172563D-01
15	15	16	2.433098D 01	5.247600D 05	1.500000D-01	7.000000D-02	8.204236D 01	1.207791D 04	5.172693D-01
16	16	17	1.225956D 01	5.247600D 05	1.500000D-01	7.000000D-02	7.926478D 01	1.113554D 04	5.172796D-01
17	17	18	3.000000D 00	4.176000D 06	3.000000D-01	7.000000D-02	1.968900D 00	2.722400D 02	0.0
18	18	19	1.650000D 01	4.176000D 06	3.000000D-01	7.000000D-02	1.968900D 00	2.722400D 02	0.0
19	19	20	1.100000D 01	4.176000D 06	3.000000D-01	7.000000D-02	1.968900D 00	2.722400D 02	0.0
20	20	21	1.100000D 01	4.176000D 06	3.000000D-01	7.000000D-02	1.968900D 00	2.722400D 02	0.0
21	21	22	1.000000D 01	4.176000D 06	3.000000D-01	7.000000D-02	1.968900D 00	2.722400D 02	0.0
22	22	23	1.200000D 01	4.176000D 06	3.000000D-01	7.000000D-02	1.968900D 00	2.722400D 02	0.0
23	23	24	1.750000D 01	4.176000D 06	3.000000D-01	7.000000D-02	1.968900D 00	2.722400D 02	0.0
24	24	25	1.900000D 01	4.176000D 06	3.000000D-01	7.000000D-02	1.968900D 00	2.722400D 02	0.0

ESG-79-30, Vol III

ESTIMATE OF STEAM GENERATOR CAPITAL COST - SUPERHEATER

DATA SHEET

CASE No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SUPERHEATER																	
S.H. TEMP °F	1000	1050	1050	1000	1000	1050	1000	1000	1050	1050	1000	1050	1000	1000	1050	1000	1050
h _{SN} BTU/lb	1480.1	1510.8	1510.8	1460.4	1460.4	1493.2	1480.1	1480.1	1510.8	1510.8	1460.4	1493.2	1480.1	1460.4	1493.2	1481.7	1459.3
Δh = h _{SN} - h _g BTU/lb	341.8	372.5	372.5	378.4	378.4	411.2	341.8	341.8	372.5	372.5	378.4	411.2	341.8	378.4	411.2	325.7	350.3
THROTTLE FLOW lb/hr	729,242	699,548	697,346	740,907	738,081	706,764	735,570	737,554	704,744	706,496	752,046	718,889	649,945	657,236	628,852	792,677	698,674
SH DUTY - 10° BTU/hr	2.49	2.61	2.60	2.50	2.79	2.91	2.51	2.52	2.63	2.63	2.84	2.96	2.72	2.49	2.59	2.39	2.46
SH DUTY - MWE	73	76.3	76.1	82.1	81.8	85.2	73.7	73.9	76.9	77.1	83.4	88.6	65.1	72.9	75.8	70	72
% TOTAL POWER	28%	30	30	32	32	34	29	29	30	30	33	36	26	29	31	28.5	29
SOD. FLOW WNA 10° lb/hr	3.59	3.60	3.58	3.59	3.60	3.61	3.44	3.47	3.55	3.55	3.83	3.88	2.86	2.86	2.97	3.08	3.15
SOD. TEMP. IN - °F	1100																
SOD. TEMP. OUT - °F	869	858	858	840	842	831	859	858	853	853	853	846	841	814	809	841	840
SOD. ΔT - °F	231	242	242	260	258	269	243	242	247	247	247	254	259	286	291	259	260
STEAM FLOW WNA 10° lb/hr	7.29	7.00	6.97	7.41	7.38	7.07	7.36	7.38	7.05	7.06	7.52	7.19	6.50	6.57	6.29	7.33	6.99
STEAM TEMP. IN - °F	636	636	636	674	674	674	686	686	636	636	674	674	636	674	674	750	752
STEAM TEMP. OUT - °F	1000	1050	1050	1000	1000	1050	1000	1000	1050	1050	1000	1050	1000	1000	1050	1000	1050
STEAM ΔT - °F	364	414	414	326	326	376	364	364	414	414	326	376	364	326	376	250	298
GREATER ΔT - STD - °F	233	222	222	166	168	157	221	222	217	217	179	172	205	140	135	100	88
LEAST ΔT - LTD - °F	100	50	50	100	100	50	100	100	50	50	100	50	100	100	50	91	50
LOG MEAN ΔT - LTD - °F	157	115	115	130	131	94	153	153	114	114	136	99	146	119	86	95	67
OVERALL U° BTU/hr-ft²-F	400			420			400				420		400			500	
AREA - Q/ΔT - LT - ft²	3965	5674	5652	5128	5071	7371	4101	4118	5766	5766	4972	7272	3801	4981	7171	5032	7343
SURFACE AREA LOG ΔT - ft²	359			315			359				315		359			400	
SUPERHEATER COST 100¢	1.42	2.04	2.03	1.62	1.60	2.32	1.47	1.48	2.07	2.07	1.57	2.29	1.37	1.57	2.26	2.01	2.94

ESTIMATE OF STEAM GENERATOR CAPITAL COST - REHEATER

DATA SHEET

CASE NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 ST REHEATER																	
STEAM TEMP. OUT - °F	1000	1050	1050	1000	1000	1050	1000	1000	1050	1050	1000	1050	1000	1000	1050	1000	1050
STEAM PRESS. OUT - PSIA	407	→	→	542	→	→	297.5	327.7	297.5	327.7	433.1	→	407.0	542.0	→	906.0	→
h OUT - BTU/lb	1523	1544.8	→	1519.1	→	1546.2	1526.2	1525.4	1552.8	1552.0	1522.9	1549.1	1523.1	1519.1	1545	1508.3	1536.3
STEAM TEMP. IN - °F	656	698.4	698.5	651.7	→	694.4	586.0	607.1	626.2	647.9	601.2	642.2	657.2	653.3	696.1	702.2	748.8
STEAM PRESS. IN - PSIA	452.2	→	→	602.2	→	→	330.6	364.1	330.6	364.1	481.2	→	452.2	602.2	→	1041.4	→
h IN - BTU/lb	1335.7	1359.6	1359.6	1322.9	1322.6	1348.4	1305.0	1314.3	1327.4	1337.1	1301.5	1325.9	1336.5	1323.8	1349.4	1324.5	1355.5
Δh = h OUT - h IN - BTU/lb	1873	190.2	190.2	196.2	196.5	197.8	221.2	211.1	225.4	214.9	221.4	223.2	186.6	195.3	195.6	183.8	180.8
STEAM REHEAT FLOW - lb/hr	653,016	627,539	631,500	656,662	661,411	634,603	606,491	620,518	583,092	596,318	620,415	595,665	587,076	589,008	564,688	650,440	623,086
REHEATER DUTY - 10 ⁶ BTU/hr	1.22	1.19	1.20	1.29	1.30	1.26	1.34	1.31	1.31	1.28	1.37	1.33	1.10	1.15	1.10	1.20	1.12
REHEATER DUTY - MWT	36	35	35.2	37.8	38.1	36.8	39.3	38.4	38.5	37.6	40.3	39.0	32.1	33.7	32.4	35.0	33.0
% TOTAL POWER	14%	14	14	15	15	15	15	15	15	15	16	15	13	14	13	14½	14
SODIUM FLOW - WWT	1.76	1.64	1.65	1.65	1.68	1.56	1.84	1.80	1.77	1.73	1.85	1.75	1.42	1.34	1.27	1.58	1.44
SODIUM TEMP IN - °F	1100	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→	→
SODIUM TEMP OUT - °F	869	858	858	840	842	831	859	858	853	853	853	846	841	814	809	841	840
SODIUM ΔT - °F	231	242	242	260	258	269	243	242	247	247	247	254	259	286	291	259	260
STEAM FLOW - WWT - 10 ⁶ lb/hr	6.53	6.28	6.32	6.57	6.61	6.35	6.06	6.21	5.83	5.96	6.20	5.96	5.88	5.89	5.65	6.50	6.22
STEAM TEMP. IN. - °F	656	698	699	652	652	694	586	607	626	648	601	642	657	653	696	702	749
STEAM TEMP. OUT - °F	1000	1050	1050	1000	1000	1050	1000	1000	1050	1050	1000	1050	1000	1000	1050	1000	1050
STEAM ΔT - °F	344	352	351	348	348	356	414	393	424	402	399	408	343	347	354	298	301
GREATER ΔT - GTD - °F	213	160	159	188	190	137	271	251	227	205	252	204	184	161	113	139	91
LEAST ΔT - LTD - °F	100	50	50	100	100	50	100	100	50	50	100	50	100	100	50	100	50
LOG MEAN ΔT - LMDT - °F	149	95	94	139	140	86	172	178	117	110	164	110	138	128	77	118	68
OVERALL "U" - BTU/hr-ft ² -°F	240	→	→	250	→	→	230	→	→	→	250	→	240	250	→	400	→
AREA - ft ² - U-LMTD - ft ²	3412	5219	5319	3712	3714	5860	5387	3200	4868	5059	3341	4836	3321	3594	5714	2542	4118
SURFACE AREA COST - \$/ft ²	413	→	→	382	→	→	413	→	→	→	382	→	413	382	→	450	→
1 ST REHEATER COST - 10 ⁶ \$	1.41	2.16	2.20	1.42	1.42	2.24	1.40	1.32	2.01	2.09	1.27	1.05	1.37	1.37	2.18	1.14	1.85

ESG-79-30, VOL III

C-22

NOD17SR000-003
Page 19

DATA SHEET

ESTIMATE OF 2ND REHEATER CAPITAL COST

CASE NO.	13	14	15	16	17
2ND REHEATER					
STEAM REHEAT TEMP OUT - °F	1000	1000	1050	1000	1050
STEAM PRESSURE OUT - PSIA	136.3	178.4	178.4	330.4	330.4
h _{OUT} - BTU/lb	1530.9	1529.7	1556.0	1525.3	1551.9
STEAM REHEAT TEMP IN - °F	735.6	729.8	773.6	760.0	805.2
STEAM PRESS IN - PSIA	151.5	198.2	198.2	379.7	379.7
h _{IN} - BTU/lb	1395	1389.6	1412.1	1396.7	1420.7
Δh = h _{OUT} - h _{IN} - BTU/lb	136.1	140.1	143.9	128.6	131.2
REHEATER FLOW - STEAM - lb/HR	558,150	553,753	532,056	605,860	580,998
REHEATER DUTY - 10 ⁸ BTU/HR	75.96	77.58	76.56	77.91	76.23
REHEATER DUTY - MWt	22.3	22.7	22.4	22.8	22.3
% TOTAL POWER - %	8%	9%	9%	9%	9%
SODIUM FLOW - WNa - 10 ⁶ lb/HR	0.98	0.90	0.88	1.03	0.98
SOD. TEMP. IN - °F	1100	1100	1100	1100	1100
SOD. TEMP. OUT - °F	841	814	809	841	840
SOD. ΔT - °F	259	286	291	259	260
STEAM FLOW - 10 ⁵ lb/HR	5.58	5.54	5.32	6.06	5.81
STEAM TEMP IN - °F	736	730	774	760	805
STEAM TEMP OUT - °F	1000	1000	1050	1000	1050
STEAM ΔT - °F	264	270	276	240	245
GREATER ΔT - GTD - °F	105	100	50	100	50
LEAST ΔT - LTD - °F	100	84	35	81	35
LOG MEAN ΔT - LMTD - °F	102	92	42	90	42
OVERALL U - BTU/HR-FT ² -°F	200	200	200	350	350
AREA = Q/U-LMTD - FT ²	3724	4216	9114	2473	5185
SURFACE AREA COST - \$/FT ²	500	480	480	500	500
2ND REHEATER COST - 10 ⁶ \$	1.86	2.02	4.38	1.24	2.59

ESG-79-30, Vol III

C-23

TOTAL AND DIFFERENTIAL COSTS - HYBRID PLANT PARAMETRIC STEAM CYCLE STUDY

2-5-79 J. HULLER

DATA SHEET

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. THROTTLE PRESS. PSIA	1815	1815	1815	2415	2415	2415	1815	1815	1815	1815	2415	2415	1815	2415	2415	3515	3515
2. GROSS CYCLE EFF. %	43.2	43.8	43.9	44.2	44.3	45.0	43.5	43.6	44.1	44.2	44.6	45.3	44.2	45.2	45.9	45.4	46.0
3. Δ EFFICIENCY - %	BASE	+0.6	+0.7	+1.0	+1.1	+1.8	+0.3	+0.4	+0.9	+1.0	+1.4	+2.1	+1.0	+2.0	+2.7	+2.2	+2.8
4. STEAM GEN. POWER MWT	259.3	255.7	255.1	253.4	252.8	248.9	247.5	256.9	254.0	253.4	251.1	247.2	253.4	247.8	244.0	246.7	243.5
5. Δ S.G. POWER MWT	BASE	-3.6	-4.2	-5.9	-6.5	-10.4	-11.8	-2.4	-5.3	-5.9	-8.2	-12.1	-5.9	-11.5	-15.3	-12.6	-15.8
6.																	
7.																	
8.																	
9. STEAM GENERATOR PRICE																	
10. EVAPORATOR - \$10 ⁶	2.63	2.59	2.58	2.96	2.92	2.90	3.04	3.05	2.96	2.96	2.12	2.07	2.53	2.89	2.62	4.35	4.30
11. SUPERHEATER - \$10 ⁶	1.42	2.04	2.03	1.62	1.60	2.32	1.47	1.48	2.07	2.07	1.57	2.29	1.37	1.57	2.26	2.01	2.94
12. 1 ST REHEATER - \$10 ⁶	1.41	2.16	2.20	1.42	1.42	2.24	1.40	1.32	2.01	2.09	1.27	1.85	1.37	1.37	2.18	1.14	1.85
13. 2 ND REHEATER - \$10 ⁶	—	—	—	—	—	—	—	—	—	—	—	—	1.86	2.02	4.38	1.24	2.59
14. TOTAL S.G. PRICE \$10 ⁶	5.46	6.79	6.81	6.00	5.94	7.46	5.91	5.85	7.04	7.12	4.96	6.21	7.13	7.85	11.64	8.74	11.68
15. Δ S.G. PRICE \$10 ⁶	BASE	+1.33	+1.35	+0.54	+0.48	+2.00	+0.45	+0.39	+1.58	+1.66	-0.50	+0.75	+1.67	+2.39	+6.18	+3.28	+6.22
16.																	
17. ADDED PUMP + MOTOR COST \$10 ⁶	BASE	—	—	—	—	—	—	—	—	—	+1.42	+1.42	—	—	—	+1.42	+1.42
18. Δ T = 500°F INSTEAD OF 475°F																	
19.																	
20. ADDED SOD. PUMP & VALVE \$10 ⁶	BASE	—	—	—	—	—	—	—	—	—	—	—	+0.20	+0.20	+0.20	+0.20	+0.20
21.																	
22. TURBINE GEN. COST \$10 ⁶	12.34	13.50	13.60	12.95	13.05	14.24	12.39	12.49	13.55	13.65	13.10	14.29	14.89	15.50	17.32	16.42	18.47
23. Δ TURBINE GEN. COST \$10 ⁶	BASE	+1.16	+1.26	+0.61	+0.71	+1.90	+0.05	+0.15	+1.21	+1.31	+0.76	+1.75	+2.55	+3.16	+4.98	+4.08	+6.13
24.																	
25. REMAINING PLANT COST \$10 ⁶																	
26. \$100 x 10 ⁶ (P/P ₀) ⁻¹	110.00	108.93	108.75	108.24	108.06	106.89	109.46	109.29	108.42	108.24	107.55	106.38	108.24	106.56	105.42	106.23	105.26
27. Δ SAVINGS - PLANT COST \$10 ⁶	BASE	-1.07	-1.25	-1.76	-1.94	-3.11	-0.54	-0.71	-1.58	-1.76	-2.45	-3.62	-1.76	-3.44	-4.58	-3.77	-4.78
28.																	
29. TOTAL CAPITAL \$10 ⁶	127.80	129.22	129.16	127.19	127.05	128.59	127.76	127.63	129.01	129.01	127.03	128.30	130.46	130.11	134.58	133.01	137.03
30. Δ CAPITAL \$10 ⁶	BASE	+1.42	+1.36	-0.61	-0.75	+0.79	-0.04	-0.17	+1.21	+1.21	-0.77	+0.50	+2.66	+2.31	+6.78	+5.21	+9.23
31.																	
32. ANNUAL Δ FUEL SAVINGS \$10 ⁶ /yr																	
33. \$7,000/yr MWT x AMWT	BASE	-0.26	-0.30	-0.42	-0.46	-0.74	-0.84	-0.17	-0.38	-0.42	-0.58	-0.86	-0.42	-0.82	-1.09	-0.89	-1.12
34.																	
35.																	
36.																	
37.																	
38.																	

ESG-79-30, VOL III

C-24

NO. 1 SR000-003

APPENDIX B
ESTIMATED TURBINE-GENERATOR PERFORMANCE
AND COST DATA

RECEIVED
JAN 8 1979

Correspondence Dept.

January 4, 1979

ENC To
Springer

ANDERSON, M
MAYNARD
C. Ash x
DALENT
DAUMASH
JEN + B. =
BRINDLEY
CARDENAS
CCHARRAN, J C
CRANFORD
DE LOS PRADOS
DETTERMAN
E. VINSON x
FEILER
GULFE
HARTZLER
HILLIG
HOLBROOK

Rockwell International
Energy Systems Group
8900 DeSota Avenue
Canoga Park, California 91304

Re: C-21725-S

Attention: Mr. T. H. Springer

Subject: Estimated Turbine-Generator Performance
and Cost Data
Solar Central Receiver Hybrid Power System
Phase I

Reference: AI Contract N935-0012FX
DOE Contract ET-78-C-03-2233

Dear Mr. Springer:

Enclosed please find three (3) copies of tabulation dated January 3, 1979 showing estimated turbine-generator performance and cost data (17 cases) for the 100 MW_e commercial plant.

In addition to the baseline turbine conditions, i.e. 1800 psig - 1000°/1000°F, we have considered 2400 psig and 3500 psig with single and double reheats at 1000°F and 1050°F. HAR^P (heater above reheat point) cycles at 1800 psig and 2400 psig were also analyzed.

The turbine-generator cost includes the turbine, generator, accessories and installation labor. The turbine accessories would include the excitation system, lube system, inlet valves, steam seal system, electrohydraulic speed governing system, insulation and lagging, and generator H₂ and CO₂ manifolds, etc. Not included is the turbine-generator foundation, extraction piping, drain systems, condenser, heat rejection equipment, pumps, condensate piping, electrical work, etc., which is considered a standoff for the alternates considered. Feedwater heater cost is included as an incremental cost over the base 1800 psig, 1000°/1000°F, 6 heater cycle. Likewise the main steam, reheater and feedwater piping costs for the various cases are shown as an incremental cost over the base cycle.

WITTINGER		
WOLIN		
WULOVICS		
WURTIN AB		
WYKOURT		
WYDERFUETT		
WYDONALD JS		
WYKENTZIE DE		
WYEVERS GN		
WYDERWITZ		
WYDSES		
WYDURPHY		
WYDDEKAMP		
WYDARER T		
WYDARINS		
WYDERJUL		
WYDRELEY		
WYDECKECK		
WYDERS		
WYDERIV		
WYDSTONE		
WYDTONUM		
WYDWARD		
WYDILLER		
WYDSEKICA		
WYDWILLIAMS		

Springer

St. L. Johnson

GOV

U/C

route 62

S. Tucker

ESG-79-30, Vol III
C-26

12565g

Stearns-Roger

PAGE 2

Rockwell International
Energy Systems Group
Canoga Park, CA 91304

January 4, 1979

Please advise if you have any questions, or desire additional work in this task.

Very truly yours,

STEARNS-ROGER ENGINEERING CO.

Allen W. McKenzie
Allen W. McKenzie
Project Engineer

AWM:vr

Enclosure — *To Springer*

cc: W.R. Lang - w/encl.
L. J. Dubberly - w/encl.

11	12	13	14	15	16	17
TC2F-23 (HARP)	TC2F-23 (HARP)	TC2F-23 (2RH)	TC2F-23 (2RH)	TC2F-23 (2RH)	TC2F-23 (SC-2RH)	TC2F-23 (SC-2RH)
112,000	112,000	112,000	112,000	112,000	112,000	112,000
7,641	7,533	7,720	7,541	7,430	7,523	7,412
44.6	45.3	44.2	45.2	45.9	45.4	46.0
2,415	2,415	1,815	2,415	2,415	3,515	3,515
1,000	1,050	1,000	1,000	1,050	1,000	1,050
752,000	718,900	649,900	657,200	628,850	732,700	698,700
433	433	407	542	542	906	906
1,000	1,050	1,000	1,000	1,050	1,000	1,050
620,400	595,700	587,700	598,000	564,700	650,400	622,100
N/A	N/A	136	178	178	330	330
		1,000	1,000	1,050	1,000	1,050
		558,150	553,750	532,100	605,900	581,000
2.0	2.0	2.0	2.0	2.0	2.0	2.0
493,700	476,000	469,300	458,100	441,400	473,100	455,300
476	464	482	464	451	470	456
514.8	514.8	453.6	483.0	483.0	547.0	547.0
7	7	7	7	7	8	8
12,745,000	13,660,000	14,490,000	14,895,000	16,345,000	15,296,000	16,747,000
200,000	200,000	150,000	200,000	200,000	400,000	400,000
150,000	425,000	250,000	400,000	775,000	725,000	1,325,000
13,095,000	14,285,000	14,890,000	15,495,000	17,320,000	16,421,000	18,472,000
131	143	149	155	173	164	185

JOB NO. C21725 DATE 1-17-77

CUSTOMER ROCKWELL INTL INC 100 MAW SOLAR HYBRID

SUBJECT HEAT BALANCE DATA

CASE NO.	1	2	3	4	5	6	7	8	9
TURB. INLET									
FLOW ¹ / _{HR}	729242	699548	697346	740917	738081	706764	735570	737554	704764
TEMP °F	1000	1050	1050	1000	1000	1050	1000	1000	1050
PRESS PSIA	1815	1815	1815	2415	2415	2415	1815	1815	1815
ENTH Btu	1480.1	1510.8	1510.8	1460.4	1460.4	1493.2	1480.1	1480.1	1510.8
HP TURB EXH									
FLOW	653016	627539	631500	656662	661411	634603	606491	620518	583692
TEMP	656.0	698.4	698.5	651.7	651.7	694.4	586.0	607.1	626.2
PRESS	452.2	452.2	452.2	602.2	602.2	602.2	330.6	364.1	330.6
ENTH	1335.7	1359.6	1359.6	1322.9	1322.9	1348.4	1305.6	1314.3	1327.4
RR TURB IN									
TEMP	1000	1050	1050	1000	1000	1050	1000	1000	1050
PRESS	407.0	407.0	407.0	542.0	542.0	542.0	297.5	327.7	297.5
ENTH	1523.0	1549.8	1549.8	1519.1	1519.1	1546.2	1526.2	1525.4	1552.8
CASE NO.	10	11	12	13	14	15	16	17	18
TURB. INLET									
FLOW	706496	752016	718889	647945	657136	628852	732677	698674	
TEMP	1050	1000	1050	1000	1000	1050	1000	1050	
PRESS	1815	2415	2415	1815	2415	2415	3515	3515	
ENTH	1510.8	1460.4	1493.2	1430.1	1460.4	1493.2	1421.7	1459.3	
HP TURB EXH									
FLOW	596338	620415	595665	587096	589008	564688	650440	622086	
TEMP	647.9	601.2	642.2	657.2	653.3	696.1	702.2	748.8	
PRESS	369.1	451.2	451.2	452.2	602.2	602.2	1141.4	1041.4	
ENTH	1337.1	1301.5	1325.9	1336.5	1323.2	1349.4	1324.5	1355.5	
1ST RR TURB IN									
TEMP	1050	1000	1050	1000	1000	1050	1000	1050	
PRESS	327.7	433.1	433.1	407.0	542.0	542.0	906.0	906.0	
ENTH	1552.0	1522.9	1549.1	1523.1	1519.1	1545.4	1508.3	1536.3	
1ST RR TURB EXH									
FLOW				558150	553753	592056	605810	580998	
TEMP				735.4	729.8	773.6	760.0	805.2	
PRESS				151.5	198.2	198.2	379.7	379.7	
ENTH				1394.8	1389.6	1412.1	1396.7	1420.7	
2ND RR TURB IN									
TEMP				1000	1000	1050	1000	1050	
PRESS				136.3	175.4	175.4	330.4	330.4	
ENTH				1530.9	1529.7	1556.0	1523.3	1551.9	

APPENDIX D
TOWER ANALYSIS AND RECEIVER MASS DISTRIBUTION

ESG-79-30, Vol III

D-1

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Stearns-Roger

JOB NO. 21725 DATE 6/18/79 PAGE 1
BY RJC CHK.
CUSTOMER _____ PROJECT _____
SUBJECT SOLAR CENTRAL RECEIVER FOR HYBRID POWER SUBSYSTEM

Stearns-Roger

PAGE 2

JOB NO. 21725

DATE 6/18/79

BY RJC

CHK.

CUSTOMER

PROJECT

SUBJECT DESIGN PARAMETERS

SEISMIC LOADS

GROUND RESPONSE SPECTRA FROM NRC REG. GUIDE 1.60

MAX. HOR. GROUND ACCEL. = .35 G'S

MAX. VERT. GROUND ACCEL. = .35 G'S

DAMPING RATIO = .07 (FROM NRC REG. GUIDE 1.61)

WIND LOADS

WIND VELOCITY @ 30' = 90 MPH

LOADS BASED ON ANSI A58.1-1972.

REINFORCED CONCRETE DESIGN

CONCRETE f'_c = 4 KSI

REBAR f_y = 60 KSI

VERTICAL REBAR DETERMINED PER STRENGTH DESIGN PROVISIONS
OF ACI 318-71.

LOAD COMBINATIONS:

- 1) $0.75 (1.4D + 1.7W)$
- 2) $0.9D + 1.3W$
- 3) $0.75 (1.4D + 1.87E)$
- 4) $0.9D + 1.43E$ (E OPPOSING D)

HOOP REBAR SIZED IN ACCORD WITH ACI 307-69.

RECENER STIFFNESS

RECENER STIFFNESS ASSUMED EQUAL TO 20% OF
TOWER STIFFNESS AT TOP.

Stearns-Roger

PAGE 3

JOB NO. 21725

DATE 6/18/79

BY RJC

CHK.

CUSTOMER

PROJECT

SUBJECT DESIGN PARAMETERS (CONT'D)

EQUIVALENT AREA AND MOMENT OF INERTIA OF RECEIVER STRUCTURE:

$$E_R = 4176000 \text{ K/ft}^2 \text{ (STEEL)}$$

$$E_C = 524760 \text{ K/ft}^2 \text{ (FOR CONC. W/ } f'_c = 4 \text{ KSI)}$$

$$A_R = .2 \frac{E_C}{E_R} \left[\frac{\pi (D_o^2 - D_i^2)}{4} \right]$$

$$= .2 \times \frac{524760}{4176000} \left[\frac{\pi (34^2 - 32.5^2)}{4} \right] = 1.9689 \text{ ft}^2$$

$$I_R = .2 \frac{E_C}{E_R} \left[\frac{\pi (D_o^4 - D_i^4)}{64} \right] = 272.24 \text{ ft}^4$$

MAT FOUNDATION

$$\text{CONCRETE } f'_c = 3 \text{ KSI}$$

$$\text{REBAR } f_y = 60 \text{ KSI}$$

ALLOWABLE NET SOIL BEARING PRESS = 10 KSF

FOR OVERTURNING, POSITIVE PRESSURE MUST BE MAINTAINED OVER AT LEAST 80% OF MAT CONTACT AREA.

REBAR WT. ASSUMED = 75 #/cu. yd.

TOWER ANALYZED AS FIXED BASE MODEL.

Stearns-Roger

PAGE 4

JOB NO. 21725

DATE 6/18/79

BY RJC

CHK

CUSTOMER

PROJECT

SUBJECT RECEIVER WEIGHTS

Structure Mat'l	=	200 K
SS Liner	=	50 K
Outer Shell	=	50 K
Insulation	=	5 K
		<u>305 K</u>

Receiver Panels	=	20 K
Headers + Insulation	=	29 K
Tubing	=	40 K
Valves	=	28 K
Pumps	=	4.5 K
		<u>114.5 K</u>

TOTAL WT. ABOVE = 305 + 52 + 114.5 + 19 + 126 + 244 = 860.5 K

ESG-79-30, Vol III

D-6

Stearns-Roger

JOB NO. 21725 DATE 6/18/79 PAGE 5
BY RJC CH'K. _____
CUSTOMER _____ PROJECT _____
SUBJECT RECEIVER MODEL

NODE	W _x	W _y
18	41.96	136.72
19	79.93	63.92
20	75.96	64.41
21	66.24	55.21
22	306.18	294.63
23	60.59	45.11
24	181.66	162.50
25	47.98	38.00
Σ	860.50	860.50

Stearns-Roger

PAGE 6

JOB NO. 21725

DATE 6/18/79

BY RJC

CHK.

CUSTOMER

PROJECT

SUBJECT MATERIAL QUANTITIES

TOWER

1) CONCRETE $f'_c = 4 \text{ KSI}$
VOLUME = 1466 cu. yds

2) REBAR $f_y = 60 \text{ KSI}$
WT. = 175 TONS

FOUNDATION MAT

1) CONCRETE $f'_c = 3 \text{ KSI}$
VOLUME = 5027 cu. yds

2) REBAR $f_y = 60 \text{ KSI}$
WT. = 189 TONS

3) SOIL EXCAVATION = 7055 cu. yds

** 3163 - CONCRETE TOWER ANALYSIS PROGRAM ** INPUT DATA CARD LIST.

(																		CARD COLUMNS										)
CARD NO.	1	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80											
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*											
1	SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM																											
2	1	0	8	1	1	1	1	0	0			32.2			FT		KIPS											
3																												
4																												
5	15			524760		15		15		.07		.625																
6		17.		25.		.75		.9167		365.		1.063		1.063														
7		41.96		136.72				331.5		.625																		
8	4176000.			3		1.5689		272.24				3.		.07														
9		79.93		63.92				518.5																				
10												16.5																
11		75.96		64.41				374.																				
12												11.																
13		66.24		55.21				357.																				
14												11.																
15		306.18		294.63				374.																				
16												10.																
17		60.59		45.11				501.5																				
18												12.																
19		181.66		162.5				620.5																				
20												12.5																
21		47.98		38.				323.																				
22												19.																
23	2.38E-6			.2		.2		38.		.04		103.																
24	90.			C				42.		365.				.02														
25	0	0		0.		.35		.35																				
26	-1	999		99.																								
27	-1	999		99.																								
28		4.		60.		.0033		.05	.00138889		.002		.49															
29		1.05		1.40		1.40		.9	1.43		-1.43																	
30		1.05		1.28		.9		1.3	1.05		1.28		.9		1.3													
31		7.407407		500.																								

D-9
ESG-79-30, Vol 111

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

NO. OF TOWER SECTIONS	1
TOWER ROTARY INERTIA KEY	0
NO. OF MASS POINTS ABOVE TOP OF TWR	8
WIND VORTEX SHEDDING ANALYSIS KEY	1
DRAG WIND ANALYSIS KEY	1
SEISMIC ANALYSIS KEY	1
CONCRETE DESIGN KEY	1
MODAL DATA PRINT KEY	0
PLOT KEY	0
ACCELERATION OF GRAVITY	32.2
INPUT UNITS FOR LENGTH	FT
INPUT UNITS FOR FORCE	KIPS

SOIL SPRINGS:

X-DIRECTION	0.0
Y-DIRECTION	0.0
ROCKING	0.0

SOIL DAMPING RATIOS:

X-DIRECTION	0.0
Y-DIRECTION	0.0
ROCKING	0.0

NOTE: A VALUE OF ZERO FOR SOIL SPRING
IMPLIES INFINITE STIFFNESS.

FOUNDATION PROPERTIES:

DIMENSION, H1	0.0
DIMENSION, H2	0.0
FDN WEIGHT, X-DIR	0.0
FDN WEIGHT, Y-DIR	0.0
FDN ROTARY INERTIA	0.0

D-10
ESG-79-30, Vol 1 III

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

TOWER SECTION PROPERTIES:

SECTION NO. 1

NO. OF SEGMENTS -----	15
MODULUS OF ELASTICITY -----	5.247600D 05
POISSON'S RATIO -----	1.500000D-01
WEIGHT DENSITY -----	1.500000D-01
MATERIAL DAMPING RATIO ----	7.000000D-02
NET PRESSURE COEFFICIENT --	6.250000D-01
OUTER RADIUS AT TOP -----	1.700000D 01
OUTER RADIUS AT BOTTOM ----	2.500000D 01
WALL THICKNESS AT TOP -----	7.500000D-01
WALL THICKNESS AT BOTTOM --	9.167000D-01
SECTION LENGTH -----	3.650000D 02
DISTR. WT/LENGTH AT TOP ---	1.063000D 00
DISTR. WT/LENGTH AT BOTTOM	1.063000D 00

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

ADDITIONAL MASSES ABOVE TOP OF TOWER:

MASS POINT NO. 1

WEIGHT, X-DIR ----- 4.196000D 01
 WEIGHT, Y-DIR ----- 1.367200D 02
 ROTARY INERTIA ----- 0.0
 TRIB. AREA (FOR WIND) --- 3.315000D 02
 NET PRESSURE COEFF. -- 6.250000D-01

CONNECTING BEAM PROPERTIES:

MODULUS OF ELASTICITY - 4.176000D 06
 POISSON'S RATIO ----- 3.000000D-01
 CROSS-SECTIONAL AREA -- 1.968900D 00
 MOMENT OF INERTIA ----- 2.722400D 02
 SHEAR SHAPE FACTOR ---- 0.0
 LENGTH ----- 3.000000D 00
 MATERIAL DAMPING RATIO 7.000000D-02

MASS POINT NO. 2

WEIGHT, X-DIR ----- 7.993000D 01
 WEIGHT, Y-DIR ----- 6.392000D 01
 ROTARY INERTIA ----- 0.0
 TRIB. AREA (FOR WIND) --- 5.185000D 02
 NET PRESSURE COEFF. -- 6.250000D-01

CONNECTING BEAM PROPERTIES:

MODULUS OF ELASTICITY - 4.176000D 06
 POISSON'S RATIO ----- 3.000000D-01
 CROSS-SECTIONAL AREA -- 1.968900D 00
 MOMENT OF INERTIA ----- 2.722400D 02
 SHEAR SHAPE FACTOR ---- 0.0
 LENGTH ----- 1.650000D 01
 MATERIAL DAMPING RATIO 7.000000D-02

MASS POINT NO. 3

WEIGHT, X-DIR ----- 7.596000D 01
 WEIGHT, Y-DIR ----- 6.441000D 01
 ROTARY INERTIA ----- 0.0
 TRIB. AREA (FOR WIND) --- 3.740000D 02
 NET PRESSURE COEFF. -- 6.250000D-01

CONNECTING BEAM PROPERTIES:

MODULUS OF ELASTICITY - 4.176000D 06
 POISSON'S RATIO ----- 3.000000D-01
 CROSS-SECTIONAL AREA -- 1.968900D 00
 MOMENT OF INERTIA ----- 2.722400D 02
 SHEAR SHAPE FACTOR ---- 0.0
 LENGTH ----- 1.100000D 01
 MATERIAL DAMPING RATIO 7.000000D-02

ESG-79-30, Vol 1 III
 D-12

MASS POINT NO. 4

WEIGHT, X-DIR ----- 6.624000D 01
 WEIGHT, Y-DIR ----- 5.521000D 01
 ROTARY INERTIA ----- 0.0
 TRIB. AREA (FOR WIND) 3.570000D 02
 NET PRESSURE COEFF. --- 6.250000D 01

CONNECTING BEAM PROPERTIES:

MODULUS OF ELASTICITY - 4.176000D 06
 POISSON'S RATIO ----- 3.000000D 01
 CROSS-SECTIONAL AREA -- 1.968900D 00
 MOMENT OF INERTIA ----- 2.722400D 02
 SHEAR SHAPE FACTOR ---- 0.0
 LENGTH ----- 1.100000D 01
 MATERIAL DAMPING RATIO 7.000000D 02

MASS POINT NO. 5

WEIGHT, X-DIR ----- 3.061800D 02
 WEIGHT, Y-DIR ----- 2.946300D 02
 ROTARY INERTIA ----- 0.0
 TRIB. AREA (FOR WIND) 3.740000D 02
 NET PRESSURE COEFF. -- 6.250000D 01

CONNECTING BEAM PROPERTIES:

MODULUS OF ELASTICITY - 4.176000D 06
 POISSON'S RATIO ----- 3.000000D 01
 CROSS-SECTIONAL AREA -- 1.968900D 00
 MOMENT OF INERTIA ----- 2.722400D 02
 SHEAR SHAPE FACTOR ---- 0.0
 LENGTH ----- 1.000000D 01
 MATERIAL DAMPING RATIO 7.000000D 02

MASS POINT NO. 6

WEIGHT, X-DIR ----- 6.059000D 01
 WEIGHT, Y-DIR ----- 4.511000D 01
 ROTARY INERTIA ----- 0.0
 TRIB. AREA (FOR WIND) 5.015000D 02
 NET PRESSURE COEFF. -- 6.250000D 01

CONNECTING BEAM PROPERTIES:

MODULUS OF ELASTICITY - 4.176000D 06
 POISSON'S RATIO ----- 3.000000D 01
 CROSS-SECTIONAL AREA -- 1.968900D 00
 MOMENT OF INERTIA ----- 2.722400D 02
 SHEAR SHAPE FACTOR ---- 0.0
 LENGTH ----- 1.200000D 01
 MATERIAL DAMPING RATIO 7.000000D 02

MASS POINT NO. 7

D-13
 E-36
 79-30, Vol 111

WEIGHT, X-DIR ----- 1.816600D 02
WEIGHT, Y-DIR ----- 1.625000D 02
ROTARY INERTIA ----- 0.0
TRIB. AREA (FOR WIND) 6.205000D 02
NET PRESSURE COEFF. -- 6.250000D-01

CONNECTING BEAM PROPERTIES:

MODULUS OF ELASTICITY - 4.176000E 06
POISSON'S RATIO ----- 3.000000E-01
CROSS-SECTIONAL AREA -- 1.968900E 00
MOMENT OF INERTIA ----- 2.722400E 02
SHEAR SHAPE FACTOR ---- 0.0
LENGTH ----- 1.750000E 01
MATERIAL DAMPING RATIO 7.000000E-02

MASS POINT NO. 8.

WEIGHT, X-DIR ----- 4.798000D 01
WEIGHT, Y-DIR ----- 3.800000D 01
ROTARY INERTIA ----- 0.0
TRIB. AREA (FOR WIND) 3.230000D 02
NET PRESSURE COEFF. -- 6.250000D-01

CONNECTING BEAM PROPERTIES:

MODULUS OF ELASTICITY - 4.176000D 06
POISSON'S RATIO ----- 3.000000D-01
CROSS-SECTIONAL AREA -- 1.968900D 00
MOMENT OF INERTIA ----- 2.722400D 02
SHEAR SHAPE FACTOR ---- 0.0
LENGTH ----- 1.900000D 01
MATERIAL DAMPING RATIO 7.000000D-02

ESG-79-30, Vol III
D-14

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

DATA FOR VORTEX SHEDDING ANALYSIS:

MASS DENSITY OF AIR -----	2.380000D-06
VON KARMAN (LIFT) COEFF. -----	2.000000D-01
STROUHAL NUMBER -----	2.000000D-01
CRITICAL DIAMETER -----	3.800000D-01
DAMPING RATIO -----	4.000000D-02
CUT-OFF VELOCITY -----	1.030000D-02

ESG-79-30, Vol III
D-15

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

DATA FOR DRAG WIND ANALYSIS (PER ANSI A58.1-1972):

BASIC WIND VELOCITY AT 30 FT -	9.000000D 01 MPH
TYPE OF EXPOSURE -	C
AVERAGE HORIZONTAL DIMENSION -	4.200000D 01 FT
VERTICAL DIMENSION -	3.650000D 02 FT
FUNDAMENTAL LATERAL FREQUENCY	0.0 CPS
STRUCTURE DAMPING COEFFICIENT	2.000000D-02

ESG-79-30, Vol 1 III
D-16

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

DATA FOR SEISMIC ANALYSIS:

NO. OF MODES, X-DIR ----- 0
NO. OF MODES, Y-DIR ----- 0
CUT-OFF FREQUENCY (CPS) - 0.0
SCALAR MULTIPLIER, X-DIR 3.500000D-01
SCALAR MULTIPLIER, Y-DIR 3.500000D-01

RESPONSE SPECTRA PER NRC REGULATORY GUIDE 1.60

MODAL DAMPING VALUES, X-DIR:

FROM TO DAMPING RATIO
MODE MODE

1 999 9.900000D 01

MODAL DAMPING VALUES, Y-DIR:

FROM TO DAMPING RATIO
MODE MODE

1 999 9.900000D 01

ESG-79-30, Vol III
D-17

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

DATA FOR CONCRETE DESIGN:

DESIGN IS BASED ON STRENGTH DESIGN PROVISIONS OF ACI 318-71.

CONCRETE F'C (KSI) -----	4.000000D 00
REBAR FY (KSI) -----	6.000000D 01
MINIMUM VERTICAL STEEL RATIO -----	3.300000D-03
MAXIMUM VERTICAL STEEL RATIO -----	5.000000D-02
MIN. HOOP STEEL (AREA/UNIT HEIGHT) -----	1.388800D-03
NOMINAL HOOP STEEL RATIO -----	2.000000D-03
REBAR UNIT WEIGHT -----	4.900000D-01

LOAD FACTORS:

DEAD LOAD + SEISMIC

CMB. 1		CMB. 2	
DEAD LOAD -----	1.050000D 00	DEAD LOAD -----	9.000000D-01
X-SEISMIC -----	1.400000D 00	X-SEISMIC -----	1.430000D 00
Y-SEISMIC -----	1.400000D 00	Y-SEISMIC -----	-1.430000D 00

DEAD LOAD + VORTEX SHEDDING

CMB. 1		CMB. 2	
DEAD LOAD -----	1.050000D 00	DEAD LOAD -----	9.000000D-01
VORTEX SHEDDING -----	1.290000D 00	VORTEX SHEDDING -----	1.300000D 00

DEAD LOAD + DRAG WIND

CMB. 1		CMB. 2	
DEAD LOAD -----	1.050000D 00	DEAD LOAD -----	9.000000D-01
DRAG WIND -----	1.280000D 00	DRAG WIND -----	1.300000D 00

COST DATA (MATERIAL + LABOR):

CONCRETE (PER UNIT VOLUME)	7.437407D 00
REBAR (PER UNIT WEIGHT)	5.030000D 02

ESG-9-30, Vol 1
D-18

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * NODAL Y-COORDINATES AND LUMPED WEIGHTS * * * * *

NODE	Y-COORDINATE	WX	WY	ROT. INERTIA
1	0.0	0.0	0.0	0.0
2	1.209785D 01	5.331813D 02	5.331813D 02	0.0
3	3.642990D 01	5.160998D 02	5.160998D 02	0.0
4	6.076190D 01	4.992974D 02	4.992974D 02	0.0
5	8.509384D 01	4.827440D 02	4.827440D 02	0.0
6	1.094257D 02	4.664696D 02	4.664696D 02	0.0
7	1.337575D 02	4.504643D 02	4.504643D 02	0.0
8	1.580893D 02	4.347279D 02	4.347279D 02	0.0
9	1.824210D 02	4.192606D 02	4.192606D 02	0.0
10	2.067526D 02	4.040624D 02	4.040624D 02	0.0
11	2.310841D 02	3.891331D 02	3.891331D 02	0.0
12	2.554155D 02	3.744729D 02	3.744729D 02	0.0
13	2.797468D 02	3.600817D 02	3.600817D 02	0.0
14	3.040781D 02	3.459596D 02	3.459596D 02	0.0
15	3.284092D 02	3.321065D 02	3.321065D 02	0.0
16	3.527401D 02	3.185224D 02	3.185224D 02	0.0
17	3.650000D 02	0.0	0.0	0.0
18	3.680000D 02	4.196000D 01	1.367200D 02	0.0
19	3.845000D 02	7.993000D 01	6.392000D 01	0.0
20	3.955000D 02	7.596000D 01	6.441000D 01	0.0
21	4.065000D 02	6.624000D 01	5.521000D 01	0.0
22	4.165000D 02	3.061800D 02	2.946300D 02	0.0
23	4.265000D 02	6.059000D 01	4.511000D 01	0.0
24	4.460000D 02	1.816600D 02	1.625000D 02	0.0
25	4.650000D 02	4.798000D 01	3.800000D 01	0.0
SUMMATION		7.187074D 03	7.187074D 03	0.0

CENTER OF GRAVITY OF X WEIGHTS: Y = 1.961293D 02

CENTER OF GRAVITY OF Y WEIGHTS: Y = 1.954384D 02

ROTARY INERTIA ABOUT C.G. OF X WEIGHTS: IZ = 1.172756D 08

D-19
ESG-79-30, Vol 111

ESTIMATE OF STEAM GENERATOR CAPITAL COSTS - EVAPORATOR

CASE No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
EVAPORATOR																	
THRUSTLE PRESS - PSIA	1815			2415			1815				2415		1815	2415		3515	
S.G. PRESS. - PSIA	2000			2600			2000				2600		2000	2600		3700	
SATURATION TEMP - °F	635.8			673.9			635.8				673.9		635.8	673.9			
hg - SAT. TEMP. - BTU/lb	1131.3			1082			1138.3				1082		1138.3	1082		1096	1109
FW TEMP - °F	452.6			483			483.5				514.8		453.6	483		547	
hw - SAT. LIQ. BTU/lb	435.3			468			468.5				505		435.3	468		542	
Δh = hg - hfw BTU/lb	703			614			669.8				577		703	614		554	542
THRUSTLE FLOW lb/hr	729,242	699,548	697,346	740,907	738,081	706,764	735,870	737,554	704,764	706,496	752,016	718,889	649,945	657,236	628,852	733,677	698,674
EVAPORATOR DUTY 10 ⁶ BTU/hr	5.13	4.92	4.90	4.55	4.53	4.34	4.93	4.94	4.72	4.73	4.34	4.15	4.57	4.04	3.86	4.06	3.96
EVAPORATOR DUTY - MW	150	144	143.6	133.3	132.8	127.1	144	144.7	138.3	138.6	127.1	121.5	133.9	118.2	113.1	119	116
% TOTAL POWER	58%	56	56	53	53	51	56	56	55	55	51	49	53	48	47	48	48
SOD. FLOW - MW - 10 ⁶ lb/hr	5.36	5.32	5.30	5.23	5.17	5.15	5.31	5.35	5.19	5.20	5.71	5.62	5.23	5.10	5.04	5.62	5.54
SOD. TEMP. IN - °F	869	858	858	840	842	831	859	858	853	853	853	846	841	814	809	841	840
SOD. TEMP. OUT - °F	550										600		550			600	
SOD. ΔT - °F	319	308	308	290	292	281	309	308	303	303	253	246	291	264	259	241	240
FW TEMP. IN - °F	453			483			484				515		454	483		547	
STEAM TEMP. OUT - °F	636			674			636				674		636	674		750	752
STEAM ΔT - °F	183			191			152				159		182	191		203	205
GREATER ΔT - °F	233	222	222	166	168	157	223	222	217	217	179	172	205	140	135	91	88
LEAST ΔT - °F	97			67			66				115	115	96	67		53	53
LOG MEAN ΔT - °F	155	151	151	109	110	106	129	129	127	127	145	142	144	99	97	70	69
OVERALL U - BTU/hr-ft ² -°F	240			250			240				250		240	250		400	
AREA - Q/UΔT - ft ²	13,790	13,526	13,521	16,697	16,473	16,377	15,924	15,956	15,486	15,518	11,972	11,690	13,223	16,323	15,918	14,500	14,348
SURFACE AREA COST \$/ft ²	191			177			191				177		191	177		300	
EVAPORATOR COST 10 ⁶ \$	2.63	2.59	2.58	2.96	2.92	2.90	3.04	3.05	2.96	2.96	2.12	2.07	2.63	2.89	2.82	4.35	4.30

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

LATERAL MODE FREQUENCIES

MODE ——— FREQUENCY ———
NO. (CPS)

1	5.577161D-01
2	2.359025D 00
3	5.194883D 00
4	9.147312D 00
5	1.396225D 01
6	1.895653D 01
7	2.405024D 01
8	2.947949D 01
9	3.503166D 01
10	4.038668D 01
11	4.533969D 01
12	4.976635D 01
13	5.359058D 01
14	5.676065D 01
15	5.924833D 01
16	6.106543D 01
17	6.188380D 01
18	6.266452D 01
19	6.902749D 01
20	1.568297D 02
21	2.551740D 02
22	3.445234D 02
23	5.547098D 02

ESG-79-30, Vol III

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * L A T E R A L M O D E S H A P E S * * * * *

MODE NO. 1			MODE NO. 2		MODE NO. 3	
NODE	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION
1	0.0	0.0	0.0	0.0	0.0	0.0
2	1.372654D-03	-1.330115D-04	-7.460930D-03	3.975001D-04	1.986907D-02	-7.035691D-04
3	9.063917D-03	-4.000449D-04	-3.635429D-02	1.098405D-03	8.237972D-02	-1.755106D-03
4	2.327052D-02	-6.652090D-04	-8.064608D-02	1.647501D-03	1.628700D-01	-2.270591D-03
5	4.392742D-02	-9.270181D-04	-1.361303D-01	2.022384D-03	2.457114D-01	-2.223367D-03
6	7.093044D-02	-1.183597D-03	-1.980134D-01	2.203283D-03	3.150303D-01	-1.634547D-03
7	1.041210D-01	-1.432514D-03	-2.610299D-01	2.175265D-03	3.564319D-01	-5.834014D-04
8	1.432846D-01	-1.672777D-03	-3.196141D-01	1.930407D-03	3.588650D-01	7.899866D-04
9	1.881532D-01	-1.900669D-03	-3.681216D-01	1.469858D-03	3.163438D-01	2.291311D-03
10	2.383985D-01	-2.114765D-03	-4.010995D-01	8.057299D-04	2.293167D-01	3.689073D-03
11	2.935279D-01	-2.312032D-03	-4.136114D-01	-3.752609D-05	1.052738D-01	4.741718D-03
12	3.533890D-01	-2.490365D-03	-4.015910D-01	-1.022642D-03	-4.154509D-02	5.232892D-03
13	4.171697D-01	-2.647788D-03	-3.621136D-01	-2.099935D-03	-1.916022D-01	5.011315D-03
14	4.844217D-01	-2.782615D-03	-2.938114D-01	-3.208837D-03	-3.226148D-01	4.029849D-03
15	5.545676D-01	-2.894504D-03	-1.970220D-01	-4.281135D-03	-4.131042D-01	2.377601D-03
16	6.270105D-01	-2.982730D-03	-7.396885D-02	-5.246146D-03	-4.465637D-01	2.985884D-04
17	6.641635D-01	-3.010518D-03	-3.303946D-03	-5.669939D-03	-4.377053D-01	-7.899092D-04
18	6.732789D-01	-3.058020D-03	1.442624D-02	-6.146486D-03	-4.334054D-01	-2.070914D-03
19	7.253062D-01	-3.237818D-03	1.351180D-01	-8.371018D-03	-3.451716D-01	-8.425524D-03
20	7.614187D-01	-3.323804D-03	2.335938D-01	-9.485281D-03	-2.325236D-01	-1.195150D-02
21	7.983395D-01	-3.385172D-03	3.427531D-01	-1.031561D-02	-8.465002D-02	-1.481982D-02
22	8.323874D-01	-3.421441D-03	4.486928D-01	-1.083636D-02	7.404497D-02	-1.682160D-02
23	8.736154D-01	-3.447673D-03	5.813156D-01	-1.123530D-02	2.867135D-01	-1.849849D-02
24	9.341323D-01	-3.464710D-03	7.807836D-01	-1.150334D-02	6.228750D-01	-1.968067D-02
25	1.000000D 00	-3.467728D-03	1.000000D 00	-1.155469D-02	1.000000D 00	-1.993269D-02

D-22

ES-79-30, Vol III

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * L A T E R A L M O D E S H A P E S * * * * *

MODE NO. 4			MODE NO. 5		MODE NO. 6	
MODE	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION
1	0.0	0.0	0.0	0.0	0.0	0.0
2	-4.893599D-02	1.155867D-03	8.440906D-02	-1.307739D-03	-1.181064D-01	1.207656D-03
3	-1.775468D-01	2.440502D-03	2.705457D-01	-2.028878D-03	-3.362573D-01	9.629508D-04
4	-3.079250D-01	2.299125D-03	3.973845D-01	-4.495132D-04	-3.993431D-01	-1.907500D-03
5	-3.958069D-01	9.081542D-04	3.932445D-01	2.464245D-03	-2.435343D-01	-5.085357D-03
6	-4.074357D-01	-1.301418D-03	2.411979D-01	5.241672D-03	5.625783D-02	-6.062515D-03
7	-3.282834D-01	-3.690323D-03	-1.009075D-02	6.409521D-03	3.238514D-01	-3.636522D-03
8	-1.682344D-01	-5.528691D-03	-2.620676D-01	5.104295D-03	3.877571D-01	1.171322D-03
9	3.869880D-02	-6.165270D-03	-4.056267D-01	1.531689D-03	1.952816D-01	5.514486D-03
10	2.410809D-01	-5.210445D-03	-3.700104D-01	-2.974378D-03	-1.399429D-01	6.423705D-03
11	3.824298D-01	-2.682085D-03	-1.603933D-01	-6.406093D-03	-3.980451D-01	2.888482D-03
12	4.167814D-01	9.387417D-04	1.351560D-01	-6.939920D-03	-3.941023D-01	-3.078931D-03
13	3.234044D-01	4.782183D-03	3.775123D-01	-3.861807D-03	-1.128711D-01	-7.373143D-03
14	1.160455D-01	7.805761D-03	4.378406D-01	1.898767D-03	2.605843D-01	-6.450064D-03
15	-1.573660D-01	9.125217D-03	2.623704D-01	8.007750D-03	4.528961D-01	-6.466141D-05
16	-4.268571D-01	8.393142D-03	-9.293316D-02	1.182825D-02	2.955385D-01	8.039243D-03
17	-5.327292D-01	7.371963D-03	-2.883124D-01	1.238803D-02	9.305710D-02	1.107764D-02
18	-5.527236D-01	5.949509D-03	-3.255417D-01	1.238519D-02	5.589258D-02	1.361452D-02
19	-5.820625D-01	-2.572983D-03	-5.024907D-01	7.792141D-03	-2.296981D-01	1.841464D-02
20	-5.205742D-01	-8.602373D-03	-5.530408D-01	1.004170D-03	-4.103192D-01	1.341884D-02
21	-3.936974D-01	-1.438985D-02	-5.178597D-01	-7.617285D-03	-5.054447D-01	3.113578D-03
22	-2.255553D-01	-1.913629D-02	-3.989580D-01	-1.622181D-02	-4.751878D-01	-9.579390D-03
23	3.248401D-02	-2.357347D-02	-1.474550D-01	-2.516363D-02	-2.689714D-01	-2.403355D-02
24	4.793909D-01	-2.687947D-02	3.651878D-01	-3.219743D-02	2.733039D-01	-3.600963D-02
25	1.000000D 00	-2.766098D-02	1.000000D 00	-3.401804D-02	1.000000D 00	-3.936593D-02

D-23
ESG-79-30, Vol III

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * L A T E R A L M O D E S H A P E S * * * * *

MODE NO. 7			MODE NO. 8			MODE NO. 9		
MODE	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION		
1	0.0	0.0	0.0	0.0	0.0	0.0		
2	1.856985D-01	-1.217857D-03	-3.146198D-01	1.193301D-03	4.810495D-01	-8.419502D-04		
3	4.647179D-01	3.573902D-04	-6.693692D-01	-2.627545D-03	8.231390D-01	5.655158D-03		
4	4.048389D-01	4.735885D-03	-3.231110D-01	-8.421883D-03	4.272695D-03	1.074468D-02		
5	2.107305D-02	7.110936D-03	3.797617D-01	-7.434233D-03	-8.199742D-01	3.307393D-03		
6	-3.804226D-01	4.395758D-03	6.443389D-01	1.104120D-03	-3.379151D-01	-8.036966D-03		
7	-4.523205D-01	-1.991017D-03	1.420940D-01	8.290145D-03	6.572055D-01	-8.883518D-03		
8	-1.155794D-01	-6.843743D-03	-5.575346D-01	5.434351D-03	7.375765D-01	6.298417D-03		
9	3.446271D-01	-5.585801D-03	-6.090361D-01	-4.870031D-03	-3.503973D-01	1.064423D-02		
10	5.089561D-01	1.240271D-03	8.730258D-02	-1.029857D-02	-9.203244D-01	-1.991188D-03		
11	2.040826D-01	7.667960D-03	7.056677D-01	-3.181353D-03	-2.504478D-02	-1.280628D-02		
12	-3.091302D-01	7.271537D-03	4.572794D-01	8.727557D-03	9.529000D-01	-3.461068D-03		
13	-5.457403D-01	-5.052472D-04	-3.872529D-01	1.004313D-02	4.028816D-01	1.230990D-02		
14	-2.520402D-01	-8.805750D-03	-7.563438D-01	-2.827573D-03	-8.325375D-01	7.132204D-03		
15	3.156392D-01	-9.224940D-03	-1.165038D-01	-1.498477D-02	-6.738660D-01	-1.460642D-02		
16	5.990658D-01	-5.183699D-04	7.578357D-01	-1.121013D-02	7.351920D-01	-2.057625D-02		
17	4.732386D-01	4.841865D-03	7.856082D-01	-4.561132D-03	9.641097D-01	-1.443507D-02		
18	4.506971D-01	1.003777D-02	7.882021D-01	2.763891D-03	9.955269D-01	-6.495602D-03		
19	1.173230D-01	2.682046D-02	4.765334D-01	3.153831D-02	7.748752D-01	3.115969D-02		
20	-1.621348D-01	2.595258D-02	8.716050D-02	3.701550D-02	3.453066D-01	4.436548D-02		
21	-4.187234D-01	1.553369D-02	-2.866232D-01	2.856057D-02	-1.367442D-01	4.000189D-02		
22	-4.971743D-01	-8.245601D-04	-4.845386D-01	9.348340D-03	-4.471302D-01	1.956579D-02		
23	-3.596487D-01	-2.113702D-02	-4.333429D-01	-1.695477D-02	-4.893917D-01	-1.178740D-02		
24	1.901657D-01	-3.902133D-02	1.070963D-01	-4.158388D-02	2.643786D-02	-4.359880D-02		
25	1.000000D 00	-4.442362D-02	1.000000D 00	-4.970046D-02	1.000000D 00	-5.506077D-02		

ESG-79-30, Vol III
D-24

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * L A T E R A L M O D E S H A P E S * * * * *

MODE NO. 10			MODE NO. 11		MODE NO. 12	
MODE	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION
1	0.0	0.0	0.0	0.0	0.0	0.0
2	-5.687298D-01	1.615791D-04	-5.970611D-01	-4.539538D-04	6.811093D-01	1.027392D-03
3	-7.369431D-01	-7.294883D-03	-5.181579D-01	-7.349270D-03	3.097932D-01	7.386161D-03
4	4.282348D-01	-8.625339D-03	7.068645D-01	-4.690642D-03	-8.652794D-01	1.433174D-03
5	7.859009D-01	2.827874D-03	3.158405D-01	5.544511D-03	2.828368D-01	-5.060203D-03
6	-3.719033D-01	7.642617D-03	-8.371670D-01	1.423577D-03	7.137827D-01	4.201338D-03
7	-8.609257D-01	-3.577948D-03	-7.924623D-02	-7.736037D-03	-7.861913D-01	3.750386D-03
8	3.093146D-01	-9.481056D-03	8.889617D-01	4.020988D-04	-1.722196D-01	-6.823437D-03
9	9.118513D-01	2.932560D-03	-2.211840D-01	8.212441D-03	9.428511D-01	1.371199D-03
10	-2.777050D-01	1.046943D-02	-8.454990D-01	-3.544910D-03	-5.308133D-01	6.808117D-03
11	-9.558064D-01	-3.209486D-03	5.457699D-01	-7.689453D-03	-5.695646D-01	-6.661588D-03
12	2.822094D-01	-1.220889D-02	6.590669D-01	7.524724D-03	1.000000 00	-1.576734D-03
13	1.000000D 00	2.813080D-03	-8.509381D-01	6.345864D-03	-2.306577D-01	1.001627D-02
14	-3.108930D-01	1.163252D-02	-3.270464D-01	-9.086540D-03	-8.646047D-01	-4.127864D-03
15	-9.865634D-01	-8.440407D-03	1.000000 00	2.604907D-03	9.440245D-01	-8.839693D-04
16	5.008819D-01	-2.325991D-02	-2.481030D-01	2.181175D-02	-4.647012D-02	2.169533D-02
17	8.834531D-01	-1.981180D-02	-7.169879D-01	2.136071D-02	-6.321013D-01	2.414020D-02
18	9.338354D-01	-1.363941D-02	-7.759073D-01	1.771731D-02	-7.027026D-01	2.262667D-02
19	8.592357D-01	2.314963D-02	-8.289030D-01	-1.411663D-02	-8.753100D-01	-7.227208D-03
20	4.897694D-01	4.177280D-02	-5.446228D-01	-3.586334D-02	-6.400513D-01	-3.423310D-02
21	4.322194D-03	4.291738D-02	-9.781470D-02	-4.181771D-02	-1.798959D-01	-4.549876D-02
22	-3.517196D-01	2.532971D-02	2.671373D-01	-2.799381D-02	2.348641D-01	-3.367259D-02
23	-4.684650D-01	-5.590176D-03	4.321561D-01	7.166241D-04	4.621113D-01	-3.367505D-03
24	-4.197433D-02	-4.000337D-02	8.805191D-02	3.612710D-02	1.381370D-01	3.835066D-02
25	8.897776D-01	-5.355768D-02	-7.906425D-01	5.130706D-02	-8.352542D-01	5.767134D-02

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * L A T E R A L M O D E S H A P E S * * * * *

MODE NO. 13			MODE NO. 14		MODE NO. 15	
MODE	X-DISPL.	Z-ROTATION	X-CISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION
1	0.0	0.0	0.0	0.0	0.0	0.0
2	6.632125D-01	1.355371D-03	7.171586D-01	1.740826D-03	7.167046D-01	1.930861D-03
3	4.888205D-02	5.915318D-03	-1.864570D-01	4.958130D-03	-3.822501D-01	3.652198D-03
4	-7.015266D-01	-9.186549D-04	-4.581874D-01	-1.922237D-03	-9.524231D-02	-1.713813D-03
5	6.964327D-01	-1.871934D-03	8.338479D-01	9.377733D-04	5.647483D-01	2.322726D-03
6	1.840226D-03	5.005625D-03	-6.650712D-01	2.735665D-03	-8.220653D-01	-2.531181D-04
7	-7.172169D-01	-2.441020D-03	6.955087D-02	-3.932335D-03	7.839610D-01	-1.165056D-03
8	7.791760D-01	-2.304348D-03	5.935071D-01	3.245028D-03	-4.602040D-01	2.720338D-03
9	-1.142646D-01	5.557814D-03	-9.173693D-01	-1.193145D-04	-3.153299D-02	-3.256265D-03
10	-6.783006D-01	-3.853503D-03	7.099445D-01	-3.144023D-03	5.318528D-01	2.736270D-03
11	8.936092D-01	-1.804505D-03	-8.880236D-02	5.202672D-03	-8.852356D-01	-1.541497D-03
12	-3.302100D-01	5.956662D-03	-6.076271D-01	-3.843233D-03	1.000000D 00	-7.996782D-04
13	-5.304818D-01	-6.496144D-03	1.000000D 00	1.656125D-03	-8.445019D-01	1.585634D-03
14	1.000000D 00	-1.435802D-03	-9.153529D-01	4.962314D-03	4.937972D-01	-5.538744D-03
15	-6.390143D-01	2.090353D-03	3.392467D-01	-1.650691D-03	2.377637D-02	-1.393943D-04
16	-1.353575D-01	-1.829576D-02	3.070332D-01	1.721829D-02	-4.464080D-01	-1.529509D-02
17	4.731605D-01	-2.313089D-02	-3.891598D-01	2.479502D-02	2.935238D-01	-2.505347D-02
18	5.441897D-01	-2.387196D-02	-4.685788D-01	2.771801D-02	3.766953D-01	-2.990797D-02
19	8.023398D-01	-4.170559D-05	-8.346740D-01	6.660310D-03	8.263997D-01	-1.260965D-02
20	6.422563D-01	2.841916D-02	-7.233078D-01	-2.667715D-02	7.666108D-01	2.376727D-02
21	2.266203D-01	4.337732D-02	-2.952184D-01	-4.707599D-02	3.461108D-01	4.852848D-02
22	-1.547322D-01	3.500080D-02	1.675559D-01	-4.097349D-02	-1.461787D-01	4.504587D-02
23	-4.434859D-01	6.721885D-03	4.914662D-01	-1.080177D-02	-5.205795D-01	1.438841D-02
24	-1.586858D-01	-3.686340D-02	2.210708D-01	4.112287D-02	-2.639139D-01	-4.393442D-02
25	8.053406D-01	-5.846512D-02	-9.053174D-01	6.836396D-02	9.762687D-01	-7.594194D-02

ESG-79-30, Vol II
D-26

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * L A T E R A L M O D E S H A P E S * * * * *

MODE NO. 16			MODE NO. 17		MODE NO. 18	
NODE	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION
1	0.0	0.0	0.0	0.0	0.0	0.0
2	-6.011513D-01	-1.727166D-03	1.328396D-01	3.917136D-04	1.000000D 00	3.020017D-03
3	4.445515D-01	-2.189853D-03	-1.108068D-01	3.920837D-04	-9.254833D-01	2.277769D-03
4	-2.080116D-01	7.909097D-04	7.891215D-02	-7.631920D-05	8.500755D-01	3.048455D-04
5	-8.940210D-02	-1.842003D-03	-3.500040D-02	3.098367D-04	-7.387061D-01	1.198961D-03
6	3.740334D-01	1.183939D-03	-1.244563D-02	-2.262696D-04	6.282025D-01	-4.896615D-04
7	-6.064403D-01	-1.028351D-03	6.119977D-02	2.649547D-04	-5.144142D-01	8.496591D-04
8	7.492711D-01	3.152611D-04	-1.071513D-01	-2.372956D-04	4.111497D-01	-6.090860D-04
9	-7.910842D-01	2.118407D-04	1.497830D-01	1.883883D-04	-3.192018D-01	6.327445D-04
10	7.355095D-01	-9.189665D-04	-1.883875D-01	-2.466355D-04	2.424938D-01	-4.917390D-04
11	-5.981643D-01	1.191765D-03	2.268500D-01	6.059006D-05	-1.808157D-01	4.414671D-04
12	4.061398D-01	-1.980495D-03	-2.648821D-01	-5.176986D-04	1.335671D-01	-2.938111D-04
13	-1.726962D-01	1.134469D-03	3.176383D-01	-4.052382D-04	-1.003627D-01	3.177439D-04
14	-6.057225D-02	-3.712513D-03	-3.708123D-01	-2.157206D-03	7.772262D-02	2.948546D-05
15	3.436675D-01	-2.289297D-03	4.925832D-01	-3.431871D-03	-7.085095D-02	5.138519D-04
16	-5.318951D-01	-1.305474D-02	-5.618543D-01	-1.184893D-02	6.547236D-02	1.189811D-03
17	2.056190D-01	-2.406512D-02	1.630596D-01	-2.326081D-02	-1.366339D-02	2.498811D-03
18	2.878207D-01	-3.023267D-02	2.436117D-01	-2.993754D-02	-2.243611D-02	3.293878D-03
19	7.831303D-01	-1.678279D-02	7.525760D-01	-1.845314D-02	-8.040631D-02	2.226107D-03
20	7.673591D-01	2.036156D-02	7.572079D-01	1.851293D-02	-8.307609D-02	-1.861461D-03
21	3.715297D-01	4.759141D-02	3.781438D-01	4.651927D-02	-4.272551D-02	-5.056842D-03
22	-1.237083D-01	4.648767D-02	-1.119470D-01	4.656109D-02	1.121165D-02	-5.185243D-03
23	-5.243066D-01	1.677981D-02	-5.197685D-01	1.769614D-02	5.734239D-02	-2.066786D-03
24	-2.889133D-01	-4.461399D-02	-2.969694D-01	-4.441682D-02	3.391071D-02	4.921869D-03
25	1.000000D 00	-7.944142D-02	1.000000D 00	-8.018391D-02	-1.113150D-01	9.004256D-03

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * L A T E R A L M O D E S H A P E S * * * * *

MODE NO. 19			MODE NO. 20			MODE NO. 21		
MODE	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION		
1	0.0	0.0	0.0	0.0	0.0	0.0		
2	-5.191146D-07	4.473100D-08	4.462138D-08	-2.780919D-08	3.806786D-09	2.270839D-08		
3	-5.808237D-07	1.598467D-07	1.020700D-07	-1.021960D-07	-1.706470D-09	8.431270D-08		
4	-4.931113D-07	3.707723D-07	1.931392D-07	-2.361197D-07	-6.210652D-08	1.956833D-07		
5	-1.550900D-06	7.980603D-07	3.858250D-07	-5.115141D-07	-1.498991D-07	4.253232D-07		
6	-4.022779D-06	1.694262D-06	8.663585D-07	-1.106763D-06	-2.792123D-07	9.250996D-07		
7	-8.224719D-06	3.646783D-06	1.914448D-06	-2.429099D-06	-5.986057D-07	2.043376D-06		
8	-1.779325D-05	8.005618D-06	4.406135D-06	-5.431996D-06	-1.444660D-06	4.600257D-06		
9	-4.286693D-05	1.788456D-05	1.032150D-05	-1.239886D-05	-3.447199D-06	1.057612D-05		
10	-9.236170D-05	4.085459D-05	2.472119D-05	-2.892652D-05	-8.278361D-06	2.486834D-05		
11	-2.625418D-04	9.476978D-05	6.069935D-05	-6.906233D-05	-2.054176D-05	5.986344D-05		
12	-3.926803D-04	2.283938D-04	1.521052D-04	-1.689750D-04	-5.236335D-05	1.478791D-04		
13	-2.392593D-03	5.419108D-04	4.057309D-04	-4.240499D-04	-1.358270D-04	3.750789D-04		
14	-1.928928D-03	1.448863D-03	8.207761D-04	-1.098504D-03	-3.793936D-04	9.785743D-04		
15	-4.106595D-02	3.155112D-03	7.529812D-03	-2.826174D-03	-4.634805D-04	2.643458D-03		
16	1.536827D-01	1.179653D-02	-8.636085D-02	-9.759392D-03	-3.429716D-02	6.663613D-03		
17	-4.728500D-01	1.566887D-02	1.000000D-00	-6.332053D-03	1.000000D-00	2.120456D-02		
18	-5.174897D-01	1.363870D-02	9.919287D-01	1.273748D-02	8.835111D-01	5.764417D-02		
19	-5.039793D-01	-2.042013D-02	1.221997D-01	7.203873D-02	-5.276549D-01	3.126549D-02		
20	-1.501505D-01	-3.915899D-02	-5.021213D-01	2.707031D-02	-1.267059D-01	-8.094705D-02		
21	2.310643D-01	-2.341034D-02	-3.810313D-01	-4.307515D-02	5.924539D-01	-1.296152D-02		
22	2.679767D-01	1.939172D-02	1.252555D-01	-4.204896D-02	6.533836D-02	1.029082D-01		
23	-1.929754D-01	4.621840D-02	2.883465D-01	1.366913D-02	-9.975233D-01	1.823459D-02		
24	-5.211675D-01	-3.004415D-02	-1.572229D-01	1.103753D-02	2.098770D-01	-5.766630D-02		
25	1.000000D-00	-1.050701D-01	1.919534D-01	-3.308532D-02	-1.934243D-01	5.996220D-02		

D-28
ESG-79-30, Vol III

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * L A T E R A L M O D E S H A P E S * * * * *

MODE NO. 22			MODE NO. 23		
NODE	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION	
1	0.0	0.0	0.0	0.0	
2	-2.014025D-08	5.492587D-08	1.114110D-08	-5.482803D-08	
3	-4.457772D-08	2.034989D-07	1.612110D-08	-2.034330D-07	
4	-9.045960D-08	4.731311D-07	3.349598D-08	-4.735897D-07	
5	-1.781931D-07	1.031340D-06	7.154749D-08	-1.033526D-06	
6	-3.639531D-07	2.247786D-06	1.415882D-07	-2.255146D-06	
7	-8.425274D-07	4.972670D-06	3.229649D-07	-4.995528D-06	
8	-1.982931D-06	1.121511D-05	7.603934D-07	-1.128345D-05	
9	-4.634051D-06	2.583842D-05	1.817452D-06	-2.603696D-05	
10	-1.123454D-05	6.089364D-05	4.416207D-06	-6.146635D-05	
11	-2.799617D-05	1.469928D-04	1.099518D-05	-1.486541D-04	
12	-7.141952D-05	3.639709D-04	2.813456D-05	-3.688420D-04	
13	-1.875485D-04	9.259006D-04	7.410797D-05	-9.404126D-04	
14	-5.090432D-04	2.423983D-03	2.012689D-04	-2.468138D-03	
15	-1.267261D-03	6.545928D-03	5.577272D-04	-6.680977D-03	
16	-1.757426D-02	1.796400D-02	3.419214D-03	-1.865243D-02	
17	8.636212D-01	3.866506D-02	-3.691191D-01	-3.481625D-02	
18	6.825387D-01	8.324905D-02	-2.193910D-01	-6.569369D-02	
19	-7.386918D-01	-4.064625D-02	4.176301D-01	1.061806D-01	
20	5.463757D-01	-9.821443D-02	-7.934469D-01	-5.706046D-02	
21	5.151977D-01	9.153412D-02	1.000000D 00	-3.676691D-02	
22	-2.641147D-01	-1.868424D-02	-1.476599D-01	9.189760D-02	
23	1.000000D 00	-6.310648D-02	2.831986D-01	-5.478624D-02	
24	-1.324963D-01	7.078844D-02	-2.372426D-02	3.087985D-02	
25	1.132861D-01	-5.479809D-02	1.724324D-02	-1.867420D-02	

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

VERTICAL MODE FREQUENCIES

MODE NO.	FREQUENCY (CPS)
1	6.554931D 00
2	1.402813D 01
3	2.248744D 01
4	3.433033D 01
5	4.206548D 01
6	4.795759D 01
7	5.937040D 01
8	6.955986D 01
9	7.661128D 01
10	8.472652D 01
11	9.415066D 01
12	1.030985D 02
13	1.076729D 02
14	1.111478D 02
15	1.180566D 02
16	1.237389D 02
17	1.260837D 02
18	1.310691D 02
19	1.330643D 02
20	1.348768D 02
21	1.456686D 02
22	1.532175D 02
23	1.853224D 02

D-30
ESG-79-30, Vol III

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * VERTICAL MODE SHAPES * * * * *

	MODE NO. 1	MODE NO. 2	MODE NO. 3	MODE NO. 4	MODE NO. 5	MODE NO. 6
MODE	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.
1	0.0	0.0	0.0	0.0	0.0	0.0
2	2.745895D-02	-2.987293D-02	1.198996D-01	1.892944D-01	3.956967D-02	-2.689164D-01
3	8.394891D-02	-9.020085D-02	3.538202D-01	5.303495D-01	1.056764D-01	-6.865407D-01
4	1.414213D-01	-1.497053D-01	5.562014D-01	7.444774D-01	1.325473D-01	-7.679120D-01
5	1.997043D-01	-2.027698D-01	7.031943D-01	7.708596D-01	1.081433D-01	-4.588378D-01
6	2.582031D-01	-2.499440D-01	7.761868D-01	5.954101D-01	4.013209D-02	9.709785D-02
7	3.164020D-01	-2.878524D-01	7.640831D-01	2.564100D-01	-4.630489D-02	6.238078D-01
8	3.737679D-01	-3.144991D-01	6.648562D-01	-1.632795D-01	-1.176559D-01	8.487827D-01
9	4.297535D-01	-3.282649D-01	4.861662D-01	-5.560171D-01	-1.449648D-01	6.435230D-01
10	4.838002D-01	-3.280112D-01	2.449390D-01	-8.165963D-01	-1.155170D-01	9.636745D-02
11	5.353415D-01	-3.131497D-01	-3.409937D-02	-8.701160D-01	-3.864674D-02	-5.231406D-01
12	5.838073D-01	-2.836916D-01	-3.209234D-01	-6.932356D-01	5.693105D-02	-8.954630D-01
13	6.286259D-01	-2.402752D-01	-5.828227D-01	-3.228899D-01	1.336482D-01	-8.149189D-01
14	6.692289D-01	-1.841691D-01	-7.889314D-01	1.504986D-01	1.597005D-01	-3.028402D-01
15	7.059544D-01	-1.172502D-01	-9.126000D-01	6.043715D-01	1.221429D-01	3.917569D-01
16	7.355498D-01	-4.195645D-02	-9.361244D-01	9.151258D-01	3.313010D-02	9.108349D-01
17	7.478164D-01	-1.737739D-03	-8.938009D-01	9.530513D-01	-2.004107D-02	9.404271D-01
18	7.630014D-01	4.804982D-02	-8.414077D-01	1.000000D 00	-8.586274D-02	9.770598D-01
19	8.354318D-01	3.187004D-01	-4.101178D-01	8.617650D-01	-3.967737D-01	4.226284D-01
20	8.800547D-01	4.925591D-01	-1.008472D-01	6.631221D-01	-5.304365D-01	-4.890383D-02
21	9.206230D-01	6.561769D-01	2.138110D-01	3.819107D-01	-5.649359D-01	-5.085532D-01
22	9.542463D-01	7.942900D-01	4.909627D-01	8.920828D-02	-5.140013D-01	-8.301247D-01
23	9.729780D-01	8.776201D-01	6.926547D-01	-3.174637D-01	2.662573D-02	-2.094582D-01
24	9.953739D-01	9.788134D-01	9.455576D-01	-8.664836D-01	8.094941D-01	7.523884D-01
25	1.000000D 00	1.000000D 00	1.000000D 00	-9.924056D-01	1.000000D 00	1.000000D 00

ESG-79-30, Vol III
D-31

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * VERTICAL MODE SHAPES * * * * *

	MODE NO. 7	MODE NO. 8	MODE NO. 9	MODE NO. 10	MODE NO. 11	MODE NO. 12
NODE	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.
1	0.0	0.0	0.0	0.0	0.0	0.0
2	3.028617D-01	-1.670668D-01	1.364083D-01	-3.000631D-01	5.454994D-01	5.573599D-01
3	6.909150D-01	-3.324445D-01	2.402514D-01	-4.413482D-01	5.983889D-01	3.931675D-01
4	5.513421D-01	-1.461277D-01	3.434302D-02	1.165598D-01	-5.257620D-01	-7.056325D-01
5	-2.607549D-02	2.043458D-01	-2.238419D-01	5.081092D-01	-6.522159D-01	-1.733334D-01
6	-6.040889D-01	3.469287D-01	-1.982048D-01	9.978642D-02	5.072175D-01	7.896877D-01
7	-7.272529D-01	1.192529D-01	8.866938D-02	-4.840390D-01	7.039511D-01	-8.939347D-02
8	-2.801497D-01	-2.465114D-01	2.697414D-01	-3.107526D-01	-4.913917D-01	-7.888322D-01
9	4.064001D-01	-3.582803D-01	1.018397D-01	3.709116D-01	-7.537181D-01	3.700270D-01
10	7.972182D-01	-8.358799D-02	-2.075167D-01	4.792686D-01	4.800629D-01	6.880552D-01
11	5.684297D-01	2.937283D-01	-2.540009D-01	-1.860190D-01	8.016322D-01	-6.349207D-01
12	-1.243725D-01	3.643331D-01	3.575909D-02	-5.760430D-01	-4.753360D-01	-4.819821D-01
13	-7.463765D-01	3.674824D-02	2.900807D-01	-4.156910D-02	-8.477137D-01	8.433937D-01
14	-7.952901D-01	-3.457164D-01	1.666670D-01	5.843405D-01	4.797368D-01	1.792478D-01
15	-2.033195D-01	-3.618398D-01	-1.864779D-01	2.767146D-01	8.917416D-01	-9.512724D-01
16	5.808221D-01	2.417823D-02	-3.039414D-01	-5.021040D-01	-4.963375D-01	1.931818D-01
17	7.539714D-01	2.120345D-01	-1.598675D-01	-4.934070D-01	-7.138547D-01	5.537032D-01
18	9.624397D-01	4.445856D-01	1.848450D-02	-4.826408D-01	-9.831238D-01	1.000000D 00
19	1.000000D 00	1.000000D 00	9.629258D-01	7.420358D-01	4.673638D-01	-1.208962D-01
20	6.514432D-01	8.629743D-01	1.000000D 00	1.000000D 00	1.000000D 00	-7.334295D-01
21	6.029099D-02	2.848039D-01	4.169892D-01	4.995535D-01	5.961382D-01	-5.223394D-01
22	-4.948158D-01	-2.542546D-01	-3.145079D-01	-2.506263D-01	-2.060452D-01	1.266435D-01
23	-2.413548D-01	-2.174526D-01	-2.191204D-01	-2.023296D-01	-2.057637D-01	1.957386D-01
24	2.281284D-01	1.059051D-01	7.137689D-02	3.907653D-02	9.350996D-03	5.158956D-02
25	3.676449D-01	2.210612D-01	1.939017D-01	1.720293D-01	2.047434D-01	-3.573748D-01

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * V E R T I C A L M O D E S H A P E S * * * * *

	MODE NO. 13	MODE NO. 14	MODE NO. 15	MODE NO. 16	MODE NO. 17	MODE NO. 18
MODE	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.
1	0.0	0.0	0.0	0.0	0.0	0.0
2	7.112812D-03	-5.664393D-01	5.637001D-01	-5.484240D-01	5.263624D-01	4.976189D-01
3	3.496585D-03	-1.829192D-01	-1.596165D-02	1.826669D-01	-3.030584D-01	-3.719073D-01
4	-9.256500D-03	7.163310D-01	-5.605662D-01	3.178497D-01	-5.663894D-02	1.479851D-01
5	1.434735D-03	-3.231589D-01	6.218144D-01	-6.260518D-01	4.055673D-01	1.202957D-01
6	8.203992D-03	-5.095147D-01	-8.086063D-02	5.352305D-01	-6.005085D-01	-3.697027D-01
7	-6.388597D-03	7.054942D-01	-5.575990D-01	-9.372795D-02	5.600735D-01	5.430250D-01
8	-5.547486D-03	1.195849D-02	6.905694D-01	-4.247587D-01	-2.959820D-01	-6.018245D-01
9	9.783952D-03	-7.417705D-01	-1.770578D-01	6.938250D-01	-9.341139D-02	5.337231D-01
10	1.444385D-04	5.408762D-01	-5.227168D-01	-5.386108D-01	4.617729D-01	-3.531025D-01
11	-1.027059D-02	3.645546D-01	7.651164D-01	4.386905D-02	-6.753239D-01	9.583891D-02
12	5.891876D-03	-8.407078D-01	-3.124955D-01	4.981891D-01	6.524605D-01	1.899603D-01
13	7.196418D-03	2.664115D-01	-4.447487D-01	-7.641426D-01	-3.992814D-01	-4.545935D-01
14	-1.049545D-02	6.701559D-01	8.328190D-01	5.904696D-01	-9.341283D-04	6.562332D-01
15	-1.087180D-03	-8.057199D-01	-4.931001D-01	-6.670585D-02	4.187149D-01	-7.673659D-01
16	1.165242D-02	-5.871419D-02	-2.982964D-01	-5.189551D-01	-7.231085D-01	7.773359D-01
17	2.747061D-03	4.143653D-01	2.818389D-01	1.597800D-01	4.685120D-02	4.586733D-02
18	-8.277060D-03	1.000000D 00	1.000000D 00	1.000000D 00	1.000000D 00	-8.596324D-01
19	-3.663046D-02	6.535845D-02	2.615792D-01	4.707220D-01	7.237902D-01	-8.722487D-01
20	-1.109773D-02	-6.423909D-01	-6.129383D-01	-6.377899D-01	-7.052926D-01	6.903922D-01
21	2.809766D-02	-5.117109D-01	-5.849231D-01	-7.145956D-01	-9.119498D-01	1.000000D 00
22	3.683040D-02	1.275205D-01	1.116906D-01	1.163441D-01	1.318547D-01	-1.328281D-01
23	-1.778015D-01	6.406022D-02	1.269453D-01	1.743209D-01	2.440104D-01	-2.892133D-01
24	-2.481574D-01	-1.216441D-01	-5.907865D-02	-5.531899D-02	-6.365203D-02	6.758201D-02
25	1.000000D 00	3.685958D-01	1.180387D-01	8.531230D-02	8.307285D-02	-7.955370D-02

ESG-79-30, Vol III
D-33

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * V E R T I C A L M O D E S H A P E S * * * * *

	MODE NO. 19	MODE NO. 20	MODE NO. 21	MODE NO. 22	MODE NO. 23
NODE	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.
1	0.0	0.0	0.0	0.0	0.0
2	-6.953911D-01	1.000000D-00	2.312044D-06	-2.639559D-08	8.106008D-09
3	6.009930D-01	-9.719860D-01	-3.885738D-06	2.642219D-08	-1.070463D-08
4	-4.221149D-01	9.166241D-01	8.108353D-06	-4.982732D-08	2.229983D-09
5	1.627384D-01	-8.409778D-01	-1.787682D-05	1.430759D-07	-8.640912D-09
6	8.746648D-02	7.521368D-01	3.991485D-05	-4.482725D-07	-7.805320D-09
7	-3.578620D-01	-5.557160D-01	-8.972132D-05	1.315523D-06	-5.272738D-09
8	6.010318D-01	5.557160D-01	2.027637D-04	-3.788335D-06	-4.041519D-09
9	-7.958654D-01	-4.673796D-01	-4.609593D-04	1.088917D-05	-7.094241D-08
10	9.292655D-01	3.813827D-01	1.054535D-03	-3.145733D-05	3.474396D-07
11	-9.964399D-01	-3.043739D-01	-2.428813D-03	9.145293D-05	-1.990326D-06
12	1.000350D-00	2.374114D-01	5.633985D-03	-2.675365D-04	1.096046D-05
13	-9.482170D-01	-1.806650D-01	-1.316752D-02	7.875746D-04	-6.123795D-05
14	8.528470D-01	1.336086D-01	3.101993D-02	-2.333677D-03	3.435919D-04
15	-7.269078D-01	-9.520176D-02	-7.369235D-02	6.963018D-03	-1.938369D-03
16	5.826977D-01	6.403759D-02	1.766280D-01	-2.092904D-02	1.099421D-02
17	7.814601D-02	1.299595D-02	-1.242205D-01	2.107710D-02	-2.572287D-02
18	-5.464482D-01	-5.018953D-02	-4.966470D-01	7.307736D-02	-7.117569D-02
19	-7.270412D-01	-9.057808D-02	1.000000D-00	-2.180004D-01	5.011203D-01
20	5.022453D-01	5.525716D-02	-2.269842D-01	1.245140D-01	-9.218077D-01
21	7.929145D-01	9.489135D-02	-9.451145D-01	1.582116D-01	1.000000D-00
22	-9.905760D-02	-1.119158D-02	5.306496D-02	-1.169227D-01	-8.034106D-02
23	-2.436704D-01	-3.115549D-02	6.572480D-01	1.000000D-00	7.794253D-02
24	5.331040D-02	6.447578D-03	-1.033437D-01	-1.345782D-01	-6.336246D-03
25	-5.882526D-02	-6.726619D-03	8.045524D-02	8.810939D-02	2.348911D-03

ESG-79-30, Vol. III
D-34

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

COMPOSITE MODAL DAMPING RATIOS

	LATERAL	VERTICAL
MODE	DAMP. RATIO	DAMP. RATIO
1	7.000000D-02	7.000000D-02
2	7.000000D-02	7.000000D-02
3	7.000000D-02	7.000000D-02
4	7.000000D-02	7.000000D-02
5	7.000000D-02	7.000000D-02
6	7.000000D-02	7.000000D-02
7	7.000000D-02	7.000000D-02
8	7.000000D-02	7.000000D-02
9	7.000000D-02	7.000000D-02
10	7.000000D-02	7.000000D-02
11	7.000000D-02	7.000000D-02
12	7.000000D-02	7.000000D-02
13	7.000000D-02	7.000000D-02
14	7.000000D-02	7.000000D-02
15	7.000000D-02	7.000000D-02
16	7.000000D-02	7.000000D-02
17	7.000000D-02	7.000000D-02
18	7.000000D-02	7.000000D-02
19	7.000000D-02	7.000000D-02
20	7.000000D-02	7.000000D-02
21	7.000000D-02	7.000000D-02
22	7.000000D-02	7.000000D-02
23	7.000000D-02	7.000000D-02

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

DYNAMIC WIND RESPONSE (VORTEX SHEDDING)

CRITICAL WIND VELOCITY = 1.059661D 02

NOTE: CRITICAL WIND VELOCITY EXCEEDS 1.030000D 02.
NO FURTHER CALCULATIONS WILL BE MADE.

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

DRAG WIND RESPONSE

GUST_FACTOR = 1.0307940 00

NODE	EFF. VELOCITY PRESSURE	TRIBUTARY AREA	NET PRESSURE COEFFICIENT	NODAL FORCE
1	2.137454D-02	0.0	0.0	0.0
2	2.137454D-02	1.203689D 03	6.250000D-01	1.608018D 01
3	2.259399D-02	1.177733D 03	6.250000D-01	1.663106D 01
4	2.614996D-02	1.151778D 03	6.250000D-01	1.882434D 01
5	2.879132D-02	1.125822D 03	6.250000D-01	2.025869D 01
6	3.093625D-02	1.099867D 03	6.250000D-01	2.126609D 01
7	3.275284D-02	1.073911D 03	6.250000D-01	2.199024D 01
8	3.436528D-02	1.047956D 03	6.250000D-01	2.250831D 01
9	3.580004D-02	1.022000D 03	6.250000D-01	2.286727D 01
10	3.710390D-02	9.960444D 02	6.250000D-01	2.309821D 01
11	3.833231D-02	9.700889D 02	6.250000D-01	2.322290D 01
12	3.941365D-02	9.441333D 02	6.250000D-01	2.325736D 01
13	4.045180D-02	9.181778D 02	6.250000D-01	2.321372D 01
14	4.142723D-02	8.922222D 02	6.250000D-01	2.310146D 01
15	4.234849D-02	8.662667D 02	6.250000D-01	2.292818D 01
16	4.322215D-02	8.403111D 02	6.250000D-01	2.270003D 01
17	4.364613D-02	0.0	0.0	0.0
18	4.374833D-02	3.315000D 02	6.250000D-01	9.064107D 00
19	4.430002D-02	5.195000D 02	6.250000D-01	1.435597D 01
20	4.465848D-02	3.740000D 02	6.250000D-01	1.043892D 01
21	4.500959D-02	3.570000D 02	6.250000D-01	1.004283D 01
22	4.532351D-02	3.740000D 02	6.250000D-01	1.059437D 01
23	4.569263D-02	5.015000D 02	6.250000D-01	1.432185D 01
24	4.621840D-02	6.205000D 02	6.250000D-01	1.792407D 01
25	4.677260D-02	3.230000D 02	6.250000D-01	9.442219D 00

ESG-79-30, Vol III
D-37

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

DRAG WIND RESPONSE

NODAL DISPLACEMENTS

NODE	X-DISPL.	Z-ROTATION
1	0.0	0.0
2	6.400364D-04	5.478287D-05
3	3.917550D-03	1.628276D-04
4	9.779912D-03	2.675586D-04
5	1.813589D-02	3.634635D-04
6	2.088275D-02	4.650397D-04
7	4.190592D-02	5.567881D-04
8	5.707891D-02	6.432121D-04
9	7.426330D-02	7.238207D-04
10	9.330820D-02	7.981341D-04
11	1.140538D-01	8.656931D-04
12	1.363255D-01	9.260719D-04
13	1.593416D-01	9.783967D-04
14	1.847112D-01	1.023270D-03
15	2.104373D-01	1.060805D-03
16	2.369202D-01	1.089670D-03
17	2.504785D-01	1.101173D-03
18	2.538010D-01	1.113705D-03
19	2.723711D-01	1.170107D-03
20	2.856966D-01	1.196881D-03
21	2.989761D-01	1.216466D-03
22	3.112071D-01	1.228956D-03
23	3.260174D-01	1.238545D-03
24	3.477591D-01	1.244993D-03
25	3.714329D-01	1.246492D-03

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

DRAG WIND RESPONSE

B E A M L O A D S

MEMB	NODE	SHEAR	MOMENT
1	1	4.181324D 02	1.018050D 05
	2	4.181324D 02	9.674650D 04
2	2	4.020522D 02	9.674650D 04
	3	4.020522D 02	8.696374D 04
3	3	3.854211D 02	8.696374D 04
	4	3.854211D 02	7.758568D 04
4	4	3.665968D 02	7.758568D 04
	5	3.655968D 02	6.866567D 04
5	5	3.463381D 02	6.866567D 04
	6	3.463381D 02	6.023861D 04
6	6	3.250720D 02	6.023861D 04
	7	3.250720D 02	5.232902D 04
7	7	3.030818D 02	5.232902D 04
	8	3.030818D 02	4.495451D 04
8	8	2.805735D 02	4.495451D 04
	9	2.805735D 02	3.812768D 04
9	9	2.577062D 02	3.812768D 04
	10	2.577062D 02	3.185728D 04
10	10	2.346080D 02	3.185728D 04
	11	2.346080D 02	2.614891D 04
11	11	2.113851D 02	2.614891D 04
	12	2.113851D 02	2.100561D 04
12	12	1.831277D 02	2.100561D 04
	13	1.881277D 02	1.642821D 04
13	13	1.649140D 02	1.642821D 04
	14	1.649140D 02	1.241565D 04
14	14	1.418126D 02	1.241565D 04
	15	1.418126D 02	8.965197D 03
15	15	1.183844D 02	8.965197D 03
	16	1.183844D 02	6.072624D 03
16	16	9.618434D 01	6.072624D 03
	17	9.618434D 01	4.893418D 03
17	17	9.618434D 01	4.893418D 03
	18	9.618434D 01	4.604865D 03
18	18	8.712024D 01	4.604865D 03
	19	8.712024D 01	3.167381D 03
19	19	7.276426D 01	3.167381D 03
	20	7.276426D 01	2.366974D 03
20	20	6.232534D 01	2.366974D 03
	21	6.232534D 01	1.681395D 03
21	21	5.229251D 01	1.681395D 03
	22	5.228251D 01	1.158570D 03
22	22	4.168814D 01	1.158570D 03
	23	4.168314D 01	6.583123D 02
23	23	2.736629D 01	6.583123D 02
	24	2.736529D 01	1.794022D 02
24	24	9.442219D 00	1.794022D 02
	25	9.442219D 00	0.0

ESG-79-30, Vol III
D-39

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

SPECTRAL ACCELERATIONS, X-DIRECTION (G'S)

MODE	FREQUENCY	DAMP. RATIO	ACCELERATION
1	5.577161D-01	7.000000D-02	2.868028D-01
2	2.350025D 00	7.000000D-02	3.054721D-01
3	5.194883D 00	7.000000D-02	3.573137D-01
4	9.147312D 00	7.000000D-02	7.847511D-01
5	1.396225D 01	7.000000D-02	6.013838D-01
6	1.895653D 01	7.000000D-02	4.961093D-01
7	2.405024D 01	7.000000D-02	4.271021D-01
8	2.947943D 01	7.000000D-02	3.757512D-01
9	3.503166D 01	7.000000D-02	3.500000D-01
10	4.032559D 01	7.000000D-02	3.500000D-01
11	4.533909D 01	7.000000D-02	3.500000D-01
12	4.976535D 01	7.000000D-02	3.500000D-01
13	5.359058D 01	7.000000D-02	3.500000D-01
14	5.676066D 01	7.000000D-02	3.500000D-01
15	5.924833D 01	7.000000D-02	3.500000D-01
16	6.106543D 01	7.000000D-02	3.500000D-01
17	6.183360D 01	7.000000D-02	3.500000D-01
18	6.266452D 01	7.000000D-02	3.500000D-01
19	8.962749D 01	7.000000D-02	3.500000D-01
20	1.563907D 02	7.000000D-02	3.500000D-01
21	2.551740D 02	7.000000D-02	3.500000D-01
22	3.445234D 02	7.000000D-02	3.500000D-01
23	5.547098D 02	7.000000D-02	3.500000D-01

ESG-79-30, Vol III
D-40

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

SPECTRAL ACCELERATIONS, Y-DIRECTION (G'S)

MODE	FREQUENCY	DAMP. RATIO	ACCELERATION
1	6.554931D 00	7.000000D-02	8.428421D-01
2	1.402813D 01	7.000000D-02	5.996051D-01
3	2.248744D 01	7.000000D-02	4.455480D-01
4	3.433033D 01	7.000000D-02	3.500000D-01
5	4.205548D 01	7.000000D-02	3.500000D-01
6	4.795759D 01	7.000000D-02	3.500000D-01
7	5.937040D 01	7.000000D-02	3.500000D-01
8	6.955986D 01	7.000000D-02	3.500000D-01
9	7.661128D 01	7.000000D-02	3.500000D-01
10	8.472652D 01	7.000000D-02	3.500000D-01
11	9.415006D 01	7.000000D-02	3.500000D-01
12	1.030985D 02	7.000000D-02	3.500000D-01
13	1.075729D 02	7.000000D-02	3.500000D-01
14	1.111478D 02	7.000000D-02	3.500000D-01
15	1.180566D 02	7.000000D-02	3.500000D-01
16	1.237389D 02	7.000000D-02	3.500000D-01
17	1.280837D 02	7.000000D-02	3.500000D-01
18	1.310691D 02	7.000000D-02	3.500000D-01
19	1.330643D 02	7.000000D-02	3.500000D-01
20	1.348768D 02	7.000000D-02	3.500000D-01
21	1.456686D 02	7.000000D-02	3.500000D-01
22	1.532175D 02	7.000000D-02	3.500000D-01
23	1.853224D 02	7.000000D-02	3.500000D-01

ESG-79-30, Vol 111
D-41

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

* * * * * RSS SUM - DISPLACEMENTS, VELOCITIES, AND ACCELERATIONS - LATERAL EARTHQUAKE * * * * *

NODE	RELATIVE DISPLACEMENTS		RELATIVE VELOCITIES		ABSOLUTE ACCELERATIONS	
	X-TRANSL.	Z-ROTATION	X-TRANSL.	Z-ROTATION	X-TRANSL.	Z-ROTATION
1	0.0	0.0	0.0	0.0	0.0	0.0
2	2.447345D-03	1.978670D-04	3.755394D-02	1.515784D-03	3.416321D 00	4.049590D-02
3	1.443421D-02	5.869377D-04	1.553022D-01	4.101352D-03	7.120167D 00	9.156939D-02
4	3.566039D-02	9.624691D-04	3.197432D-01	5.095210D-03	1.056726D 01	1.154044D-01
5	6.575580D-02	1.323088D-03	5.164671D-01	7.571666D-03	1.341453D 01	1.266985D-01
6	1.043014D-01	1.667911D-03	7.330808D-01	8.629802D-03	1.559186D 01	1.363388D-01
7	1.508467D-01	1.996519D-03	9.595355D-01	9.376049D-03	1.719509D 01	1.472793D-01
8	2.049279D-01	2.368961D-03	1.187954D 00	9.933182D-03	1.840540D 01	1.580890D-01
9	2.660869D-01	2.605546D-03	1.412513D 00	1.043823D-02	1.936698D 01	1.664052D-01
10	3.338714D-01	2.895536D-03	1.629701D 00	1.105960D-02	2.005230D 01	1.725545D-01
11	4.078331D-01	3.151861D-03	1.839061D 00	1.192935D-02	2.039775D 01	1.799160D-01
12	4.875282D-01	3.405310D-03	2.044139D 00	1.318352D-02	2.027784D 01	1.938120D-01
13	5.724988D-01	3.631847D-03	2.253006D 00	1.482619D-02	1.969501D 01	2.181970D-01
14	6.622787D-01	3.842443D-03	2.477874D 00	1.676921D-02	1.891322D 01	2.526513D-01
15	7.563673D-01	4.028971D-03	2.733031D 00	1.885793D-02	1.863446D 01	2.915904D-01
16	8.542029D-01	4.187491D-03	3.031461D 00	2.091673D-02	1.973583D 01	3.273578D-01
17	9.046794D-01	4.254799D-03	3.200695D 00	2.182644D-02	2.078615D 01	3.398613D-01
18	9.170961D-01	4.331366D-03	3.244001D 00	2.305199D-02	2.107648D 01	3.555080D-01
19	9.882646D-01	4.702746D-03	3.503709D 00	2.552969D-02	2.157754D 01	4.974061D-01
20	1.038057D 00	4.895196D-03	3.705852D 00	3.336636D-02	2.165149D 01	6.074794D-01
21	1.089355D 00	5.040323D-03	3.937414D 00	3.655558D-02	2.255090D 01	7.166495D-01
22	1.137019D 00	5.131222D-03	4.175384D 00	3.881671D-02	2.484582D 01	8.142921D-01
23	1.195172D 00	5.206609D-03	4.494621D 00	4.078173D-02	3.000424D 01	9.379418D-01
24	1.281309D 00	5.247350D-03	5.018677D 00	4.224146D-02	4.223683D 01	1.069593D 00
25	1.375916D 00	5.256190D-03	5.646785D 00	4.256578D-02	5.970521D 01	1.116117D 00

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

RSS SUM - BEAM LOADS - LATERAL EARTHQUAKE

MEMB	NODE	SHEAR	MOMENT
1	1	1.830507D 03	3.679651D 05
	2	1.830507D 03	3.492695D 05
2	2	1.818163D 03	3.492695D 05
	3	1.818163D 03	3.130804D 05
3	3	1.772395D 03	3.130804D 05
	4	1.772395D 03	2.794073D 05
4	4	1.694212D 03	2.794073D 05
	5	1.694212D 03	2.488312D 05
5	5	1.591969D 03	2.488312D 05
	6	1.591969D 03	2.216240D 05
6	6	1.471763D 03	2.216240D 05
	7	1.471763D 03	1.978575D 05
7	7	1.340376D 03	1.978575D 05
	8	1.340376D 03	1.773213D 05
8	8	1.203951D 03	1.773213D 05
	9	1.203951D 03	1.594392D 05
9	9	1.083405D 03	1.594392D 05
	10	1.083405D 03	1.434287D 05
10	10	9.716413D 02	1.434287D 05
	11	9.716413D 02	1.284683D 05
11	11	8.820278D 02	1.284683D 05
	12	8.820278D 02	1.138151D 05
12	12	8.152755D 02	1.138151D 05
	13	8.152755D 02	9.898341D 04
13	13	7.724971D 02	9.898341D 04
	14	7.724971D 02	8.367612D 04
14	14	7.432815D 02	8.367612D 04
	15	7.432815D 02	6.787803D 04
15	15	7.124122D 02	6.787803D 04
	16	7.124122D 02	5.182187D 04
16	16	6.732126D 02	5.182187D 04
	17	6.732126D 02	4.373836D 04
17	17	6.732126D 02	4.373836D 04
	18	6.732126D 02	4.177044D 04
18	18	6.671209D 02	4.177044D 04
	19	6.671209D 02	3.104748D 04
19	19	6.447612D 02	3.104748D 04
	20	6.447612D 02	2.413000D 04
20	20	6.155013D 02	2.413000D 04
	21	6.155013D 02	1.752886D 04
21	21	5.803167D 02	1.752886D 04
	22	5.803167D 02	1.192401D 04
22	22	3.787677D 02	1.192401D 04
	23	3.787677D 02	7.392293D 03
23	23	3.265913D 02	7.392293D 03
	24	3.265913D 02	1.694923D 03
24	24	8.920648D 01	1.694923D 03
	25	8.920648D 01	9.881976D 06

ESG-79-30, Vol III
D-43

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

RSS SUM - DISPLACEMENTS, VELOCITIES, AND ACCELERATIONS - VERTICAL EARTHQUAKE

NODE	REL. Y-DISPL.	REL. Y-VEL.	ABS. Y-ACCEL.
1	0.0	0.0	0.0
2	7.1981100-04	3.1039390-02	3.0070810 00
3	2.1974140-03	9.3936060-02	5.9115350 00
4	3.7044930-03	1.5741760-01	8.6256690 00
5	5.2281090-03	2.2096320-01	1.1182750 01
6	6.7550610-03	2.8410330-01	1.3655050 01
7	8.2719120-03	3.4637410-01	1.6016750 01
8	9.7650210-03	4.0733970-01	1.8253730 01
9	1.1220560-02	4.6658990-01	2.0449240 01
10	1.2624490-02	5.2367020-01	2.2599910 01
11	1.3952550-02	5.7808110-01	2.4682880 01
12	1.5220410-02	6.2925060-01	2.6688300 01
13	1.6383550-02	6.7673060-01	2.8585080 01
14	1.7437490-02	7.1980790-01	3.0352430 01
15	1.8367850-02	7.5790410-01	3.1958430 01
16	1.9160410-02	7.9038340-01	3.3354830 01
17	1.9479420-02	8.0339240-01	3.3846620 01
18	1.9874980-02	8.1964270-01	3.4640360 01
19	2.1774000-02	8.9903330-01	3.7997190 01
20	2.2950400-02	9.4964300-01	4.0381220 01
21	2.4627180-02	9.9688800-01	4.2595410 01
22	2.4923550-02	1.0369220 00	4.4793420 01
23	2.5425530-02	1.0597510 00	4.6095080 01
24	2.6027620-02	1.0876310 00	4.8039910 01
25	2.6152280-02	1.0934900 00	4.8538480 01

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

RSS SUM - BEAM LOADS - VERTICAL EARTHQUAKE

MEMB NODE AXIAL LOAD

1	1	4.376662D 03
	2	4.376662D 03
2	2	4.354736D 03
	3	4.354736D 03
3	3	4.291045D 03
	4	4.291045D 03
4	4	4.188809D 03
	5	4.188809D 03
5	5	4.051379D 03
	6	4.051379D 03
6	6	3.882028D 03
	7	3.882028D 03
7	7	3.684034D 03
	8	3.684034D 03
8	8	3.460482D 03
	9	3.460482D 03
9	9	3.214267D 03
	10	3.214287D 03
10	10	2.940485D 03
	11	2.940485D 03
11	11	2.666205D 03
	12	2.666205D 03
12	12	2.370658D 03
	13	2.370658D 03
13	13	2.065299D 03
	14	2.065299D 03
14	14	1.753378D 03
	15	1.753378D 03
15	15	1.440670D 03
	16	1.440670D 03
16	16	1.131108D 03
	17	1.131108D 03
17	17	1.131108D 03
	18	1.131108D 03
18	18	9.947701D 02
	19	9.947701D 02
19	19	9.223369D 02
	20	9.223369D 02
20	20	8.435930D 02
	21	8.435930D 02
21	21	7.712704D 02
	22	7.712704D 02
22	22	3.639454D 02
	23	3.639454D 02
23	23	2.996838D 02
	24	2.996838D 02
24	24	5.728397D 01
	25	5.728397D 01

ESG-79-30, Vol III
D-45

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

BEAM LOADS DUE TO DEAD LOAD

MEMB --- NODE --- AXIAL LOAD

1	1	7.187074D 03
	2	6.919839D 03
2	2	6.919839D 03
	3	6.395211D 03
3	3	6.395211D 03
	4	5.887530D 03
4	4	5.887530D 03
	5	5.396527D 03
5	5	5.396527D 03
	6	4.921933D 03
6	6	4.921933D 03
	7	4.463479D 03
7	7	4.463479D 03
	8	4.020895D 03
8	8	4.020895D 03
	9	3.593914D 03
9	9	3.593914D 03
	10	3.182266D 03
10	10	3.182266D 03
	11	2.785681D 03
11	11	2.785681D 03
	12	2.403891D 03
12	12	2.403891D 03
	13	2.036627D 03
13	13	2.036627D 03
	14	1.693620D 03
14	14	1.693620D 03
	15	1.344601D 03
15	15	1.344601D 03
	16	1.019300D 03
16	16	1.019300D 03
	17	8.605000D 02
17	17	8.605000D 02
	18	8.605000D 02
18	18	7.237800D 02
	19	7.237800D 02
19	19	6.598600D 02
	20	6.598600D 02
20	20	5.954500D 02
	21	5.954500D 02
21	21	5.402400D 02
	22	5.402400D 02
22	22	2.456100D 02
	23	2.456100D 02
23	23	2.005000D 02
	24	2.005000D 02
24	24	3.800000D 01
	25	3.800000D 01

ESG-79-30, Vol III
D-46

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

LOAD CMB. 1 (1.05) * DEAD LOAD + (1.28) * WIND

* * * * R E B A R D E S I G N - D E A D L O A D + D R A G W I N D * * * *

MEMB	NODE	OUTER RADIUS (IN)	WALL THICK. (IN)	DESIGN AXIAL LOAD (KIPS)	DESIGN MOMENT (IN-KIPS)	REQ'D STEEL RATIO	REQ'D REBAR (SQ. IN)
1	1	3.000000 02	1.100040 01	7.546427 03	1.563725 06	3.300000-03	6.717185 01
	2	2.968181 02	1.093410 01	7.265831 03	1.486026 06	3.300000-03	6.605312 01
2	2	2.968181 02	1.093410 01	7.265831 03	1.486026 06	3.300000-03	6.605312 01
	3	2.904184 02	1.030074 01	6.714971 03	1.335763 06	3.300000-03	6.382927 01
3	3	2.904184 02	1.030074 01	6.714971 03	1.335763 06	3.300000-03	6.382927 01
	4	2.840180 02	1.056739 01	6.181906 03	1.191716 06	3.300000-03	6.164045 01
4	4	2.840180 02	1.056739 01	6.181906 03	1.191716 06	3.300000-03	6.164045 01
	5	2.776192 02	1.053404 01	5.666353 03	1.054705 06	3.300000-03	5.948665 01
5	5	2.776192 02	1.053404 01	5.666353 03	1.054705 06	3.300000-03	5.948665 01
	6	2.712195 02	1.040069 01	5.168029 03	9.252650 05	3.300000-03	5.736788 01
6	6	2.712195 02	1.040069 01	5.168029 03	9.252650 05	3.300000-03	5.736788 01
	7	2.648193 02	1.026734 01	4.686653 03	8.037737 05	3.300000-03	5.528414 01
7	7	2.648193 02	1.026734 01	4.686653 03	8.037737 05	3.300000-03	5.528414 01
	8	2.534204 02	1.013398 01	4.221940 03	6.905012 05	3.300000-03	5.323542 01
8	8	2.534204 02	1.013398 01	4.221940 03	6.905012 05	3.300000-03	5.323542 01
	9	2.520208 02	1.000063 01	3.773610 03	5.856412 05	3.300000-03	5.122173 01
9	9	2.520208 02	1.000063 01	3.773610 03	5.856412 05	3.300000-03	5.122173 01
	10	2.456212 02	9.857283 00	3.341379 03	4.893278 05	3.300000-03	4.924307 01
10	10	2.456212 02	9.857283 00	3.341379 03	4.893278 05	3.300000-03	4.924307 01
	11	2.392217 02	9.733933 00	2.924965 03	4.016473 05	3.300000-03	4.729943 01
11	11	2.392217 02	9.733933 00	2.924965 03	4.016473 05	3.300000-03	4.729943 01
	12	2.328222 02	9.600583 00	2.524086 03	3.226462 05	3.300000-03	4.539082 01
12	12	2.328222 02	9.600583 00	2.524086 03	3.226462 05	3.300000-03	4.539082 01
	13	2.264229 02	9.467234 00	2.138459 03	2.523374 05	3.300000-03	4.351724 01
13	13	2.264229 02	9.467234 00	2.138459 03	2.523374 05	3.300000-03	4.351724 01
	14	2.200233 02	9.333866 00	1.767801 03	1.907044 05	3.300000-03	4.167868 01
14	14	2.200233 02	9.333866 00	1.767801 03	1.907044 05	3.300000-03	4.167868 01
	15	2.136239 02	9.200538 00	1.411831 03	1.377054 05	3.300000-03	3.987516 01
15	15	2.136239 02	9.200538 00	1.411831 03	1.377054 05	3.300000-03	3.987516 01
	16	2.072245 02	9.067191 00	1.070265 03	9.327550 04	3.300000-03	3.810666 01
16	16	2.072245 02	9.067191 00	1.070265 03	9.327550 04	3.300000-03	3.810666 01
	17	2.040000 02	9.000000 00	9.035250 02	7.516289 04	3.300000-03	3.722882 01

D-47

ESG-79-30, Vol III

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

LOAD CMB. 2 (0.90) = DEAD LOAD + (1.30) * WIND

* * * * REBAR DESIGN - DEAD LOAD + DRAG WIND * * * *

MEMB	NODE	OUTER RADIUS (IN)	WALL THICK. (IN)	DESIGN AXIAL LOAD (KIPS)	DESIGN MOMENT (IN-KIPS)	REQ'D STEEL RATIO	REQ'D REBAR (SQ. IN)
1	1	3.000000 02	1.100040 01	6.468366 03	1.588158 06	3.300000-03	6.717185 01
2	2	2.968181 02	1.093410 01	6.227855 03	1.509245 06	3.300000-03	6.605312 01
2	2	2.968181 02	1.093410 01	6.227855 03	1.509245 06	3.300000-03	6.605312 01
3	3	2.904184 02	1.080074 01	5.755690 03	1.356634 06	3.300000-03	6.382927 01
3	3	2.904184 02	1.080074 01	5.755690 03	1.356634 06	3.300000-03	6.382927 01
4	4	2.840188 02	1.066739 01	5.298777 03	1.210337 06	3.300000-03	6.164835 01
4	4	2.840188 02	1.066739 01	5.298777 03	1.210337 06	3.300000-03	6.164835 01
5	5	2.776192 02	1.053404 01	4.856874 03	1.071184 06	3.300000-03	5.948665 01
5	5	2.776192 02	1.053404 01	4.856874 03	1.071184 06	3.300000-03	5.948665 01
6	6	2.712195 02	1.040069 01	4.429740 03	9.397223 05	3.300000-03	5.736788 01
6	6	2.712195 02	1.040069 01	4.429740 03	9.397223 05	3.300000-03	5.736788 01
7	7	2.648199 02	1.026734 01	4.017131 03	8.163327 05	3.300000-03	5.528414 01
7	7	2.648199 02	1.026734 01	4.017131 03	8.163327 05	3.300000-03	5.528414 01
8	8	2.584204 02	1.013398 01	3.618806 03	7.012903 05	3.300000-03	5.323542 01
8	8	2.584204 02	1.013398 01	3.618806 03	7.012903 05	3.300000-03	5.323542 01
9	9	2.520208 02	1.000063 01	3.234523 03	5.947919 05	3.300000-03	5.122173 01
9	9	2.520208 02	1.000063 01	3.234523 03	5.947919 05	3.300000-03	5.122173 01
10	10	2.456212 02	9.867283 00	2.864039 03	4.969736 05	3.300000-03	4.924307 01
10	10	2.456212 02	9.867283 00	2.864039 03	4.969736 05	3.300000-03	4.924307 01
11	11	2.392217 02	9.733933 00	2.507113 03	4.079230 05	3.300000-03	4.729943 01
11	11	2.392217 02	9.733933 00	2.507113 03	4.079230 05	3.300000-03	4.729943 01
12	12	2.328222 02	9.600583 00	2.163502 03	3.276875 05	3.300000-03	4.539082 01
12	12	2.328222 02	9.600583 00	2.163502 03	3.276875 05	3.300000-03	4.539082 01
13	13	2.264228 02	9.467234 00	1.832965 03	2.562801 05	3.300000-03	4.351724 01
13	13	2.264228 02	9.467234 00	1.832965 03	2.562801 05	3.300000-03	4.351724 01
14	14	2.200233 02	9.333886 00	1.515258 03	1.936842 05	3.300000-03	4.167868 01
14	14	2.200233 02	9.333886 00	1.515258 03	1.936842 05	3.300000-03	4.167868 01
15	15	2.136239 02	9.200538 00	1.210141 03	1.398571 05	3.300000-03	3.987516 01
15	15	2.136239 02	9.200538 00	1.210141 03	1.398571 05	3.300000-03	3.987516 01
16	16	2.072245 02	9.067191 00	9.173699 02	9.473293 04	3.300000-03	3.810666 01
16	16	2.072245 02	9.067191 00	9.173699 02	9.473293 04	3.300000-03	3.810666 01
17	17	2.040000 02	9.000000 00	7.744500 02	7.633731 04	3.300000-03	3.722882 01

ESG-79-30, Vol III
D-4R

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

LOAD CMB. 1 (1.05) * DEAD LOAD + (1.40) * X-SEISMIC + (1.40) * Y-SEISMIC

* * * * REBAR DESIGN - DEAD LOAD + SEISMIC * * * *

MEMB	NODE	OUTER RADIUS (IN)	WALL THICK. (IN)	DESIGN AXIAL LOAD (KIPS)	DESIGN MOMENT (IN-KIPS)	REQ'D STEEL RATIO	REQ'D REBAR (SQ. IN)
1	1	3.000000 02	1.100040 01	1.367375 04	6.181813 06	1.530910 02	3.116184 02
	2	2.968181 02	1.093410 01	1.339316 04	5.867728 06	1.442985 02	2.888293 02
2	2	2.968181 02	1.093410 01	1.336246 04	5.867728 06	1.445184 02	2.892695 02
	3	2.904184 02	1.080074 01	1.281160 04	5.259750 06	1.264411 02	2.445649 02
3	3	2.904184 02	1.080074 01	1.272243 04	5.259750 06	1.271416 02	2.459199 02
	4	2.840188 02	1.066739 01	1.218937 04	4.694043 06	1.093275 02	2.042120 02
4	4	2.840188 02	1.066739 01	1.204624 04	4.694043 06	1.105645 02	2.065226 02
	5	2.776192 02	1.053404 01	1.153069 04	4.180365 06	9.388521 03	1.692399 02
5	5	2.776192 02	1.053404 01	1.133828 04	4.180365 06	9.570411 03	1.725187 02
	6	2.712195 02	1.040069 01	1.083996 04	3.723284 06	8.079399 03	1.404539 02
6	6	2.712195 02	1.040069 01	1.060287 04	3.723284 06	8.323054 03	1.446697 02
	7	2.648199 02	1.026734 01	1.012149 04	3.324005 06	7.054092 03	1.181756 02
7	7	2.648199 02	1.026734 01	9.844300 03	3.324005 06	7.363083 03	1.233520 02
	8	2.584204 02	1.013398 01	9.379588 03	2.978998 06	6.329304 03	1.021040 02
8	8	2.584204 02	1.013398 01	9.066615 03	2.978998 06	6.705470 03	1.081723 02
	9	2.520208 02	1.000630 01	8.618284 03	2.678579 06	5.868998 03	9.109704 01
9	9	2.520208 02	1.000630 01	8.273612 03	2.678579 06	6.312774 03	9.798521 01
	10	2.456212 02	9.867283 00	7.841381 03	2.409602 06	5.596227 03	8.350769 01
10	10	2.456212 02	9.867283 00	7.469259 03	2.409602 06	6.108395 03	9.115033 01
	11	2.392217 02	9.733933 00	7.052845 03	2.158267 06	5.412955 03	7.758475 01
11	11	2.392217 02	9.733933 00	6.657652 03	2.158267 06	5.993444 03	8.590500 01
	12	2.328222 02	9.600583 00	6.256773 03	1.912093 06	5.210885 03	7.167464 01
12	12	2.328222 02	9.600583 00	5.843007 03	1.912093 06	5.859354 03	8.059421 01
	13	2.264228 02	9.467234 00	5.457380 03	1.662921 06	4.903169 03	6.465829 01
13	13	2.264228 02	9.467234 00	5.029877 03	1.662921 06	5.514984 03	7.272632 01
	14	2.200233 02	9.333886 00	4.659219 03	1.405759 06	4.284260 03	5.410979 01
14	14	2.200233 02	9.333886 00	4.223230 03	1.405759 06	4.893697 03	6.180692 01
	15	2.136239 02	9.200538 00	3.867260 03	1.140351 06	3.463521 03	4.165105 01
15	15	2.136239 02	9.200538 00	3.428769 03	1.140351 06	4.133641 03	4.994835 01
	16	2.072245 02	9.067191 00	3.087203 03	8.706074 05	3.300000 03	3.810666 01
16	16	2.072245 02	9.067191 00	2.653817 03	8.706074 05	3.300000 03	3.810666 01
	17	2.040000 02	9.000000 00	2.487077 03	7.348044 05	3.300000 03	3.722882 01

ESG-79-30, Vol III
D-49

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

LOAD CMB. 2 (0.90) * DEAD LOAD + (1.43 * X-SEISMIC + (-1.43) * Y-SEISMIC

* * * * * REBAR DESIGN = DEAD LOAD + SEISMIC * * * * *

MEMB	NODE	OUTER RADIALS (IN)	WALL THICK. (IN)	DESIGN AXIAL LOAD (KIPS)	DESIGN MOMENT (IN-KIPS)	REQ'D STEEL RATIO	REQ'D REBAR (SQ. IN)
1	1	3.000000 C2	1.100040 D1	2.097393D 02	6.314280D 06	2.120187D-02	4.315663D 02
	2	2.968181D C2	1.093410D D1	-3.077202D 01	5.993465D 06	2.069483D-02	4.142297D 02
2	2	2.968181D C2	1.093410D D1	5.821544D-01	5.993465D 06	2.066831D-02	4.136988D 02
	3	2.904184D C2	1.080074D D1	-4.715833D 02	5.372459D 06	1.990812D-02	3.850669D 02
3	3	2.904184D C2	1.080074D D1	-3.805043D 02	5.372459D 06	1.982642D-02	3.834667D 02
	4	2.840183D C2	1.066739D D1	-8.374177D 02	4.794629D 06	1.909444D-02	3.566636D 02
4	4	2.840183D C2	1.066739D D1	-6.912200D 02	4.794629D 06	1.895734D-02	3.541628D 02
	5	2.776192D C2	1.053404D D1	-1.133123D 03	4.269944D 06	1.830298D-02	3.293339D 02
5	5	2.776192D C2	1.053404D D1	-9.365982D 02	4.269944D 06	1.811046D-02	3.264639D 02
	6	2.712195D C2	1.040069D D1	-1.363733D 03	3.803068D 06	1.756879D-02	3.054195D 02
6	6	2.712195D C2	1.040069D D1	-1.121561D 03	3.803068D 06	1.732116D-02	3.011147D 02
	7	2.648199D C2	1.026734D D1	-1.534169D 03	3.395234D 06	1.691802D-02	2.834237D 02
7	7	2.648199D C2	1.026734D D1	-1.251038D 03	3.395234D 06	1.661597D-02	2.783635D 02
	8	2.594204D C2	1.013398D D1	-1.649363D 03	3.042834D 06	1.635807D-02	2.638874D 02
8	8	2.594204D C2	1.013398D D1	-1.329683D 03	3.042834D 06	1.600239D-02	2.581497D 02
	9	2.520208D C2	1.000063D D1	-1.713966D 03	2.735977D 06	1.586387D-02	2.462348D 02
9	9	2.520208D C2	1.000063D D1	-1.361968D 03	2.735977D 06	1.545541D-02	2.398947D 02
	10	2.456212D C2	9.867283D 00	-1.732351D 03	2.461236D 06	1.538341D-02	2.295534D 02
10	10	2.456212D C2	9.867283D 00	-1.352255D 03	2.461236D 06	1.492340D-02	2.226892D 02
	11	2.392217D C2	9.733933D 00	-1.709221D 03	2.204516D 06	1.484713D-02	2.128063D 02
11	11	2.392217D C2	9.733933D 00	-1.305560D 03	2.204516D 06	1.433719D-02	2.054973D 02
	12	2.328222D C2	9.600583D 00	-1.649171D 03	1.953066D 06	1.417603D-02	1.949883D 02
12	12	2.328222D C2	9.600583D 00	-1.226539D 03	1.953066D 06	1.361813D-02	1.873146D 02
	13	2.264223D C2	9.467234D 00	-1.557077D 03	1.698555D 06	1.330150D-02	1.754074D 02
13	13	2.264223D C2	9.467234D 00	-1.120413D 03	1.698555D 06	1.269838D-02	1.674540D 02
	14	2.200233D C2	9.333886D 00	-1.43819D 03	1.435882D 06	1.216304D-02	1.536180D 02
14	14	2.200233D C2	9.333886D 00	-9.927872D 02	1.435882D 06	1.151852D-02	1.454778D 02
	15	2.136239D C2	9.200538D 00	-1.297905D 03	1.164787D 06	1.072601D-02	1.296065D 02
15	15	2.136239D C2	9.200538D 00	-8.500179D 02	1.164787D 06	1.004587D-02	1.213881D 02
	16	2.072245D C2	9.067191D 00	-1.142789D 03	8.892632D 05	8.987564D-03	1.037836D 02
16	16	2.072245D C2	9.067191D 00	-7.001151D 02	8.892632D 05	8.281483D-03	9.563019D 01
	17	2.040000D C2	9.000000D 00	-9.430350D 02	7.505502D 05	7.645608D-03	8.625361D 01

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM

TOWER COSTS:

HOOP REINF. COST	=	19399.36	WEIGHT	=	3.879871D 01
VERT REINF. COST	=	154982.47	WEIGHT	=	3.099649D 02
TOTAL REBAR COST	=	174381.83	WEIGHT	=	3.487637D 02
CONCRETE COST	=	293263.13	VOLUME	=	3.959052D 04

TOTAL COST = 467644.95

SOLAR TOWER MAT FDN - HYBRID RECEIVER SUBSYSTEM

UNIT WEIGHT OF MAT	▣	1.500000D-01
UNIT WEIGHT OF SOIL	▣	1.100000D-01
START MAT THICKNESS	▣	5.000000D 00
FINAL MAT THICKNESS	▣	1.500000D 01
THICKNESS INCREMENT	▣	5.000000D-01
UNIT COST OF MAT	▣	5.925926D 00
MAT TYPE	▣	C

ESG-79-30, Vol III
D-52

60-68114

SOLAR TOWER MAT FDN - HYBRID RECEIVER SUBSYSTEM

MAT DIMENSIONS FOR LOAD CASE 1

AXIAL LOAD AT TOP OF MAT = 1.156400D 04
 SHEAR AT TOP OF MAT = 1.831000D 03
 MOMENT AT TOP OF MAT = 3.679650D 05
 ALLOWABLE BEARING PRESSURE = 1.000000D 01
 GROUND ACCELERATION (G'S) = 3.500000D-01
 LOAD DIRECTION (SQ. MAT) =

THICKNESS	SIDE/DIA	T/D	VOLUME	COST	PRESS.	% AREA
5.00	97.15	0.0515	37064.	219640.	6.643	80.00
5.50	95.24	0.0577	39185.	232205.	7.047	80.00
6.00	93.51	0.0642	41206.	244183.	7.445	80.00
6.50	91.93	0.0707	43141.	255649.	7.837	80.00
7.00	90.47	0.0774	44999.	266663.	8.223	80.00
7.50	89.13	0.0842	46790.	277275.	8.604	80.00
8.00	87.88	0.0910	48520.	287526.	8.981	80.00
8.50	86.71	0.0980	50195.	297452.	9.353	80.00
9.00	85.62	0.1051	51820.	307082.	9.721	80.00
9.50	84.82	0.1120	53685.	318133.	10.000	80.34
10.00	84.79	0.1179	56461.	334586.	10.000	81.73
10.50	84.77	0.1239	59258.	351160.	10.000	83.07
11.00	84.77	0.1298	62082.	367891.	10.000	84.35
11.50	84.79	0.1356	64937.	384810.	10.000	85.59
12.00	84.83	0.1415	67822.	401911.	10.000	86.79
12.50	84.89	0.1473	70740.	419198.	10.000	87.94
13.00	84.95	0.1530	73689.	436677.	10.000	89.03
13.50	85.04	0.1588	76675.	454370.	10.000	90.09
14.00	85.14	0.1644	79702.	472306.	10.000	91.10
14.50	85.25	0.1701	82764.	490451.	10.000	92.07
15.00	85.37	0.1757	85862.	508813.	10.000	92.99

ESG-79-30 Vol 111
 D-53

SOLAR TOWER MAT FDN - HYBRID RECEIVER SUBSYSTEM

MAT DIMENSIONS FOR LOAD CASE 2

AXIAL LOAD AT TOP OF MAT = 2.813000D 03
 SHEAR AT TOP OF MAT = 1.831000D 03
 MOMENT AT TOP OF MAT = 3.673650D 05
 ALLOWABLE BEARING PRESSURE = 1.000000D 01
 GROUND ACCELERATION (G'S) = -3.500000D-01
 LOAD DIRECTION (SQ. MAT) =

THICKNESS	SIDE/DIA	T/D	VOLUME	COST	PRESS.	% AREA
5.00	154.71	0.0323	93996.	557015.	1.231	80.00
5.50	150.45	0.0366	97780.	579439.	1.336	80.00
6.00	146.66	0.0409	101365.	600682.	1.441	80.00
6.50	143.26	0.0454	104778.	620906.	1.544	80.00
7.00	140.18	0.0499	108041.	640241.	1.647	80.00
7.50	137.38	0.0546	111171.	658792.	1.750	80.00
8.00	134.81	0.0593	114184.	676647.	1.851	80.00
8.50	132.44	0.0642	117092.	693877.	1.953	80.00
9.00	130.24	0.0691	119905.	710546.	2.053	80.00
9.50	128.20	0.0741	122631.	726705.	2.153	80.00
10.00	126.30	0.0792	125280.	742400.	2.253	80.00
10.50	124.52	0.0843	127857.	757669.	2.353	80.00
11.00	122.84	0.0895	130367.	772548.	2.452	80.00
11.50	121.26	0.0948	132817.	787066.	2.550	80.00
12.00	119.78	0.1002	135211.	801250.	2.649	80.00
12.50	118.37	0.1056	137552.	815124.	2.747	80.00
13.00	117.03	0.1111	139845.	828710.	2.844	80.00
13.50	115.76	0.1166	142092.	842025.	2.942	80.00
14.00	114.56	0.1222	144296.	855088.	3.039	80.00
14.50	113.40	0.1279	146461.	867914.	3.136	80.00
15.00	112.31	0.1336	148587.	880517.	3.232	80.00

NO-BUILD

ESG-79-30, Vol III
 D-54

Stearns-Roger

(X50000)

PAGE 1 OF 1

JOB NO. C21725 DATE 7-7-79 BY AWM CHK.
CUSTOMER ROCKWELL / ESG PROJECT SOLAR HYBRID POWER
SUBJECT 100 MWE RECEIVER TOWER (1.4 SOLAR MULTIPLE)

Stearns-Roger

JOB NO. 21725 DATE 7/10/79 PAGE 1
BY RJC CH'K. _____
CUSTOMER ROCKWELL/ESG PROJECT SOLAR HYBRID POWER
SUBJECT MATERIAL QUANTITIES

TOWER

1) CONCRETE $f'_c = 4$ KSI
VOLUME = 1837 cu. yds.

2) REBAR $f_y = 60$ KSI
WT. = 236 TONS

FOUNDATION MAT

1) CONCRETE $f'_c = 3$ KSI
VOLUME = 5501 cu. yds.

2) REBAR $f_y = 60$ KSI
WT. = 206 TONS

3) SOIL EXCAVATION = 7717 cu. yds.

*** G163 - CONCRETE TOWER ANALYSIS PROGRAM *** INPUT DATA CARD LIST:

CARD NO.	CARD COLUMNS															
	1	5	10	15	20	25	30	35	40	45	50	55	60	65	70	80
1	SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)															
2	1	0	2	1	1	1	1	1	0	0	32.2			FT		KIPS
3																
4																
5	15			524760.		.15		.15		.07	.622					
6		17.		25.		.75		.9167	457.18		1.		1.			
7		700.		700.				2141.		.5						
8	4176000.			.3	1.9689		272.24				48.06		.07			
9																
10											25.1					
11	2.38E-6			.2		.2		38.		.04	103.					
12	90.			C				42.	457.18				.02			
13	0	0		0.		.35		.35								
14	-1	999		99.												
15	-1	999		99.												
16	4.			60.		.0033		.05	.00138889		.002		.49			
17	1.05			1.40		1.40		.9	1.43		-1.43					
18	1.05			1.28		.9		1.3	1.05		1.28		.9		1.3	
19	7.407407			500.												

ESG-79-30, Vol III

D-58

PII8-02

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

NO. OF TOWER SECTIONS -----	1
TOWER ROTARY INERTIA KEY -----	0
NO. OF MASS POINTS ABOVE TOP OF TWR	2
WIND VORTEX SHEDDING ANALYSIS KEY --	1
DRAG WIND ANALYSIS KEY -----	1
SEISMIC ANALYSIS KEY -----	1
CONCRETE DESIGN KEY -----	1
MODAL DATA PRINT KEY -----	0
PLOT KEY -----	0
ACCELERATION OF GRAVITY -----	32.2
INPUT UNITS FOR LENGTH -----	FT
INPUT UNITS FOR FORCE -----	KIPS

SOIL SPRINGS:

X-DIRECTION	0.0
Y-DIRECTION	0.0
ROCKING ----	0.0

SOIL DAMPING RATIOS:

X-DIRECTION	0.0
Y-DIRECTION	0.0
ROCKING ----	0.0

NOTE: A VALUE OF ZERO FOR SOIL SPRING
IMPLIES INFINITE STIFFNESS.

FOUNDATION PROPERTIES:

DIMENSION, H1 -----	0.0
DIMENSION, H2 -----	0.0
FDN WEIGHT, X-DIR -	0.0
FDN WEIGHT, Y-DIR -	0.0
FDN ROTARY INERTIA	0.0

PI188-03

ESG-79-30, Vol III

D-59

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

TOWER SECTION PROPERTIES:

SECTION NO. 1

NO. OF SEGMENTS -----	15
MODULUS OF ELASTICITY -----	6.247600D 05
POISSON'S RATIO -----	1.500000D-01
WEIGHT DENSITY -----	1.500000D-01
MATERIAL DAMPING RATIO -----	7.000000D-02
NET PRESSURE COEFFICIENT --	6.220000D-01
OUTER RADIUS AT TOP -----	1.700000D 01
OUTER RADIUS AT BOTTOM -----	2.500000D 01
WALL THICKNESS AT TOP -----	7.500000D-01
WALL THICKNESS AT BOTTOM --	3.167000D-01
SECTION LENGTH -----	4.571800D 02
DISTR. WT/LENGTH AT TOP ---	1.000000D 00
DISTR. WT/LENGTH AT BOTTOM	1.000000D 00

ESG-79-30, Vol III
D-60

11111111-08

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

ADDITIONAL MASSES ABOVE TOP OF TOWER:

MASS POINT NO. 1

WEIGHT, X-DIR ----- 7.000000D 02
 WEIGHT, Y-DIR ----- 7.000000D 02
 ROTARY INERTIA ----- 0.0
 TRIB. AREA (FOR WIND) 2.141000D 03
 NET PRESSURE COEFF. -- 5.000000D-01

CONNECTING BEAM PROPERTIES:

MODULUS OF ELASTICITY - 4.176000D 06
 POISSON'S RATIO ----- 3.000000D-01
 CROSS-SECTIONAL AREA -- 1.968900D 00
 MOMENT OF INERTIA ----- 2.722400D 02
 SHEAR SHAPE FACTOR ---- 0.0
 LENGTH ----- 4.806000D 01
 MATERIAL DAMPING RATIO 7.000000D-02

MASS POINT NO. 2

WEIGHT, X-DIR ----- 0.0
 WEIGHT, Y-DIR ----- 0.0
 ROTARY INERTIA ----- 0.0
 TRIB. AREA (FOR WIND) 0.0
 NET PRESSURE COEFF. -- 5.000000D-01

CONNECTING BEAM PROPERTIES:

MODULUS OF ELASTICITY - 4.176000D 06
 POISSON'S RATIO ----- 3.000000D-01
 CROSS-SECTIONAL AREA -- 1.968900D 00
 MOMENT OF INERTIA ----- 2.722400D 02
 SHEAR SHAPE FACTOR ---- 0.0
 LENGTH ----- 2.510000D 01
 MATERIAL DAMPING RATIO 7.000000D-02

86-1811

ESG-79-30, Vol III
 D-61

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

DATA FOR VORTEX SHEDDING ANALYSIS:

MASS DENSITY OF AIR -----	2.380000D-06
VON KARMAN (LIFT) COEFF. -----	2.000000D-01
STROUHAL NUMBER -----	2.000000D-01
CRITICAL DIAMETER -----	3.800000D 01
DAMPING RATIO -----	4.000000D-02
CUT-OFF VELOCITY -----	1.030000D 02

ES-79-30, Vol III
D-62

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

DATA FOR DRAG WIND ANALYSIS (PER ANSI A58.1-1972):

BASIC WIND VELOCITY AT 30 FT -	9.00000CD 01 MPH
TYPE OF EXPOSURE -----	C
AVERAGE HORIZONTAL DIMENSION -	4.20000CD 01 FT
VERTICAL DIMENSION -----	4.571800D 02 FT
FUNDAMENTAL LATERAL FREQUENCY	0.0 CPS
STRUCTURE DAMPING COEFFICIENT	2.000000D-02

ESS-79-30, Vol III
D-63

20-48112

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SCALAR MULTIPLE)

DATA FOR SEISMIC ANALYSIS:

NO. OF MODES, X-DIR ----- 0
 NO. OF MODES, Y-DIR ----- 0
 CUT-OFF FREQUENCY (CPS) - 0.0
 SCALAR MULTIPLIER, X-DIR 3.500000D-01
 SCALAR MULTIPLIER, Y-DIR 3.500000D-01

RESPONSE SPECTRA PER NRC REGULATORY GUIDE 1.60

MODAL DAMPING VALUES, X-DIR:

FROM MODE	TO MODE	DAMPING RATIO
1	999	9.900000D 01

MODAL DAMPING VALUES, Y-DIR:

FROM MODE	TO MODE	DAMPING RATIO
1	999	9.900000D 01

ESG-79-30, Vol III
 D-64

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

DATA FOR CONCRETE DESIGN:

DESIGN IS BASED ON STRENGTH DESIGN PROVISIONS OF ACI 318-71.

CONCRETE F'C (KSI) -----	4.000000D 00
REBAR FY (KSI) -----	6.000000D 01
MINIMUM VERTICAL STEEL RATIO -----	3.300000D-03
MAXIMUM VERTICAL STEEL RATIO -----	5.000000D-02
MIN. HOOP STEEL (AREA/UNIT HEIGHT) -----	1.388890D-03
NOMINAL HOOP STEEL RATIO -----	2.000000D-03
REBAR UNIT WEIGHT -----	4.900000D-01

LOAD FACTORS:

DEAD LOAD + SEISMIC

CMB. 1		CMB. 2	
DEAD LOAD -----	1.050000D 00	DEAD LOAD -----	9.000000D-01
X-SEISMIC -----	1.400000D 00	X-SEISMIC -----	1.430000D 00
Y-SEISMIC -----	1.400000D 00	Y-SEISMIC -----	-1.430000D 00

DEAD LOAD + VORTEX SHEDDING

CMB. 1		CMB. 2	
DEAD LOAD -----	1.050000D 00	DEAD LOAD -----	9.000000D-01
VORTEX SHEDDING -----	1.280000D 00	VORTEX SHEDDING -----	1.300000D 00

DEAD LOAD + DRAG WIND

CMB. 1		CMB. 2	
DEAD LOAD -----	1.050000D 00	DEAD LOAD -----	9.000000D-01
DRAG WIND -----	1.280000D 00	DRAG WIND -----	1.300000D 00

COST DATA (MATERIAL + LABOR):

CONCRETE (PER UNIT VOLUME)	7.407407D 00
REBAR (PER UNIT WEIGHT)	5.000000D 02

P1188-09

ESG-79-30, Vol III
D-65

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

***** NODAL Y-COORDINATES AND LUMPED WEIGHTS *****

NODE	Y-COORDINATE	WX	WY	ROT. INERTIA
1	0.0	0.0	0.0	0.0
2	1.515314D 01	6.659150D 02	6.659150D 02	0.0
3	4.563020D 01	6.445196D 02	6.445196D 02	0.0
4	7.610719D 01	6.234613D 02	6.234613D 02	0.0
5	1.065841D 02	6.027398D 02	6.027398D 02	0.0
6	1.370610D 02	5.823554D 02	5.823554D 02	0.0
7	1.675377D 02	5.623079D 02	5.623079D 02	0.0
8	1.980144D 02	5.425974D 02	5.425974D 02	0.0
9	2.284910D 02	5.232239D 02	5.232239D 02	0.0
10	2.589675D 02	5.041873D 02	5.041873D 02	0.0
11	2.894439D 02	4.854878D 02	4.854878D 02	0.0
12	3.199202D 02	4.671251D 02	4.671251D 02	0.0
13	3.503963D 02	4.490995D 02	4.490995D 02	0.0
14	3.808723D 02	4.314108D 02	4.314108D 02	0.0
15	4.113482D 02	4.140591D 02	4.140591D 02	0.0
16	4.418239D 02	3.970444D 02	3.970444D 02	0.0
17	4.571800D 02	0.0	0.0	0.0
18	5.052400D 02	7.000000D 02	7.000000D 02	0.0
19	5.303400D 02	0.0	0.0	0.0

SUMMATION 8.595534D 03 8.595534D 03 0.0

CENTER OF GRAVITY OF X WEIGHTS: Y = 2.319617D 02

CENTER OF GRAVITY OF Y WEIGHTS: Y = 2.319617D 02

ROTARY INERTIA ABOUT C.G. OF X WEIGHTS: IZ = 1.910478D 08

ESG-79-30, Vol III

D-66

10-80112

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

***** BEAM PROPERTY TABLE *****										
MEMB	JA	JB	LENGTH	MODULUS OF ELASTICITY	POISSON'S RATIO	MATERIAL DAMP. RATIO	AREA	MOMENT OF INERTIA	SHEAR SHAPE FACTOR	
1	1	2	1.515314D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.401755D 02	4.177784D 04	5.171497D-01	
2	2	3	3.047706D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.366515D 02	3.942011D 04	5.171539D-01	
3	3	4	3.047699D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.320086D 02	3.642572D 04	5.171599D-01	
4	4	5	3.047692D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.274393D 02	3.360266D 04	5.171662D-01	
5	5	6	3.047685D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.229438D 02	3.094440D 04	5.171729D-01	
6	6	7	3.047677D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.185220D 02	2.844455D 04	5.171800D-01	
7	7	8	3.047668D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.141738D 02	2.609682D 04	5.171875D-01	
8	8	9	3.047659D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.098994D 02	2.389504D 04	5.171955D-01	
9	9	10	3.047650D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.056987D 02	2.183319D 04	5.172040D-01	
10	10	11	3.047639D 01	5.247600D 05	1.500000D-01	7.000000D-02	1.015717D 02	1.990535D 04	5.172131D-01	
11	11	12	3.047628D 01	5.247600D 05	1.500000D-01	7.000000D-02	9.751841D 01	1.810572D 04	5.172228D-01	
12	12	13	3.047615D 01	5.247600D 05	1.500000D-01	7.000000D-02	9.353883D 01	1.642865D 04	5.172332D-01	
13	13	14	3.047602D 01	5.247600D 05	1.500000D-01	7.000000D-02	8.963296D 01	1.486858D 04	5.172443D-01	
14	14	15	3.047588D 01	5.247600D 05	1.500000D-01	7.000000D-02	8.580080D 01	1.342010D 04	5.172563D-01	
15	15	16	3.047572D 01	5.247600D 05	1.500000D-01	7.000000D-02	8.204236D 01	1.207791D 04	5.172693D-01	
16	16	17	1.535606D 01	5.247600D 05	1.500000D-01	7.000000D-02	7.926478D 01	1.113554D 04	5.172796D-01	
17	17	18	4.806000D 01	4.176000D 06	3.000000D-01	7.000000D-02	1.968900D 00	2.722400D 02	0.0	
18	18	19	2.510000D 01	4.176000D 06	3.000000D-01	7.000000D-02	1.968900D 00	2.722400D 02	0.0	

ESG-79-30, Vol III
D-67

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

LATERAL MODE FREQUENCIES

MODE NO.	FREQUENCY (CPS)
1	4.082908D-01
2	1.871089D 00
3	4.462489D 00
4	7.937362D 00
5	1.218744D 01
6	1.693752D 01
7	2.186797D 01
8	2.671935D 01
9	3.130535D 01
10	3.549785D 01
11	3.920846D 01
12	4.237471D 01
13	4.495119D 01
14	4.690942D 01
15	4.830192D 01
16	4.956847D 01

ESG-79-30, Vol III
D-68

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

* * * * * L A T E R A L M O D E S H A P E S * * * * *

MODE NO. 1			MODE NO. 2		MODE NO. 3	
MODE	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION
1	0.0	0.0	0.0	0.0	0.0	0.0
2	1.513057D-03	-1.341763D-04	-9.972172D-03	5.241062D-04	3.005943D-02	-1.066619D-03
3	1.075736D-02	-4.022301D-04	-5.255586D-02	1.424858D-03	1.316825D-01	-2.556279D-03
4	2.814948D-02	-6.664055D-04	-1.191988D-01	2.090827D-03	2.616362D-01	-3.093382D-03
5	5.354013D-02	-9.248165D-04	-2.018920D-01	2.490173D-03	3.864116D-01	-2.669756D-03
6	8.671667D-02	-1.175358D-03	-2.916446D-01	2.597617D-03	4.739823D-01	-1.394020D-03
7	1.273975D-01	-1.415737D-03	-3.787930D-01	2.398566D-03	4.986220D-01	4.946293D-04
8	1.752260D-01	-1.643512D-03	-4.534357D-01	1.892978D-03	4.456050D-01	2.638342D-03
9	2.297680D-01	-1.856156D-03	-5.059822D-01	1.098559D-03	3.148145D-01	4.600413D-03
10	2.905093D-01	-2.051135D-03	-5.277828D-01	5.286326D-05	1.223064D-01	5.930505D-03
11	3.568575D-01	-2.226016D-03	-5.117979D-01	-1.186131D-03	-1.009054D-01	6.247268D-03
12	4.281475D-01	-2.378618D-03	-4.532503D-01	-2.541483D-03	-3.131625D-01	5.324726D-03
13	5.036514D-01	-2.507192D-03	-3.501834D-01	-3.921304D-03	-4.693135D-01	3.164332D-03
14	5.825957D-01	-2.610680D-03	-2.038392D-01	-5.225795D-03	-5.297539D-01	3.246437D-05
15	6.641871D-01	-2.689034D-03	-1.875324D-02	-6.357823D-03	-4.697314D-01	-3.555324D-03
16	7.476499D-01	-2.743643D-03	1.975518D-01	-7.237475D-03	-2.867837D-01	-6.916028D-03
17	7.901552D-01	-2.763070D-03	3.150609D-01	-7.568602D-03	-1.540243D-01	-8.296487D-03
18	9.272652D-01	-2.897802D-03	7.523868D-01	-9.865069D-03	5.514530D-01	-1.787040D-02
19	1.000000D 00	-2.897802D-03	1.000000D 00	-9.865069D-03	1.000000D 00	-1.787040D-02
MODE NO. 4			MODE NO. 5		MODE NO. 6	
MODE	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION
1	0.0	0.0	0.0	0.0	0.0	0.0
2	6.881129D-02	1.668060D-03	1.318244D-01	-2.145425D-03	-2.147136D-01	2.264358D-03
3	2.581243D-01	3.271495D-03	4.258550D-01	-2.897659D-03	-5.908334D-01	1.075011D-03
4	4.385222D-01	2.553988D-03	5.862675D-01	3.394755D-04	-5.923494D-01	-4.843233D-03
5	5.271699D-01	1.206244D-05	4.846190D-01	5.170529D-03	-1.569446D-01	-9.330096D-03
6	4.725630D-01	-3.357965D-03	1.395493D-01	8.427042D-03	4.014777D-01	-7.441566D-03
7	-2.725127D-01	-6.262467D-03	-2.840924D-01	7.689873D-03	6.310339D-01	4.445117D-04
8	2.132220D-02	-7.475768D-03	-5.571393D-01	2.706182D-03	3.208582D-01	8.375016D-03
9	3.165021D-01	-6.263194D-03	-5.143782D-01	-4.185676D-03	-2.890043D-01	9.419663D-03
10	5.089814D-01	-2.713526D-03	-1.610398D-01	-9.096016D-03	-6.741328D-01	1.900906D-03
11	5.206156D-01	2.167760D-03	3.096998D-01	-8.758214D-03	-4.698653D-01	-8.167251D-03
12	3.324529D-01	6.697091D-03	6.130059D-01	-2.709893D-03	1.756329D-01	-1.147334D-02
13	2.105009D-04	9.068362D-03	5.404007D-01	5.928273D-03	6.834161D-01	-3.794203D-03
14	-3.576229D-01	8.078701D-03	1.030445D-01	1.191786D-02	5.481789D-01	9.058504D-03
15	-5.997235D-01	3.768303D-03	-4.495933D-01	1.116709D-02	-1.625727D-01	1.553392D-02
16	-6.191787D-01	-2.313555D-03	-7.730125D-01	4.016026D-03	-8.179832D-01	9.741834D-03
17	-5.279727D-01	-5.207860D-03	-7.508926D-01	-3.395667D-04	-8.620672D-01	4.257085D-03
18	3.654528D-01	-2.528076D-02	2.332716D-01	-3.054695D-02	1.520884D-01	-3.378134D-02
19	1.000000D 00	-2.528076D-02	1.000000D 00	-3.054695D-02	1.000000D 00	-3.378134D-02

ESG-79-30
Vol 1117

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

* * * * * L A T E R A L M O D E S H A P E S * * * * *

MODE NO. 7			MODE NO. 8			MODE NO. 9		
NODE	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION		
1	0.0	0.0	0.0	0.0	0.0	0.0		
2	3.108922D-01	-2.004758D-03	-4.191283D-01	1.478764D-03	5.436949D-01	-7.833635D-04		
3	7.100637D-01	1.691497D-03	-7.610327D-01	-4.637728D-03	7.332372D-01	7.229123D-03		
4	4.023816D-01	8.734618D-03	-4.543224D-02	-1.028237D-02	-3.977777D-01	9.080803D-03		
5	-3.360571D-01	8.727248D-03	7.235231D-01	-3.384018D-03	-7.569858D-01	-3.411615D-03		
6	-6.874193D-01	-3.895559D-04	3.781914D-01	8.034309D-03	3.726002D-01	-8.520693D-03		
7	-2.258340D-01	-9.219240D-03	-5.848524D-01	6.854218D-03	8.173198D-01	4.065184D-03		
8	5.334646D-01	-7.172570D-03	-6.633784D-01	-6.033156D-03	-3.487387D-01	9.994141D-03		
9	6.780174D-01	4.280700D-03	3.185248D-01	-1.044779D-02	-8.542737D-01	-4.072326D-03		
10	-1.004403D-02	1.159413D-02	8.213432D-01	2.149029D-03	3.642007D-01	-1.096194D-02		
11	-7.174611D-01	4.773435D-03	-1.187133D-02	1.247895D-02	8.799570D-01	4.878469D-03		
12	-5.419992D-01	-8.915682D-03	-8.645364D-01	2.531712D-03	-4.236100D-01	1.214176D-02		
13	3.422227D-01	-1.182754D-02	-2.921646D-01	-1.259614D-02	-8.914107D-01	-5.884606D-03		
14	8.029822D-01	1.878831D-03	7.969787D-01	-6.038471D-03	5.183708D-01	-1.178325D-02		
15	1.637450D-01	1.647944D-02	5.037868D-01	1.473942D-02	8.266412D-01	1.121422D-02		
16	-8.155046D-01	1.416945D-02	-7.977726D-01	1.741151D-02	-7.775799D-01	1.976037D-02		
17	-9.122488D-01	7.887790D-03	-9.337030D-01	1.057889D-02	-9.421898D-01	1.254362D-02		
18	1.044953D-01	-3.567748D-02	7.613350D-02	-3.680744D-02	5.857934D-02	-3.750680D-02		
19	1.000000D 00	-3.567748D-02	1.000000D 00	-3.680744D-02	1.000000D 00	-3.750680D-02		
MODE NO. 10			MODE NO. 11			MODE NO. 12		
NODE	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION		
1	0.0	0.0	0.0	0.0	0.0	0.0		
2	-6.147463D-01	-3.636004D-05	6.318578D-01	7.214580D-04	-7.032177D-01	-1.351458D-03		
3	5.485791D-01	-8.158198D-03	2.914134D-01	7.504423D-03	-4.996144D-02	-6.890355D-03		
4	7.287291D-01	-5.099253D-03	-7.982038D-01	1.028835D-03	7.252637D-01	1.631194D-03		
5	3.007424D-01	6.960411D-03	3.010686D-01	-5.587420D-03	-7.626805D-01	2.252880D-03		
6	8.721469D-01	1.466610D-03	6.168007D-01	4.709959D-03	8.150291D-02	-5.954205D-03		
7	9.745682D-03	-9.032609D-03	-7.718204D-01	3.224777D-03	6.915037D-01	3.691208D-03		
8	9.039501D-01	1.491278D-03	-3.663274D-02	-7.441652D-03	-8.777875D-01	1.875621D-03		
9	-3.498556D-01	9.225092D-03	8.300749D-01	2.711676D-03	3.054413D-01	-6.441836D-03		
10	-7.929214D-01	-5.677547D-03	-6.423242D-01	6.022680D-03	5.460701D-01	5.763212D-03		
11	7.131128D-01	-7.620012D-03	-3.194485D-01	-8.158925D-03	-9.780954D-01	-6.840500D-05		
12	4.893706D-01	1.012506D-02	9.432985D-01	7.890532D-04	6.406177D-01	-6.137800D-03		
13	-9.882276D-01	3.755138D-03	-5.162951D-01	8.702694D-03	2.041431D-01	8.375025D-03		
14	-5.940515D-03	-1.214000D-02	-5.133483D-01	-8.125770D-03	-9.365202D-01	-3.387305D-03		
15	1.000000D 00	5.911922D-03	1.000000D 00	1.241119D-03	1.000000D 00	-1.873337D-03		
16	-6.726266D-01	1.901512D-02	-5.300672D-01	1.617610D-02	-4.450141D-01	1.435271D-02		
17	-8.370168D-01	1.238183D-02	-6.731988D-01	1.070397D-02	-5.739631D-01	9.598839D-03		
18	4.187581D-02	-3.362202D-02	2.831627D-02	-2.724696D-02	-2.106068D-02	-2.337070D-02		
19	8.857885D-01	-3.362202D-02	7.122150D-01	-2.724696D-02	6.076652D-01	-2.337070D-02		

ESG-79-30, Vol 11

D-70

1148-05

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1,4 SOLAR MULTIPLE)

* * * * * L A T E R A L M O D E S H A P E S * * * * *

MODE NO. 13			MODE NO. 14			MODE NO. 15		
MODE	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION	X-DISPL.	Z-ROTATION		
1	0.0	0.0	0.0	0.0	0.0	0.0		
2	-6.703498D-01	-1.659736D-03	-6.830898D-01	-1.950502D-03	7.242910D-01	2.249454D-03		
3	1.759119D-01	-5.068691D-03	3.591679D-01	-3.795500D-03	-5.203512D-01	2.881703D-03		
4	4.034466D-01	2.449731D-03	7.551957D-02	2.180667D-03	2.420420D-01	-1.406739D-03		
5	-7.691484D-01	-1.060717D-03	-5.143527D-01	-2.492958D-03	1.087524D-01	2.451889D-03		
6	6.678721D-01	-2.509735D-03	7.748142D-01	6.103577D-04	-4.439186D-01	-1.827704D-03		
7	-1.717915D-01	4.239135D-03	-7.837884D-01	1.031484D-03	7.245689D-01	1.476462D-03		
8	-4.416421D-01	-3.890937D-03	5.387437D-01	-2.689801D-03	-9.130296D-01	-6.912748D-04		
9	8.308561D-01	1.167474D-03	-1.229312D-01	3.509986D-03	1.000000D 00	-3.916655D-05		
10	-7.913336D-01	2.366961D-03	-3.423883D-01	-3.405104D-03	-9.908501D-01	7.542324D-04		
11	3.464900D-01	-5.010961D-03	7.345741D-01	2.404332D-03	9.045683D-01	-1.295970D-03		
12	2.838664D-01	5.263279D-03	-9.667463D-01	-7.469719D-04	-7.655258D-01	1.686776D-03		
13	-8.045282D-01	-3.295384D-03	1.000000D 00	-9.307780D-04	5.970864D-01	-1.822265D-03		
14	1.000000D 00	-9.962017D-04	-8.506852D-01	2.900848D-03	-4.203900D-01	2.019602D-03		
15	-7.798422D-01	3.124622D-03	5.494076D-01	-2.991088D-03	2.416141D-01	-1.542792D-03		
16	3.053236D-01	-1.024486D-02	-1.965081D-01	6.776127D-03	-8.129133D-02	2.854435D-03		
17	3.983095D-01	-6.900605D-03	-2.584244D-01	4.585690D-03	-1.074863D-01	1.937578D-03		
18	-1.316612D-02	1.629286D-02	7.918618D-03	-1.060567D-02	3.126154D-03	-4.421112D-03		
19	-4.221170D-01	1.629286D-02	2.741210D-01	-1.060567D-02	1.140961D-01	-4.421112D-03		
MODE NO. 16								
MODE	X-DISPL.	Z-ROTATION						
1	0.0	0.0						
2	1.000000D 00	3.320463D-03						
3	-8.975473D-01	2.437808D-03						
4	8.126919D-01	-5.628955D-05						
5	-6.894029D-01	1.269028D-03						
6	5.722050D-01	-7.700577D-04						
7	-4.558726D-01	9.419042D-04						
8	3.531642D-01	-7.629228D-04						
9	-2.646310D-01	6.957135D-04						
10	1.925182D-01	-5.655981D-04						
11	-1.356097D-01	4.607783D-04						
12	9.233982D-02	-3.596729D-04						
13	-6.020881D-02	2.723885D-04						
14	3.683085D-02	-2.175105D-04						
15	-1.922048D-02	1.382428D-04						
16	6.129528D-03	-2.185981D-04						
17	8.142845D-03	-1.487607D-04						
18	-2.260848D-04	3.355829D-04						
19	-8.649216D-03	3.355829D-04						

ESB-79-30, Vol 1 III

PI-1112

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

VERTICAL MODE FREQUENCIES

MODE NO.	FREQUENCY (CPS)
1	5.5863100 00
2	1.2744570 01
3	1.9225630 01
4	2.8944940 01
5	3.9233590 01
6	4.9304550 01
7	5.8919190 01
8	6.7931730 01
9	7.6226390 01
10	8.3703750 01
11	9.0277080 01
12	9.5871440 01
13	1.0042370 02
14	1.0388400 02
15	1.0623880 02
16	1.0784920 02

ESG-79-30, Vol III
D-72

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

* * * * * VERTICAL MODE SHAPES * * * * *

MODE NO. 1		MODE NO. 2		MODE NO. 3		MODE NO. 4		MODE NO. 5		MODE NO. 6	
MODE	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	3.281718D-02	-4.022933D-02	-1.394297D-01	2.036214D-01	-2.794896D-01	3.655445D-01					
3	1.001679D-01	-1.209605D-01	-4.092094D-01	5.645243D-01	-7.068346D-01	8.113694D-01					
4	1.688007D-01	-1.977006D-01	-6.358927D-01	7.736913D-01	-7.709554D-01	5.871616D-01					
5	2.380589D-01	-2.660057D-01	-7.888254D-01	7.645523D-01	-4.239798D-01	-1.423082D-01					
6	3.072559D-01	-3.217257D-01	-8.455661D-01	5.314703D-01	1.635054D-01	-7.776852D-01					
7	3.756798D-01	-3.612418D-01	-7.950755D-01	1.339083D-01	6.848529D-01	-7.753425D-01					
8	4.425976D-01	-3.816866D-01	-6.396029D-01	-3.181367D-01	8.563686D-01	-1.119342D-01					
9	5.072624D-01	-3.811318D-01	-3.949716D-01	-6.940597D-01	5.711411D-01	6.729342D-01					
10	5.689173D-01	-3.587351D-01	-8.916099D-02	-8.799620D-01	-3.529537D-02	9.123949D-01					
11	6.268019D-01	-3.148338D-01	2.407224D-01	-8.128407D-01	-6.471676D-01	3.776446D-01					
12	6.801585D-01	-2.509809D-01	5.527750D-01	-5.015238D-01	-9.313435D-01	-5.047576D-01					
13	7.282372D-01	-1.699161D-01	8.054491D-01	-2.755266D-02	-7.178428D-01	-9.883814D-01					
14	7.703034D-01	-7.547320D-02	9.629204D-01	4.753054D-01	-1.008348D-01	-6.358922D-01					
15	8.056416D-01	2.757606D-02	1.000000D 00	8.580536D-01	5.992957D-01	2.857607D-01					
16	8.335640D-01	1.337360D-01	9.059524D-01	1.000000D 00	1.000000D 00	1.000000D 00					
17	8.434515D-01	1.851985D-01	7.967238D-01	9.234640D-01	9.323524D-01	9.356275D-01					
18	1.000000D 00	1.000000D 00	-9.326840D-01	-2.883235D-01	-1.387061D-01	-8.357639D-02					
19	1.000000D 00	1.000000D 00	-9.326840D-01	-2.883235D-01	-1.387061D-01	-8.357639D-02					
ESG-79-30, Vol 111											
MODE NO. 7		MODE NO. 8		MODE NO. 9		MODE NO. 10		MODE NO. 11		MODE NO. 12	
MODE	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4.563464D-01	-5.085008D-01	-7.088789D-01	6.220710D-01	6.451770D-01	-6.798272D-01					
3	8.481477D-01	-7.433576D-01	-7.421593D-01	3.931460D-01	1.517213D-01	8.578710D-02					
4	2.301192D-01	2.061188D-01	7.225810D-01	-8.014495D-01	-7.889722D-01	6.042021D-01					
5	6.883501D-01	8.582890D-01	7.772624D-01	-8.279547D-02	4.765514D-01	-7.933513D-01					
6	8.062225D-01	1.516447D-01	-7.426325D-01	8.646386D-01	4.325291D-01	3.035394D-01					
7	5.070388D-02	-8.261965D-01	-8.095442D-01	-2.720458D-01	-8.464436D-01	4.652490D-01					
8	8.785356D-01	-5.042258D-01	7.705624D-01	-7.835940D-01	2.450783D-01	-8.665074D-01					
9	6.663898D-01	6.482835D-01	8.381003D-01	6.150321D-01	6.768651D-01	5.498440D-01					
10	-3.695811D-01	7.921170D-01	-8.081349D-01	5.503923D-01	-8.185790D-01	2.411507D-01					
11	-9.941704D-01	-3.502000D-01	-8.615880D-01	-8.798491D-01	-1.679231D-02	-8.635007D-01					
12	-4.213104D-01	-9.671195D-01	8.573648D-01	-1.843142D-01	8.668307D-01	7.993800D-01					
13	8.959876D-01	-2.330768D-02	8.780246D-01	1.000000D 00	-7.240394D-01	-7.962036D-02					
14	1.000000D 00	1.000000D 00	-9.205086D-01	-2.636578D-01	-2.790259D-01	-7.358374D-01					
15	7.475691D-02	4.168768D-01	-8.844987D-01	-9.224012D-01	1.000000D 00	1.000000D 00					
16	-9.861259D-01	-8.842694D-01	1.000000D 00	7.110489D-01	-5.910968D-01	-4.875845D-01					
17	-9.241979D-01	-8.295125D-01	9.386116D-01	6.676458D-01	-5.551543D-01	-4.580152D-01					
18	5.630327D-02	3.745016D-02	-3.334532D-02	-1.955194D-02	1.391911D-02	1.015366D-02					
19	5.630327D-02	3.745016D-02	-3.334532D-02	-1.955194D-02	1.391911D-02	1.015366D-02					

ESG-79-30, Vol 111

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

* * * * * VERTICAL MODE SHAPES * * * * *

	MODE NO. 13	MODE NO. 14	MODE NO. 15	MODE NO. 16
NODE	Y-DISPL.	Y-DISPL.	Y-DISPL.	Y-DISPL.
1	0.0	0.0	0.0	0.0
2	-7.152529D-01	-7.204322D-01	7.340599D-01	1.000000D 00
3	3.120346D-01	4.910227D-01	-6.253419D-01	-9.728924D-01
4	2.814334D-01	-9.716277D-02	4.230989D-01	9.189518D-01
5	-7.389735D-01	-3.411634D-01	-1.533559D-01	-8.448385D-01
6	8.048939D-01	6.911891D-01	-1.436569D-01	7.572755D-01
7	-4.336055D-01	-8.476740D-01	4.394137D-01	-6.625342D-01
8	-1.857606D-01	7.629361D-01	-6.914319D-01	5.660574D-01
9	7.303175D-01	-4.583391D-01	8.772577D-01	-4.722251D-01
10	-9.132338D-01	1.530539D-02	-9.816647D-01	3.842485D-01
11	6.316608D-01	4.498121D-01	1.000000D 00	-3.041713D-01
12	-1.738966D-02	-8.184004D-01	-9.369221D-01	2.329458D-01
13	-6.316908D-01	1.000000D 00	8.039848D-01	-1.705473D-01
14	1.000000D 00	-9.524795D-01	-6.166067D-01	1.160880D-01
15	-9.059747D-01	6.878790D-01	3.909309D-01	-6.789096D-02
16	3.840408D-01	-2.642830D-01	-1.409573D-01	2.347324D-02
17	3.607937D-01	-2.483050D-01	-1.324419D-01	2.205591D-02
18	-7.275369D-03	4.672900D-03	2.361210D-03	-3.845875D-04
19	-7.275369D-03	4.672900D-03	2.361210D-03	-3.845875D-04

ESG-79-30, Vol III

D-74

ES-88112

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

COMPOSITE MODAL DAMPING RATIOS		
	LATERAL	VERTICAL
MODE	DAMP. RATIO	DAMP. RATIO
1	7.000000D-02	7.000000D-02
2	7.000000D-02	7.000000D-02
3	7.000000D-02	7.000000D-02
4	7.000000D-02	7.000000D-02
5	7.000000D-02	7.000000D-02
6	7.000000D-02	7.000000D-02
7	7.000000D-02	7.000000D-02
8	7.000000D-02	7.000000D-02
9	7.000000D-02	7.000000D-02
10	7.000000D-02	7.000000D-02
11	7.000000D-02	7.000000D-02
12	7.000000D-02	7.000000D-02
13	7.000000D-02	7.000000D-02
14	7.000000D-02	7.000000D-02
15	7.000000D-02	7.000000D-02
16	7.000000D-02	7.000000D-02

ESG-79-80, Vol III
D-75

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

DYNAMIC WIND RESPONSE (VORTEX SHEDDING)

CRITICAL WIND VELOCITY = 7.757525D 01

NODAL DISPLACEMENTS

NODE	X-DISPL.	Z-ROTATION
1	0.0	0.0
2	6.054160D-04	5.404236D-05
3	4.332757D-03	1.620067D-04
4	1.133780D-02	2.684090D-04
5	2.156443D-02	3.724895D-04
6	3.492698D-02	4.734006D-04
7	5.131203D-02	5.702184D-04
8	7.057600D-02	6.619596D-04
9	9.254393D-02	7.476064D-04
10	1.170088D-01	8.261391D-04
11	1.437320D-01	8.965754D-04
12	1.724455D-01	9.580389D-04
13	2.028563D-01	1.009825D-03
14	2.346528D-01	1.051507D-03
15	2.675155D-01	1.083065D-03
16	3.011319D-01	1.105060D-03
17	3.182518D-01	1.112895D-03
18	3.734757D-01	1.167152D-03
19	4.027712D-01	1.167152D-03

ESG-79-30, Vol III
D-76

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

DYNAMIC WIND RESPONSE (VORTEX SHEDDING)

B E A M L O A D S

MEMB	NODE	SHEAR	MOMENT
1	1	2.151482D 02	7.981777D 04
	2	2.151482D 02	7.655760D 04
2	2	2.150802D 02	7.655760D 04
	3	2.150802D 02	7.000259D 04
3	3	2.144916D 02	7.000259D 04
	4	2.144916D 02	6.346553D 04
4	4	2.130563D 02	6.346553D 04
	5	2.130563D 02	5.697223D 04
5	5	2.103722D 02	5.697223D 04
	6	2.103722D 02	5.056075D 04
6	6	2.062200D 02	5.056075D 04
	7	2.062200D 02	4.427583D 04
7	7	2.003046D 02	4.427583D 04
	8	2.003046D 02	3.817121D 04
8	8	1.924774D 02	3.817121D 04
	9	1.924774D 02	3.230515D 04
9	9	1.825884D 02	3.230515D 04
	10	1.825884D 02	2.674050D 04
10	10	1.705383D 02	2.674050D 04
	11	1.705383D 02	2.154311D 04
11	11	1.562871D 02	2.154311D 04
	12	1.562871D 02	1.678006D 04
12	12	1.398364D 02	1.678006D 04
	13	1.398364D 02	1.251838D 04
13	13	1.212129D 02	1.251838D 04
	14	1.212129D 02	8.824294D 03
14	14	1.005216D 02	8.824294D 03
	15	1.005216D 02	5.760810D 03
15	15	7.786854D 01	5.760810D 03
	16	7.786854D 01	3.387710D 03
16	16	5.342038D 01	3.387710D 03
	17	5.342038D 01	2.567333D 03
17	17	5.342038D 01	2.567333D 03
	18	5.342038D 01	5.659618D-10
18	18	6.593730D-11	6.447202D-10
	19	6.593730D-11	1.010306D-09

ESG-79-30, Vol III

PI188-03

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

DRAO WIND RESPONSE

GUST FACTOR = 1.036311D 00

NODE	EFF. VELOCITY PRESSURE	TRIBUTARY AREA	NET PRESSURE COEFFICIENT	NODAL FORCE
1	2.148893D-02	0.0	0.0	0.0
2	2.148893D-02	1.507678D 03	6.220000D-01	2.015180D 01
3	2.422436D-02	1.475167D 03	6.220000D-01	2.222716D 01
4	2.803593D-02	1.442657D 03	6.220000D-01	2.515845D 01
5	3.086389D-02	1.410146D 03	6.220000D-01	2.707544D 01
6	3.316359D-02	1.377636D 03	6.220000D-01	2.842182D 01
7	3.512699D-02	1.345125D 03	6.220000D-01	2.938963D 01
8	3.684507D-02	1.312615D 03	6.220000D-01	3.008202D 01
9	3.838335D-02	1.280104D 03	6.220000D-01	3.056177D 01
10	3.978129D-02	1.247593D 03	6.220000D-01	3.087041D 01
11	4.106618D-02	1.215083D 03	6.220000D-01	3.103706D 01
12	4.225775D-02	1.182572D 03	6.220000D-01	3.108311D 01
13	4.337078D-02	1.150062D 03	6.220000D-01	3.102478D 01
14	4.441665D-02	1.117551D 03	6.220000D-01	3.087476D 01
15	4.540433D-02	1.085041D 03	6.220000D-01	3.064317D 01
16	4.634104D-02	1.052530D 03	6.220000D-01	3.033825D 01
17	4.679562D-02	0.0	0.0	0.0
18	4.815132D-02	2.141000D 03	5.000000D-01	5.154598D 01
19	4.882299D-02	0.0	5.000000D-01	0.0

ESG-79-30, Vol III
D-78

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

DRAW WIND RESPONSE

NODAL DISPLACEMENTS

NODE	X-DISPL.	Z-ROTATION
1	0.0	0.0
2	1.105588D-03	8.698147D-05
3	7.265245D-03	2.566896D-04
4	1.846570D-02	4.185192D-04
5	3.444471D-02	5.715293D-04
6	5.491362D-02	7.148369D-04
7	7.955825D-02	8.476113D-04
8	1.080403D-01	9.690826D-04
9	1.399992D-01	1.078560D-03
10	1.750549D-01	1.175457D-03
11	2.128116D-01	1.259333D-03
12	2.528626D-01	1.329937D-03
13	2.947971D-01	1.387283D-03
14	3.382097D-01	1.431729D-03
15	3.827124D-01	1.464094D-03
16	4.279509D-01	1.485812D-03
17	4.509124D-01	1.493362D-03
18	5.243610D-01	1.545724D-03
19	5.631587D-01	1.545724D-03

ESG-79-30, Vol III
D-79

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1,4 SOLAR MULTIPLE)

DRAG WIND RESPONSE

BEAM LOADS

MEMB	NODE	SHEAR	MOMENT
1	1	4.804856D 02	1.294839D 05
	2	4.804856D 02	1.222031D 05
2	2	4.603338D 02	1.222031D 05
	3	4.603338D 02	1.081734D 05
3	3	4.381066D 02	1.081734D 05
	4	4.381066D 02	9.482126D 04
4	4	4.129482D 02	9.482126D 04
	5	4.129482D 02	8.223587D 04
5	5	3.858728D 02	8.223587D 04
	6	3.858728D 02	7.047568D 04
6	6	3.574509D 02	7.047568D 04
	7	3.574509D 02	5.958173D 04
7	7	3.280613D 02	5.958173D 04
	8	3.280613D 02	4.958351D 04
8	8	2.979793D 02	4.958351D 04
	9	2.979793D 02	4.050212D 04
9	9	2.674175D 02	4.050212D 04
	10	2.674175D 02	3.235217D 04
10	10	2.365471D 02	3.235217D 04
	11	2.365471D 02	2.514307D 04
11	11	2.055101D 02	2.514307D 04
	12	2.055101D 02	1.887989D 04
12	12	1.744269D 02	1.887989D 04
	13	1.744269D 02	1.356402D 04
13	13	1.434022D 02	1.356402D 04
	14	1.434022D 02	9.193696D 03
14	14	1.125274D 02	9.193696D 03
	15	1.125274D 02	5.764324D 03
15	15	8.188424D 01	5.764324D 03
	16	8.188424D 01	3.268843D 03
16	16	5.154598D 01	3.268843D 03
	17	5.154598D 01	2.477300D 03
17	17	5.154598D 01	2.477300D 03
	18	5.154598D 01	0.0
18	18	0.0	0.0
	19	0.0	0.0

ESG-79-30, Vol III

D-80

1515-05

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

SPECTRAL ACCELERATIONS, X-DIRECTION (G'S)

MODE	FREQUENCY	DAMP. RATIO	ACCELERATION
1	4.082908D-01	7.000000D-02	2.235234D-01
2	1.871089D 00	7.000000D-02	7.546779D-01
3	4.462489D 00	7.000000D-02	8.760596D-01
4	7.937362D 00	7.000000D-02	8.071158D-01
5	1.218744D 01	7.000000D-02	6.551008D-01
6	1.693752D 01	7.000000D-02	5.325451D-01
7	2.186797D 01	7.000000D-02	4.634496D-01
8	2.671935D 01	7.000000D-02	3.997313D-01
9	3.130535D 01	7.000000D-02	3.618064D-01
10	3.549785D 01	7.000000D-02	3.500000D-01
11	3.920846D 01	7.000000D-02	3.500000D-01
12	4.237471D 01	7.000000D-02	3.500000D-01
13	4.495119D 01	7.000000D-02	3.500000D-01
14	4.690942D 01	7.000000D-02	3.500000D-01
15	4.830192D 01	7.000000D-02	3.500000D-01
16	4.956847D 01	7.000000D-02	3.500000D-01

ESG-79-80, Vol III
D-81

89-55112

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

SPECTRAL ACCELERATIONS, Y-DIRECTION (G'S)

MODE	FREQUENCY	DAMP. RATIO	ACCELERATION
1	5.586310D 00	7.000000D-02	8.692640D-01
2	1.274457D 01	7.000000D-02	6.369297D-01
3	1.922563D 01	7.000000D-02	4.917279D-01
4	2.894494D 01	7.000000D-02	3.801033D-01
5	3.923359D 01	7.000000D-02	3.500000D-01
6	4.930455D 01	7.000000D-02	3.500000D-01
7	5.891919D 01	7.000000D-02	3.500000D-01
8	6.793173D 01	7.000000D-02	3.500000D-01
9	7.622639D 01	7.000000D-02	3.500000D-01
10	8.370375D 01	7.000000D-02	3.500000D-01
11	9.027708D 01	7.000000D-02	3.500000D-01
12	9.587144D 01	7.000000D-02	3.500000D-01
13	1.004237D 02	7.000000D-02	3.500000D-01
14	1.038840D 02	7.000000D-02	3.500000D-01
15	1.062388D 02	7.000000D-02	3.500000D-01
16	1.078492D 02	7.000000D-02	3.500000D-01

ESG-79-30, Vol III
D-82

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

***** RSS SUM - DISPLACEMENTS, VELOCITIES, AND ACCELERATIONS - LATERAL EARTHQUAKE *****

NODE	RELATIVE DISPLACEMENTS		RELATIVE VELOCITIES		ABSOLUTE ACCELERATIONS	
	X-TRANSL.	Z-ROTATION	X-TRANSL.	Z-ROTATION	X-TRANSL.	Z-ROTATION
1	0.0	0.0	0.0	0.0	0.0	0.0
2	3.677510D-03	2.776997D-04	4.784414D-02	1.790364D-03	3.766907D 00	4.629945D-02
3	2.346313D-02	8.184807D-04	2.038153D-01	4.657668D-03	8.210370D 00	9.541918D-02
4	5.921450D-02	1.333344D-03	4.187318D-01	6.648359D-03	1.185243D 01	1.134643D-01
5	1.100578D-01	1.820991D-03	6.675857D-01	7.951403D-03	1.445985D 01	1.231399D-01
6	1.750642D-01	2.281281D-03	9.312155D-01	8.772419D-03	1.618985D 01	1.335390D-01
7	2.533020D-01	2.714988D-03	1.195804D 00	9.311372D-03	1.727740D 01	1.451726D-01
8	3.438622D-01	3.123387D-03	1.452159D 00	9.761053D-03	1.794993D 01	1.558671D-01
9	4.458732D-01	3.507736D-03	1.695372D 00	1.031038D-02	1.833155D 01	1.650588D-01
10	5.585009D-01	3.868671D-03	1.925114D 00	1.113050D-02	1.846586D 01	1.735893D-01
11	6.809344D-01	4.205617D-03	2.146357D 00	1.234056D-02	1.834960D 01	1.830667D-01
12	8.123584D-01	4.516290D-03	2.370041D 00	1.397730D-02	1.799313D 01	1.953158D-01
13	9.519153D-01	4.796469D-03	2.612919D 00	1.599363D-02	1.747743D 01	2.121194D-01
14	1.098662D 00	5.040206D-03	2.895742D 00	1.828015D-02	1.706910D 01	2.342119D-01
15	1.251537D 00	5.240704D-03	3.239502D 00	2.068296D-02	1.723237D 01	2.604367D-01
16	1.409350D 00	5.392121D-03	3.660652D 00	2.298805D-02	1.838500D 01	2.877132D-01
17	1.490277D 00	5.448821D-03	3.904534D 00	2.400828D-02	1.864887D 01	3.085588D-01
18	1.754342D 00	5.865374D-03	4.874067D 00	3.289295D-02	2.839819D 01	7.393783D-01
19	1.896084D 00	5.865374D-03	5.499325D 00	3.289295D-02	4.355861D 01	7.393783D-01

ESG-75-30, Vol III

D-83/

21112-03

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1,4 SCLAR MULTIPLE)

RSS SUM - BEAM LOADS - LATERAL EARTHQUAKE

MEMB	NODE	SHEAR	MOMENT
1	1	1.877066D 03	4.135776D 05
	2	1.877066D 03	3.901270D 05
2	2	1.858190D 03	3.901270D 05
	3	1.858190D 03	3.453164D 05
3	3	1.791979D 03	3.453164D 05
	4	1.791979D 03	3.046155D 05
4	4	1.684306D 03	3.046155D 05
	5	1.684306D 03	2.688164D 05
5	5	1.549281D 03	2.688164D 05
	6	1.549281D 03	2.381610D 05
6	6	1.401868D 03	2.381610D 05
	7	1.401868D 03	2.122894D 05
7	7	1.254232D 03	2.122894D 05
	8	1.254232D 03	1.903456D 05
8	8	1.116729D 03	1.903456D 05
	9	1.116729D 03	1.711434D 05
9	9	9.980029D 02	1.711434D 05
	10	9.980029D 02	1.534101D 05
10	10	9.045781D 02	1.534101D 05
	11	9.045781D 02	1.360148D 05
11	11	8.387947D 02	1.360148D 05
	12	8.387947D 02	1.181375D 05
12	12	7.963299D 02	1.181375D 05
	13	7.963299D 02	9.935263D 04
13	13	7.661302D 02	9.935263D 04
	14	7.661302D 02	7.963997D 04
14	14	7.340922D 02	7.963997D 04
	15	7.340922D 02	5.934374D 04
15	15	6.873477D 02	5.934374D 04
	16	6.873477D 02	3.914878D 04
16	16	6.173323D 02	3.914878D 04
	17	6.173323D 02	2.966899D 04
17	17	6.173323D 02	2.966899D 04
	18	6.173323D 02	6.884404D-05
18	18	3.085293D-10	3.024125D-09
	19	3.085293D-10	4.726656D-09

ESG-79-30, Vol III

D-84

P1183-03

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

RSS SUM - DISPLACEMENTS, VELOCITIES, AND ACCELERATIONS - VERTICAL EARTHQUAKE

NODE	REL. Y-DISPL.	REL. Y-VEL.	ABS. Y-ACCEL.
1	0.0	0.0	0.0
2	1.138041D-03	4.175685D-02	3.267278D 00
3	3.472592D-03	1.262937D-01	6.644489D 00
4	5.849025D-03	2.113576D-01	9.692676D 00
5	8.243732D-03	2.961940D-01	1.257824D 01
6	1.063270D-02	3.800897D-01	1.532238D 01
7	1.299159D-02	4.623698D-01	1.794733D 01
8	1.529576D-02	5.423708D-01	2.047600D 01
9	1.752033D-02	6.194127D-01	2.291878D 01
10	1.964018D-02	6.927799D-01	2.527108D 01
11	2.163002D-02	7.617171D-01	2.752006D 01
12	2.346454D-02	8.254260D-01	2.964883D 01
13	2.511846D-02	8.830631D-01	3.163237D 01
14	2.656680D-02	9.337435D-01	3.343291D 01
15	2.778502D-02	9.765526D-01	3.500583D 01
16	2.874931D-02	1.010565D 00	3.631828D 01
17	2.909149D-02	1.022591D 00	3.664191D 01
18	3.458009D-02	1.228297D 00	4.585652D 01
19	3.458009D-02	1.228297D 00	4.585652D 01

ESG-79-30, Vol 111

D-85

P1108-03

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

RSS SUM - BEAM LOADS - VERTICAL EARTHQUAKE

MEMB NODE AXIAL LOAD

1	1	5.524437D 03
	2	5.524437D 03
2	2	5.493057D 03
	3	5.493057D 03
3	3	5.402158D 03
	4	5.402158D 03
4	4	5.256554D 03
	5	5.256554D 03
5	5	5.061196D 03
	6	5.061196D 03
6	6	4.820996D 03
	7	4.820996D 03
7	7	4.540635D 03
	8	4.540635D 03
8	8	4.224773D 03
	9	4.224773D 03
9	9	3.877908D 03
	10	3.877908D 03
10	10	3.504629D 03
	11	3.504629D 03
11	11	3.109581D 03
	12	3.109581D 03
12	12	2.697551D 03
	13	2.697551D 03
13	13	2.273734D 03
	14	2.273734D 03
14	14	1.843799D 03
	15	1.843799D 03
15	15	1.414733D 03
	16	1.414733D 03
16	16	9.968754D 02
	17	9.968754D 02
17	17	9.968754D 02
	18	9.968754D 02
18	18	1.569875D-12
	19	1.569875D-12

ESG-79-30, Vol 1 II

P1185-03

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

BEAM LOADS DUE TO DEAD LOAD

MEMB NODE AXIAL LOAD

1	1	8.595534D 03
	2	8.261765D 03
2	2	8.261765D 03
	3	7.606563D 03
3	3	7.606563D 03
	4	6.972588D 03
4	4	6.972588D 03
	5	6.359504D 03
5	5	6.359504D 03
	6	5.766972D 03
6	6	5.766972D 03
	7	5.194656D 03
7	7	5.194656D 03
	8	4.642219D 03
8	8	4.642219D 03
	9	4.109325D 03
9	9	4.109325D 03
	10	3.595635D 03
10	10	3.595635D 03
	11	3.100814D 03
11	11	3.100814D 03
	12	2.624524D 03
12	12	2.624524D 03
	13	2.166428D 03
13	13	2.166428D 03
	14	1.726190D 03
14	14	1.726190D 03
	15	1.303472D 03
15	15	1.303472D 03
	16	8.979371D 02
16	16	8.979371D 02
	17	7.000000D 02
17	17	7.000000D 02
	18	7.000000D 02
18	18	-4.206413D-12
	19	-4.206413D-12

ESG-79-30, Vol III

D-87

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

LOAD CMB. 1 (1.05) * DEAD LOAD + (1.28) * WIND

* * REBAR DESIGN - DEAD LOAD + VORTEX SHEDDING * *

MEMB	NODE	OUTER RADIUS (IN)	WALL THICK. (IN)	DESIGN AXIAL LOAD (KIPS)	DESIGN MOMENT (IN-KIPS)	REQ'D STEEL RATIO	REQ'D REBAR (SQ. IN)
1	1	3.000000D 02	1.100040D 01	9.025311D 03	1.226001D 06	3.300000D-03	6.717185D 01
	2	2.968181D 02	1.093410D 01	8.674853D 03	1.175925D 06	3.300000D-03	6.605312D 01
2	2	2.968181D 02	1.093410D 01	8.674853D 03	1.175925D 06	3.300000D-03	6.605312D 01
	3	2.904184D 02	1.080074D 01	7.986891D 03	1.075240D 06	3.300000D-03	6.382927D 01
3	3	2.904184D 02	1.080074D 01	7.986891D 03	1.075240D 06	3.300000D-03	6.382927D 01
	4	2.840188D 02	1.066739D 01	7.321218D 03	9.748305D 05	3.300000D-03	6.164045D 01
4	4	2.840188D 02	1.066739D 01	7.321218D 03	9.748305D 05	3.300000D-03	6.164045D 01
	5	2.776192D 02	1.053404D 01	6.677479D 03	8.750934D 05	3.300000D-03	5.948665D 01
5	5	2.776192D 02	1.053404D 01	6.677479D 03	8.750934D 05	3.300000D-03	5.948665D 01
	6	2.712195D 02	1.040069D 01	6.055320D 03	7.766131D 05	3.300000D-03	5.736788D 01
6	6	2.712195D 02	1.040069D 01	6.055320D 03	7.766131D 05	3.300000D-03	5.736788D 01
	7	2.648199D 02	1.026734D 01	5.454389D 03	6.800767D 05	3.300000D-03	5.528414D 01
7	7	2.648199D 02	1.026734D 01	5.454389D 03	6.800767D 05	3.300000D-03	5.528414D 01
	8	2.584204D 02	1.013398D 01	4.874330D 03	5.863098D 05	3.300000D-03	5.323542D 01
8	8	2.584204D 02	1.013398D 01	4.874330D 03	5.863098D 05	3.300000D-03	5.323542D 01
	9	2.520208D 02	1.000063D 01	4.314791D 03	4.962072D 05	3.300000D-03	5.122173D 01
9	9	2.520208D 02	1.000063D 01	4.314791D 03	4.962072D 05	3.300000D-03	5.122173D 01
	10	2.456212D 02	9.867283D 00	3.775417D 03	4.107341D 05	3.300000D-03	4.924307D 01
10	10	2.456212D 02	9.867283D 00	3.775417D 03	4.107341D 05	3.300000D-03	4.924307D 01
	11	2.392217D 02	9.733933D 00	3.255855D 03	3.309021D 05	3.300000D-03	4.729943D 01
11	11	2.392217D 02	9.733933D 00	3.255855D 03	3.309021D 05	3.300000D-03	4.729943D 01
	12	2.328222D 02	9.600583D 00	2.755750D 03	2.577417D 05	3.300000D-03	4.539082D 01
12	12	2.328222D 02	9.600583D 00	2.755750D 03	2.577417D 05	3.300000D-03	4.539082D 01
	13	2.264228D 02	9.467234D 00	2.274750D 03	1.922823D 05	3.300000D-03	4.351724D 01
13	13	2.264228D 02	9.467234D 00	2.274750D 03	1.922823D 05	3.300000D-03	4.351724D 01
	14	2.200233D 02	9.333886D 00	1.812499D 03	1.355412D 05	3.300000D-03	4.167868D 01
14	14	2.200233D 02	9.333886D 00	1.812499D 03	1.355412D 05	3.300000D-03	4.167868D 01
	15	2.136239D 02	9.200538D 00	1.368645D 03	8.848604D 04	3.300000D-03	3.987516D 01
15	15	2.136239D 02	9.200538D 00	1.368645D 03	8.848604D 04	3.300000D-03	3.987516D 01
	16	2.072245D 02	9.067191D 00	9.428339D 02	5.203522D 04	3.300000D-03	3.810666D 01
16	16	2.072245D 02	9.067191D 00	9.428339D 02	5.203522D 04	3.300000D-03	3.810666D 01
	17	2.040000D 02	9.000000D 00	7.350000D 02	3.943501D 04	3.300000D-03	3.722882D 01

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

LOAD CMB. 2 (0.90) * DEAD LOAD + (1.30) * WIND

* * REBAR DESIGN - DEAD LOAD + VORTEX SHEDDING * *

MEMB	NODE	OUTER RADIUS (IN)	WALL THICK. (IN)	DESIGN AXIAL LOAD (KIPS)	DESIGN MOMENT (IN-KIPS)	REQ'D STEEL RATIO	REQ'D REBAR (SQ. IN)
1	1	3.000000D 02	1.100040D 01	7.735981D 03	1.245157D 06	3.300000D-03	6.717185D 01
2	2	2.968181D 02	1.093410D 01	7.435588D 03	1.194299D 06	3.300000D-03	6.605312D 01
3	3	2.968181D 02	1.093410D 01	7.435588D 03	1.194299D 06	3.300000D-03	6.605312D 01
4	4	2.904184D 02	1.080074D 01	6.845907D 03	1.092040D 06	3.300000D-03	6.382927D 01
5	5	2.904184D 02	1.080074D 01	6.845907D 03	1.092040D 06	3.300000D-03	6.382927D 01
6	6	2.840188D 02	1.066739D 01	6.275329D 03	9.900623D 05	3.300000D-03	6.164045D 01
7	7	2.840188D 02	1.066739D 01	6.275329D 03	9.900623D 05	3.300000D-03	6.164045D 01
8	8	2.776192D 02	1.053404D 01	5.723553D 03	8.887668D 05	3.300000D-03	5.948665D 01
9	9	2.776192D 02	1.053404D 01	5.723553D 03	8.887668D 05	3.300000D-03	5.948665D 01
10	10	2.712195D 02	1.040069D 01	5.190275D 03	7.887477D 05	3.300000D-03	5.736788D 01
11	11	2.712195D 02	1.040069D 01	5.190275D 03	7.887477D 05	3.300000D-03	5.736788D 01
12	12	2.648199D 02	1.026734D 01	4.675190D 03	6.907029D 05	3.300000D-03	5.528414D 01
13	13	2.584204D 02	1.013398D 01	4.177997D 03	5.954709D 05	3.300000D-03	5.323542D 01
14	14	2.584204D 02	1.013398D 01	4.177997D 03	5.954709D 05	3.300000D-03	5.323542D 01
15	15	2.520208D 02	1.000063D 01	3.698392D 03	5.039604D 05	3.300000D-03	5.122173D 01
16	16	2.520208D 02	1.000063D 01	3.698392D 03	5.039604D 05	3.300000D-03	5.122173D 01
17	17	2.456212D 02	9.867283D 00	3.236072D 03	4.171518D 05	3.300000D-03	4.924307D 01
18	18	2.456212D 02	9.867283D 00	3.236072D 03	4.171518D 05	3.300000D-03	4.924307D 01
19	19	2.392217D 02	9.733933D 00	2.790733D 03	3.360725D 05	3.300000D-03	4.729943D 01
20	20	2.392217D 02	9.733933D 00	2.790733D 03	3.360725D 05	3.300000D-03	4.729943D 01
21	21	2.328222D 02	9.600583D 00	2.362072D 03	2.617689D 05	3.300000D-03	4.539082D 01
22	22	2.328222D 02	9.600583D 00	2.362072D 03	2.617689D 05	3.300000D-03	4.539082D 01
23	23	2.264228D 02	9.467234D 00	1.949786D 03	1.952867D 05	3.300000D-03	4.351724D 01
24	24	2.264228D 02	9.467234D 00	1.949786D 03	1.952867D 05	3.300000D-03	4.351724D 01
25	25	2.200233D 02	9.333386D 00	1.553571D 03	1.376590D 05	3.300000D-03	4.167868D 01
26	26	2.200233D 02	9.333386D 00	1.553571D 03	1.376590D 05	3.300000D-03	4.167868D 01
27	27	2.136239D 02	9.200338D 00	1.173125D 03	8.986863D 04	3.300000D-03	3.987516D 01
28	28	2.136239D 02	9.200338D 00	1.173125D 03	8.986863D 04	3.300000D-03	3.987516D 01
29	29	2.072245D 02	9.067191D 00	8.081433D 02	5.284827D 04	3.300000D-03	3.810666D 01
30	30	2.072245D 02	9.067191D 00	8.081433D 02	5.284827D 04	3.300000D-03	3.810666D 01
31	31	2.040000D 02	9.000000D 00	6.300000D 02	4.005118D 04	3.300000D-03	3.722882D 01

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

LOAD CMB. 1 (1.05) * DEAD LOAD + (1.28) * WIND

* * * * * REBAR DESIGN - DEAD LOAD + DRAG WIND * * * * *

MEMB	NODE	OUTER RADIUS (IN)	WALL THICK. (IN)	DESIGN AXIAL LOAD (KIPS)	DESIGN MOMENT (IN-KIPS)	REQ'D STEEL RATIO	REQ'D REBAR (SQ. IN)
1	1	3.000000D 02	1.100040D 01	9.025311D 03	1.988873D 06	3.300000D-03	6.717185D 01
	2	2.968181D 02	1.093410D 01	8.674853D 03	1.877039D 06	3.300000D-03	6.605312D 01
2	2	2.968181D 02	1.093410D 01	8.674853D 03	1.877039D 06	3.300000D-03	6.605312D 01
	3	2.904184D 02	1.080074D 01	7.986891D 03	1.661544D 06	3.300000D-03	6.382927D 01
3	3	2.904184D 02	1.080074D 01	7.986891D 03	1.661544D 06	3.300000D-03	6.382927D 01
	4	2.840188D 02	1.066739D 01	7.321218D 03	1.456455D 06	3.300000D-03	6.164045D 01
4	4	2.840188D 02	1.066739D 01	7.321218D 03	1.456455D 06	3.300000D-03	6.164045D 01
	5	2.776192D 02	1.053404D 01	6.677479D 03	1.263143D 06	3.300000D-03	5.948665D 01
5	5	2.776192D 02	1.053404D 01	6.677479D 03	1.263143D 06	3.300000D-03	5.948665D 01
	6	2.712195D 02	1.040069D 01	6.055320D 03	1.082506D 06	3.300000D-03	5.736788D 01
6	6	2.712195D 02	1.040069D 01	6.055320D 03	1.082506D 06	3.300000D-03	5.736788D 01
	7	2.648199D 02	1.026734D 01	5.454389D 03	9.151754D 05	3.300000D-03	5.528414D 01
7	7	2.648199D 02	1.026734D 01	5.454389D 03	9.151754D 05	3.300000D-03	5.528414D 01
	8	2.584204D 02	1.013398D 01	4.874330D 03	7.616028D 05	3.300000D-03	5.323542D 01
8	8	2.584204D 02	1.013398D 01	4.874330D 03	7.616028D 05	3.300000D-03	5.323542D 01
	9	2.520208D 02	1.000063D 01	4.314791D 03	6.221125D 05	3.300000D-03	5.122173D 01
9	9	2.520208D 02	1.000063D 01	4.314791D 03	6.221125D 05	3.300000D-03	5.122173D 01
	10	2.456212D 02	9.867283D 00	3.775417D 03	4.969293D 05	3.300000D-03	4.924307D 01
10	10	2.456212D 02	9.867283D 00	3.775417D 03	4.969293D 05	3.300000D-03	4.924307D 01
	11	2.392217D 02	9.733933D 00	3.255855D 03	3.861975D 05	3.300000D-03	4.729943D 01
11	11	2.392217D 02	9.733933D 00	3.255855D 03	3.861975D 05	3.300000D-03	4.729943D 01
	12	2.328222D 02	9.600583D 00	2.755750D 03	2.899950D 05	3.300000D-03	4.539082D 01
12	12	2.328222D 02	9.600583D 00	2.755750D 03	2.899950D 05	3.300000D-03	4.539082D 01
	13	2.264228D 02	9.467234D 00	2.274750D 03	2.083434D 05	3.300000D-03	4.351724D 01
13	13	2.264228D 02	9.467234D 00	2.274750D 03	2.083434D 05	3.300000D-03	4.351724D 01
	14	2.200233D 02	9.333886D 00	1.812499D 03	1.412152D 05	3.300000D-03	4.167868D 01
14	14	2.200233D 02	9.333886D 00	1.812499D 03	1.412152D 05	3.300000D-03	4.167868D 01
	15	2.136239D 02	9.200538D 00	1.368645D 03	8.854002D 04	3.300000D-03	3.987516D 01
15	15	2.136239D 02	9.200538D 00	1.368645D 03	8.854002D 04	3.300000D-03	3.987516D 01
	16	2.072245D 02	9.067191D 00	9.428339D 02	5.020943D 04	3.300000D-03	3.810666D 01
16	16	2.072245D 02	9.067191D 00	9.428339D 02	5.020943D 04	3.300000D-03	3.810666D 01
	17	2.040000D 02	9.000000D 00	7.350000D 02	3.805133D 04	3.300000D-03	3.722882D 01

FILED

ESG-79-30 Vol III

SOLAR TOWER FOR HYBRID RECEIVER SUBSYSTEM (1.4 SOLAR MULTIPLE)

LOAD CMB. 2 (0.90) * DEAD LOAD + (1.30) * WIND

* * * * REBAR DESIGN - DEAD LOAD + DRAG WIND * * * *

MEMB	NODE	OUTER RADIUS (IN)	WALL THICK. (IN)	DESIGN AXIAL LOAD (KIPS)	DESIGN MOMENT (IN-KIPS)	REQ'D STEEL RATIO	REQ'D REBAR (SQ. IN)
1	1	3.0000C0D 02	1.100040D 01	7.735981D 03	2.019949D 06	3.300000D-03	6.717185D 01
	2	2.968181D 02	1.093410D 01	7.435588D 03	1.906368D 06	3.300000D-03	6.605312D 01
2	2	2.968181D 02	1.093410D 01	7.435588D 03	1.906368D 06	3.300000D-03	6.605312D 01
	3	2.904184D 02	1.080074D 01	6.845907D 03	1.687506D 06	3.300000D-03	6.382927D 01
3	3	2.904184D 02	1.080074D 01	6.845907D 03	1.687506D 06	3.300000D-03	6.382927D 01
	4	2.840188D 02	1.066739D 01	6.275329D 03	1.479212D 06	3.300000D-03	6.164045D 01
4	4	2.840188D 02	1.066739D 01	6.275329D 03	1.479212D 06	3.300000D-03	6.164045D 01
	5	2.776192D 02	1.053404D 01	5.723553D 03	1.282880D 06	3.300000D-03	5.948665D 01
5	5	2.776192D 02	1.053404D 01	5.723553D 03	1.282880D 06	3.300000D-03	5.948665D 01
	6	2.712195D 02	1.040069D 01	5.190275D 03	1.099421D 06	3.300000D-03	5.736788D 01
6	6	2.712195D 02	1.040069D 01	5.190275D 03	1.099421D 06	3.300000D-03	5.736788D 01
	7	2.648199D 02	1.026734D 01	4.675190D 03	9.294750D 05	3.300000D-03	5.528414D 01
7	7	2.648199D 02	1.026734D 01	4.675190D 03	9.294750D 05	3.300000D-03	5.528414D 01
	8	2.584204D 02	1.013398D 01	4.177997D 03	7.735028D 05	3.300000D-03	5.323542D 01
8	8	2.584204D 02	1.013398D 01	4.177997D 03	7.735028D 05	3.300000D-03	5.323542D 01
	9	2.520208D 02	1.000063D 01	3.698392D 03	6.318330D 05	3.300000D-03	5.122173D 01
9	9	2.520208D 02	1.000063D 01	3.698392D 03	6.318330D 05	3.300000D-03	5.122173D 01
	10	2.456212D 02	9.867283D 00	3.236072D 03	5.046938D 05	3.300000D-03	4.924307D 01
10	10	2.456212D 02	9.867283D 00	3.236072D 03	5.046938D 05	3.300000D-03	4.924307D 01
	11	2.392217D 02	9.733933D 00	2.790733D 03	3.922318D 05	3.300000D-03	4.729943D 01
11	11	2.392217D 02	9.733933D 00	2.790733D 03	3.922318D 05	3.300000D-03	4.729943D 01
	12	2.328222D 02	9.600583D 00	2.362072D 03	2.945262D 05	3.300000D-03	4.539082D 01
12	12	2.328222D 02	9.600583D 00	2.362072D 03	2.945262D 05	3.300000D-03	4.539082D 01
	13	2.264228D 02	9.467234D 00	1.949786D 03	2.115988D 05	3.300000D-03	4.351724D 01
13	13	2.264228D 02	9.467234D 00	1.949786D 03	2.115988D 05	3.300000D-03	4.351724D 01
	14	2.200233D 02	9.333886D 00	1.553571D 03	1.434217D 05	3.300000D-03	4.167868D 01
14	14	2.200233D 02	9.333886D 00	1.553571D 03	1.434217D 05	3.300000D-03	4.167868D 01
	15	2.136239D 02	9.200538D 00	1.173125D 03	8.992346D 04	3.300000D-03	3.987516D 01
15	15	2.136239D 02	9.200538D 00	1.173125D 03	8.992346D 04	3.300000D-03	3.987516D 01
	16	2.072243D 02	9.067191D 00	8.081433D 02	5.099395D 04	3.300000D-03	3.810666D 01
16	16	2.072243D 02	9.067191D 00	8.081433D 02	5.099395D 04	3.300000D-03	3.810666D 01
	17	2.040000D 02	8.000000D 00	6.300000D 02	3.864588D 04	3.300000D-03	3.722882D 01

ESG-79-30, Vol III
D-91

APPENDIX E
0.8 SOLAR MULTIPLE DESIGN DATA SHEETS

ESG-79-30, Vol III

E-1

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem
Solar Multiple = 0.8

NUMBER

PREPARED BY

APPROVED BY

D. A. Carey (MDAC)

WBS NO. N00100301

PAGE 1 of 3

DATE June 22, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
New	A	Design Characteristics					
	1	Field Geometry and Size	m (f)				Field is made up of a grouping of 134.2-m square cells which are trimmed on the perimeter of the field to form a pseudo-circular shape of the given dimensions (see Figure 5.2-8).
		North-South		1542.9 (5062.0)			
		East-West		1610.2 (5282.2)			
		Distance from South Boundary to Tower		670.8 (2200.8)			
		Distance from East Boundary to Tower		805.0 (264.1)			
		Exclusion Radius		113.0 (370.0)			
	2	Field Layout				X	Heliostats are distributed throughout the field in a radial stagger array. Density and spacing are defined on a cell-by-cell basis (see Figures 5.2-9 through 5.2-13).
	3	Field Oversizing for Dirt on Mirrors, Reliability, etc.					
		Dirt	%	3.1		X	Reflectivity degraded by .97
		Reliability	%	2.0		X	assumes availability of .98
		Etc.	%	10.0		X	field/receiver power ratio = 1.1 (see Section 4.3.2).
	4	Beam Pointing Accuracy and Error Budget Versus Environmental Effects	mr 1σ		X		Wind of 10 to 20 knots.
		Azimuth					
		Maximum Peak to Peak	mr	1.0 ± 0.6			
		Mean	mr	0.4 ± 0.4			
		% Time above 1.0 mr	%	1.0

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem
Solar Multiple = 0.8

NUMBER

PREPARED BY

APPROVED BY

D. A. Carey (MDAC)

WBS NO. N001000301

PAGE 2 of 3

DATE June 22, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEM- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Elevation					
		Maximum Peak to Peak	mr	0.5 ±0.4			
		Mean	mr	0.4 ±0.4			
		% Time Above	%	1.0			
	5	Heliostat Beam Quality and Error Budget Versus Environmental Effects					Not analyzed. Three percent degradation for reflectivity assumed in performance calculations. Fifty km visibility assumed for atmospheric absorption.
	6	Heliostat Geometry and Size					
		Shape		Square			
		Glass Area	m ² (ft ²)	49.05 (528)		X	See Figures 5.2-1, 5.2-2, 5.2-3.
	7	Number of Heliostats		8496		X	
	8	Operating Characteristics					
	1	Power Required/Heliostat					
		Track		1.7 amps @ 208V			
		Starting		8.8 amps @ 208V			
		Emergency Shutdown		N/A			
		Average Daily Energy	w-h	100			

ESG-79-30, Vol III

E-4

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem
Solar Multiple = 0.8

NUMBER

PREPARED BY

APPROVED BY

D. A. Carey (MDAC)

WBS NO. N001000301

PAGE 3 of 3

DATE June 22, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	2	Heliostat Operating Modes Startup Tracking Hold Stowing (Inverted)					
	3	Control System Characteristics					Open loop, automatic with manual override (remote and at heliostat) (see Section 5.2.2).
	4	Operational and Survival Versus Environmental Conditions					Not analyzed. Specifically designed to meet requirements listed in Table 5.2-1.

ESG-79-30, Vol III

E-5

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER
Revision 0

PREPARED BY

APPROVED BY

PAGE 1 of 17

WBS NO. Dwg. N0010003J1

DATE May 3, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	A	Design Characteristics					
	1	Receiver height	m (ft)	13.5 (44.3)			
		Receiver diameter	m (ft)	10.4 (34)			
	2	Area of working surface	m ² (ft ²)	446 (4,800)			
	3	Absorber tube OD	cm (in.)	1.91 (0.75)			
		Absorber tube ID	cm (in.)	1.65 (0.65)			
		Absorber tube wall thickness	cm (in.)	0.127 (0.05)			
	4	Absorber tube length	m (ft)	17.2 (56.3)			
		Thermal Expansion	cm (in.)	12.7 (5)			
	5	Number of panels		18			
		Number of tubes per panel		96			
	6	Panel material		304 SS			
		Total mass of panels	kg (ton)	9,070 (10)			
		Mass per panel	kg (ton)	540 (0.6)			
		Panel Insulation	cm (in.)	15.2 (6)			Excluding headers Closed-pore fiberglass
	7	Heat pipe material		NA			(Not applicable)
	8	Header material		CS and SS			CS - 288°C (550°F), SS - 593°C (1100°F)
		Total mass of headers	kg (ton)	6,400 (7.2)			20 cm (8 in.) headers
		Mass per header	kg (ton)	1,600 (1.8)			
	9	Insulation material for headers					Calcium silicate
		Total mass of insulation	kg (ton)	3,400 (3.7)			

FORM 706-A REV. 6-78

bjm:53

ESG-79-30, Vol III

E-6

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Revision 0

PREPARED BY

APPROVED BY

PAGE 2 of 17

WBS NO. Dwg. N001000301

DATE May 3, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	10		Structure material Total mass of structure	kg (ton)	90,700 (100)			
	11		Support material Total mass of receiver support	kg (ton)	23,600 (26)			
	12		Piping material Total mass of receiver tubing	kg (ton)	18,200 (20)			Excluding riser, downcomer and headers
	13		Receiver valve material Number Total mass	CS 18 kg (lb)	13,400 (14)			Receiver proper only 18-15 cm (6 in.) control butterfly valves
	14		Pump material		NA			NO PUMP IN Receiver proper
	15		Total mass of other miscellaneous items in receiver proper					
			Roof	kg (ton)	6300 (7)			
			Crane	kg (ton)	2300 (2.5)			
			Cold Buffer Tanks	kg (ton)	54,500 (60)			Total 6 Empty Tanks
			Hot Buffer Tanks	kg (ton)	18,000 (20)			Total 6 Empty Tanks
			Insulation for Buffer Tanks	kg (ton)	21,800 (24)			

FORM 706-A REV. 6-78

bjm:53

ESG-79-30, Vol III

E-7

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Revision 0

PREPARED BY

APPROVED BY

PAGE 3 of 17

WBS NO. Dwg. N001000301

DATE May 3, 1979

NEW REV	NO.	A ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	16	Total dry mass on top of tower	kg (ton)	305,000 (336)			Sum of Items 6-15
	17	Total mass of sodium at top of tower	kg (ton)	106,000 (117)			Excluding riser/downcomer
		Volume of sodium in subsystem	m (gals)	481 (127,000)			Includes cold and hot buffer tanks
		Weight of sodium in subsystem	kg (lb)	408,000 (900,000)			
	18	Receiver operational seismic load					See Appendix D
		Vertical at tower top					
		Horizontal at tower top					
	19	Receiver survival seismic load					See Appendix D
		Vertical at tower top					
		Horizontal at tower top					
	20	ASME design code for receiver plus additional requirements	Section	VIII			Analysis for cyclic events
	21	Receiver surface coating		Pyromark			
		Composition		TBD			
		Absorbtivity		0.95			
		Emissivity		0.90			

FORM 706-A REV. 6-78

bjm:53

ESG-79-30, Vol III

E-8

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Revision 0

PAGE 4 of 17

DATE May 3, 1979

PREPARED BY

APPROVED BY

WBS NO. Dwg. N001000301

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	22		Receiver pressure drop correlations a. Pressure drop: $\Delta p = \left(f \frac{L}{D} + K \right) \frac{\rho v^2}{2g}$ b. Reynolds number: $Re = \frac{Dv\rho}{\mu_e}$					Δp = differential pressure f = friction factor L = length of receiver pipe in feet D = internal diameter of receiver pipe in feet v = mean velocity of flow, in feet per second g = acceleration of gravity = 32.2 ft/sec ² Re = Reynolds number ρ = weight density of fluid, pounds per ft ³ μ_e = absolute viscosity in pound mass per foot second K = resistance coefficient

ESG-79-30, Vol 111

E-9

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER
Revision 0

PREPARED BY

APPROVED BY

PAGE 5 of 17

WBS NO. Dwg. N001000301

DATE May 3, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	23	<p>Receiver heat transfer correlations (for power into receiver working fluid)</p> <p>a. For conduction through tube wall:</p> $q = \frac{2\pi K L \Delta T}{\ln \frac{d_o}{d_i}}$ <p>b. Sodium heat transfer coefficient:</p> $Nu = 7 + \frac{1}{40} (Pr Re)^{0.8}$ $h_{Na} = \frac{Nu K}{d_i}$					<p>q = heat transferred</p> <p>K = thermal conductivity of tube wall (Btu/hr-ft²-F)</p> <p>d_o = outside diameter of tube wall - inches</p> <p>d_i = inside diameter of tube wall - inches</p> <p>Nu = Nusselt number</p> <p>Pr = Prandtl number</p> <p>Re = Reynolds number</p> <p>Combined conduction through tube wall and sodium heat transfer coefficient</p> <p>L = wall thickness</p> <p>ΔT = differential temperature across wall</p>

ESG-79-30, Vol III

E-10

FORM 706-A REV. 6-78

bjm:53

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0:8

NUMBER
Revision 0

PREPARED BY

APPROVED BY

PAGE 6 of 17

WBS NO. Dwg. N001000301

DATE May 3, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	24	Receiver heat transfer correlation for receiver losses a. Air natural convection heat transfer coefficient (vertical cylinder): $Nu = 0.13 (GrPr)^{1/3}$ $Nu = \frac{hL}{K}$ $Gr = \left(\frac{\rho^2 g \beta}{\mu^2} \right) L^3 \Delta T$ $Pr = \frac{\mu C_p}{K}$					Nu = Nusselt number Gr = Grashof number Pr = Prandtl number, air K = thermal conductivity, air (Btu/hr-ft ² -°F) g = gravitational constant $\beta = \frac{1}{T} (^{\circ}R^{-1})$ for air ρ = density μ = viscosity T = temperature

ESG-79-30, Vol III

E-11

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER
Revision 0

PREPARED BY

APPROVED BY

PAGE 7 of 17

WBS NO. Dwg. N001000301

DATE May 3, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEM- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	24	b.	Forced convection: Extrapolated Achenbach data c. Assumed combined convection heat transfer coefficient: $h_{eff.} = \sqrt{h_{forced}^2 + h_{nat.}^2}$ d. Thermal radiation: $q = \mathcal{F} \epsilon \sigma A (T_1^4 - T_2^4)$					<p>h = heat transfer coefficient (Btu/hr-ft²-°F)</p> <p>q = heat flow rate (Btu/hr-ft²- °F)</p> <p>$\mathcal{F}$ = radiation factor</p> <p>ϵ = surface thermal emissivity</p> <p>σ = Stefan-Boltzmann constant</p> <p>A = radiating surface area</p> <p>T_1 = effective mean radiating surface temperature (°R)</p> <p>T_2 = radiative sink temperature (°R)</p>

FORM 706-A REV. 6-78

bjm:53

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Revision 0

PAGE 8 of 17

DATE May 3, 1979

PREPARED BY

APPROVED BY

WBS NO. Dwg. N001000301

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	25		Tower construction					Slip formed concrete
			Height to top of tower	m (ft)	111.3 (365)			
			Diameter - base	m (ft)	15.2 (50)			
			Diameter - top	m (ft)	10.4 (34)			
			Wall thickness - base	m (in.)	0.28 (11)			
			Wall thickness - top	m (in.)	0.23 (9)			
			Mat OD	m (ft)	36.6 (120)			
			Mat thickness	m (ft)	3.7 (12)			
			Receiver midpoint elevation	m (ft)	124 (407)			
			Receiver maximum elevation	m (ft)	130.8 (429)			
			Receiver Optical Elevation	m (ft)	120 (394)			
	26		Riser material		CS			
			Outside diameter	cm (in.)	51 (20)			
			Inside diameter	cm (in.)	48.5 (19.0)			
			Wall thickness	cm (in.)	1.27 (0.50)			
			Design temperature	°C (°F)	371 (700)			
			Design pressure ANSI B31.1	MN/m ² (psia)	2.76 (400)			
			Velocity at maximum flow rate	m/sec (ft/sec)	3.3 (11.1)			
			Downcomer material		SS			
			Outside diameter	cm (in.)	51 (20)			
			Inside diameter	cm (in.)	48.5 (19.0)			
			Wall thickness	cm (in.)	1.27 (0.50)			
			Design temperature	°C (°F)	621 (1150)			
			Design pressure ANSI B31.1	MN/m ² (psia)	2.76 (400)			
			Maximum flow rate	kg/h (lb/h)	1.93 x 10 ⁶ (4.26 x 10 ⁶)			
			Velocity at maximum flow rate	m/sec (ft/sec)	3.7 (12.2)			

FORM 706-A REV. 6-78

bjm:53

ESG-79-30, Vol III

E-13

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Revision 0

PREPARED BY

APPROVED BY

WBS NO. Dwg. N001000301

PAGE 9 of 17

DATE May 3, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEM- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	27		Riser total length Downcomer total length	m (ft) m (ft)	152 (500) 152 (500)			
	28		Mass of riser Mass of downcomer	kg (ton) kg (ton)	24,000 (26) 24,000 (26)			Piping material Piping material
	29		Riser/downcomer insulation material Insulation thickness - riser Insulation thickness - downcomer	cm (in.) cm (in.)	12.7 (5) 20.3 (8)			Calcium silicate
	30		Mass of riser insulation Mass of downcomer insulation	kg (ton) kg (ton)	13,600 (15) 23,000 (25)			
	31		Mass of miscellaneous items in tower Elevator Stack Stack Support	kg (ton)	TBD 60,000 (65)			

ESG-79-30, Vol III

E-14

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Revision 0

PAGE 10 of 17

DATE May 3, 1979

PREPARED BY

APPROVED BY

WBS NO. Dwg. N001000301

ESG-79-30, Vol III

E-15

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	32		Horizontal piping material					
			OD	cm (in.)	61 (24)			Sodium piping
			ID	cm (in.)	57.5 (22.63)			Evaporator to pump suction
			Wall thickness	cm (in.)	1.75 (0.687)			
			OD	cm (in.)	51 (20)			Sodium heater inlet, outlet
			ID	cm (in.)	47.8 (18.81)			Receiver to steam generator
			Wall thickness	cm (in.)	1.6 (0.593)			Superheater to evaporator
			OD	cm (in.)	36 (14)			Superheater inlet and outlet
			ID	cm (in.)	33.3 (13.12)			
			Wall thickness	cm (in.)	1.35 (0.438)			
			OD	cm (in.)	27.3 (10.75)			Reheater inlet and outlet
			ID	cm (in.)	25.5 (10.02)			
			Wall thickness	cm (in.)	0.90 (0.365)			
			OD	cm (in.)	21.9 (8.625)			Drains
			ID	cm (in.)	20.3 (7.981)			
			Wall thickness	cm (in.)	0.8 (0.322)			
	33		Horizontal piping total lengths					
			61 cm (24 in.)	m (ft)	152 (500)			CS 111, 112*
			51 cm (20 in.)	m (ft)	213 (700)			SS 116
			51 cm (20 in.)	m (ft)	152 (500)			CS 115
			36 cm (14 in.)	m (ft)	18 (60)			SS 106, 109
			25 cm (10 in.)	m (ft)	30 (100)			SS 107, 108
			20 cm (8 in.)	m (ft)	60 (200)			SS CS 500
	34		Mass of horizontal piping					
			61 cm (24 in.)	kg (ton)	38,600 (42.5)			
			51 cm (20 in.)	kg (ton)	39,000 (43)			
			51 cm (20 in.)	kg (ton)	28,000 (31)			
			36 cm (14 in.)	kg (ton)	1,700 (1.9)			
			25 cm (10 in.)	kg (ton)	1,800 (0.9)			
			20 cm (8 in.)	kg (ton)	2,600 (1.3)			

*Refers to pipe number
in referenced P&I Diagram

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Revision 0

PREPARED BY

APPROVED BY

PAGE 11 of 17

WBS NO. Dwg. N001000301

DATE May 3, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TECH- NICAL	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	35	Horizontal piping insulation material					Calcium silicate
		61 cm (24 in.)	cm (in.)	15.2 (6)			CS
		51 cm (20 in.)	cm (in.)	20.3 (8)			SS
		51 cm (20 in.)	cm (in.)	12.7 (5)			CS
		36 cm (14 in.)	cm (in.)	15.2 (6)			SS
		25 cm (10 in.)	cm (in.)	12.7 (5)			SS
		20 cm (8 in.)	cm (in.)	12.7 (5)			SS
	36	Mass of horizontal piping insulation					
		61 cm (20 in.) - 500 ft	kg (ton)	12,000 (12.5)			CS
		51 cm (20 in.) - 700 ft	kg (ton)	32,000 (35)			SS
		51 cm (20 in.) - 500 ft	kg (ton)	9,500 (10.5)			CS
		36 cm (14 in.) - 60 ft	kg (ton)	1,400 (1.6)			SS
		25 cm (10 in.) - 100 ft	kg (ton)	1,900 (2.1)			SS
		20 cm (8 in.) - 200 ft	kg (ton)	3,800 (4.2)			SS
	37	Valve size, number, and material					Ground level only
		51 cm (20 in.) check		1			1 - CS V-100
		51 cm (20 in.) block		2			1 - SS and 1 - CS, V-104 & V-205
		25 cm (10 in.) control		1			SS, superheater control, V-110
		51 cm (20 in.) control		2			1 CS, heater inlet, 1 SS rec. outlet
		5.1 cm (2 in.) block		4			V-111, V-106 V-201, 202, 204, 205

FORM 706-A REV. 6-78

bjm:53

ESG-79-30, Vol III E-16

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER
Revision 0

PREPARED BY

APPROVED BY

PAGE 12 of 17

WBS NO. Dwg. N001000301

DATE May 3, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	38	Number and mass of valves					Ground level only
		2 - 51 cm (20 in.) check	kg (lb)	1,800 (4,000)			
		3 - 51 cm (20 in.) block	kg (lb)	2,600 (5,700)			
		1 - 25 cm (10 in.) control	kg (lb)	280 (600)			
		1 - 51 cm (20 in.) block	kg (lb)	820 (1,800)			
	39	Receiver pump material					CS
		Number of receiver pumps		1			Ground level only
		Mass of receiver pump	kg (lb)	2,045 (4,500)			Dry weight
	40	Receiver pump characteristics - P-1					Centrifugal mixed flow single stage
		Type		-			
		Speed	rpm	3,540			Fixed speed
		Operating range		-			
		Head	m (ft)	130 (425)			
		NPSH	m (ft)	57.9 (190)			
		Operating temperature	°C (°F)	288 (550)			
		Power (N = 72%)	kWe (hp)	1,176 (1,576)			
		Capacity	m ³ /s ₂ (gpm)	0.76 (12,000)			
		Pump outlet pressure	MW/m ² (psia)	1.53 (222)			
		Pump inlet pressure	MW/m ² (psia)	0.41 (59)			
		Height, w/motor	m (ft)	6 (19.7)			
		Tank size	m (ft)	1.83 x 3.66 (6 x 12)			
		Inlet nozzle	m (in.)	61 (24)			
		Outlet nozzle	m (in.)	51 (20)			
		Impeller diameter	m (ft)	0.34 (1.1)			
		Casing diameter	m (ft)	0.61 (2.0)			
		Dry weight pump	kg (lb)	2,045 (4,500)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Revision 0

PREPARED BY

APPROVED BY

PAGE 13 of 17

WBS NO. Dwg. N001000301

DATE May 3, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Motor					
			Size	MW (hp)	1.31 (1,750)			
			Dimensions w/coupling	m (ft)	1.3 x 2.8 (4 x 9)			
			Voltage	V	4,160			
			Cooling		TBD			
			Weight	kg (lb)	7,300 (16,000)			
			Number of poles		2			
			Speed	rpm	3,540			
			Design conditions					
			Developed head	m ₃ (ft)	143 (470)			
			Flow rate	m ³ /s (gpm)	0.83 (13,000)			
			Speed	rpm	3,540			
			Temperature	°C (°F)	300 (600)			
			NPSH (minimum required)	m (ft)	9.1 (30)			
			Code					
	41		Steam generator heat exchanger characteristics					
			Service - Evaporator X-1					
			Number required		1			
			Type		-			
			Orientation		Vertical			
			Number of tube passes		1			
			Number of shell passes		1			
			Tube side fluid		Water			
			shell side fluid		Sodium			
			Tube material		2-1/4 Cr - 1 Mo			
			Shell material		2-1/2 Cr - 1 Mo			
			Number of tubes		1,250			
			Tube OD	cm (in.)	1.59 (5/8)			
			Tube ID	cm (in.)	1.21 (0.475)			
								Section VIII, Division 1
								Tube and shell hockey stick

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Revision 0

PREPARED BY

APPROVED BY

PAGE 14 of 17

WBS NO. Dwg. N001000301

DATE May 3, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Tube wall thickness	cm (in.)	0.190 (0.075)			
			Tube layout and pitch dimension	cm (in.)	TBD			
			Baffle type and spacing	cm (in.)	TBD			
			Unit size - height	m (ft)	29.0 (95)			
			Unit size - width	m (ft)	5.18 (17)			
			Unit size shell diameter	m (in.)	1.27 (50)			
			Mass per unit	kg (ton)	65,000 (72)			
			Active external surface area per unit	m ² (ft ²)	1,480 (15,900)			
			Inactive external surface area per unit	m ² (ft ²)	150 (1,600)			
			LMTD - preheating	°C (°F)	16 (28)			
			LMTD - nucleate boiling	°C (°F)	18 (33)			
			LMTD - film boiling	°C (°F)	79 (143)			
			Pinch point	°C (°F)	4.4 (8)			
			Sodium nozzle OD/thickness	cm (in.)	51/2.5 (20/1.0)			
			Tubesheet diameter/thickness	cm (in.)	122/30.5 (48/12)			
			Steam nozzle OD/thickness	cm (in.)	20.3/3.8 (8/1.5)			
			Weight	kg (ton)	65,000 (72)			
			Design conditions					
			Pressure-sodium side	MN/m ² (psig)	2.07 (300)			
			Pressure-steam side	MN/m ² (psig)	15.17 (2,200)			
			Temperature	°C (°F)	482 (900)			
			Code					ASME Section VIII, Division 1
	41		Service - Superheater X-2					
			Number required		1			
			Type		-			
			Orientation		Vertical			
			Number of tube passes		1			
			Number of shell passes		1			
			Tube side fluid		Steam			
			Shell side fluid		Sodium			
			Tube material		SS			Tube and shell hockey stick

FORM 706-A REV. 6-78

bjm:53

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER
Revision 0

PREPARED BY

APPROVED BY

PAGE 15 of 17

WBS NO. Dwg. N001000301

DATE May 3, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Shell material		SS			
		Number of tubes		269			
		Tube OD	cm (in.)	1.91 (3/4)			
		Tube ID	cm (in.)	1.23 (0.486)			
		Tube wall thickness	cm (in.)	0.34 (0.132)			
		Tube layout and pitch dimension	cm (in.)	TBD			
		Baffle type and spacing	cm (in.)	TBD			
		Unit size - height	m (ft)	27.7 (91)			
		Unit size - width	m (ft)	4.57 (15)			
		Unit size - shell diameter	m (in.)	0.76 (30)			
		Mass per unit	kg (ton)	20,000 (22)			
		Active external surface area per unit	m ² (ft ²)	383 (4,100)			
		Inactive external surface area per unit	m ² (ft ²)	38 (410)			
		LMTD	°C (°F)	85 (153)			
		Pinch point	°C (°F)	NA			
		Sodium nozzle OD/thickness	cm (in.)	45.7/2.54 (18/1.0)			
		Tubesheet diameter/thickness	cm (in.)	76.2/20.3 (30/8)			
		Steam nozzle OD/thickness	cm (in.)	20/3.0 (8/1.2)			
		Weight	kg (ton)	20,000 (22)			
		Design conditions					
		Pressure-sodium side	MN/m ² (psig)	2.07 (300)			
		Pressure-steam side	MN/m ² (psig)	15.2 (2,200)			
		Temperature	°C (°F)	593 (1100)			
		Code					ASME Section VIII, Division I
	41	Service - Reheater X-2					
		Number required		1			
		Type		-			
		Orientation		Vertical			Tube and shell hockey stick
		Number of tube passes		1			

FORM 706-A REV. 6-78

bjm:53

ESG-79-30, Vol III

E-20

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Revision 0

PREPARED BY

APPROVED BY

PAGE 16 of 17

WBS NO. Dwg. N001000301

DATE May 3, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Number of shell passes		1			
			Tube side fluid		Steam			
			Shell side fluid		Sodium			
			Tube material		SS			
			Shell material		SS			
			Number of tubes		166			
			Tube OD	cm (in.)	3.81 (1-1/2)			
			Tube ID	cm (in.)	3.27 (1.29)			
			Tube wall thickness	cm (in.)	0.27 (0.107)			
			Tube layout and pitch dimension	cm (in.)	TBD			
			Baffle type and spacing	cm (in.)	TBD			
			Unit size - height	m (ft)	20.1 (66)			
			Unit size - width	m (ft)	5.49 (18)			
			Unit size - shell diameter	m (in.)	0.81 (32)			
			Mass per unit	kg (ton)	22,000 (24)			
			Active external surface area per unit	m ² (ft ²)	315 (3,400)			
			Inactive external surface area per unit	m ² (ft ²)	31.5 (340)			
			LMTD	°C (°F)	95.6 (172)			
			Pinch point	°C (°F)	NA			
			Sodium nozzle OD/thickness	cm (in.)	30.5/1.9 (12/.75)			
			Tubesheet diameter/thickness	cm (in.)	81.3/12.7 (32/5)			
			Steam nozzle OD/thickness	cm (in.)	16.8/15 (6.6/.6)			
			Weight	kg (ton)	22,000 (24)			
			Design conditions					
			Pressure-sodium side	MPa ² (psia)	2.07 (300)			
			Pressure-steam side	MPa ² (psia)	3.10 (450)			
			Temperature	°C (°F)	593 (1100)			
			Code					ASME Section VIII, Division I

FORM 706-A REV. 6-78

bjm:53

ESG-79-30, Vol III

E-21

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Revision 0

PREPARED BY

APPROVED BY

PAGE 17 of 17

WBS NO. Dwg. N001000301

DATE May 3, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	42		Sodium drain tank - T-3		1			Cylindrical API type
			Number					
			Type					
			Diameter	m (ft)	9.1 (30)			
			Height	m (ft)	7.6 (25)			
			Wall thickness					
			top	cm (in.)	0.64 (0.25)			
			Bottom	cm (in.)	1.27 (0.50)			
			Volume	m ³ (gal)	3,764 (133,000)			
			Tank material		CS			
			Insulation, roof, and walls	cm (in.)	15.2 (6)			Calcium silicate with aluminum weather protection
			Base insulation	m (ft)	1 (3)			Perlitic concrete
			Electric preheat-temperature	kW	16			
			Maintenance ullage pressure	Pa (psig)	0.0069 (1)			
			Pressurization media		Argon			
			Operating temperature	°C (°F)	288 (550)			
			Operating pressure	Pa (psig)	0.0069 (1)			

FORM 706-A REV. 6-78

bjm:53

ESG-79-30, Vol III

E-22

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

1 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	B		Operating Characteristics					
	1		Receiver Incident Power					
			Total at max. insolation	MWt	234.4			Solstice Noon
			Per panel -					
			No. 1 and 18 North	MWt	15.1			Starting with No. 1 for north panel, panels numbered in clock- wise direction (20°F per panel). Vertical centerline of No. 1 panel 10° east of north.
			No. 2 and 17	MWt	14.9			
			No. 3 and 16	MWt	14.3			
			No. 4 and 15	MWt	13.9			
			No. 5 and 14 East and West	MWt	13.3			
			No. 6 and 13	MWt	12.4			
			No. 7 and 12	MWt	11.6			
			No. 8 and 11	MWt	11.2			
			No. 9 and 70 South	MWt	10.5			
			Total at design insolation	MWt	234			Equinox Noon
			Per panel -					
			No. 1 and 18 North	MWt	16.6			
			No. 2 and 17	MWt	16.4			
			No. 3 and 16	MWt	15.4			
			No. 4 and 15	MWt	14.3			
			No. 5 and 14 East and West	MWt	13.3			
			No. 6 and 13	MWt	11.8			
			No. 7 and 12	MWt	10.3			
			No. 8 and 11	MWt	9.7			
			No. 9 and 10 South	MWt	9.2			

FORM 706-A REV. 6-78

sjd:510

ESG-79-30, Vol III

E-23

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

2 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	-B ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	1	Receiver Incident Power - Continued					
		Total at min. operating condition	MWt	161.5			10 ⁰ Cutoff Winter Solstice
		Per panel - *					*Panel Power is Asymmetric
		No. 1 and 18 North	MWt	12.7/11.8			
		No. 2 and 17	MWt	12.5/10.6			
		No. 3 and 16	MWt	12.1/9.2			
		No. 4 and 15	MWt	11.8/7.7			
		No. 5 and 14 East and West	MWt	11.4/6.4			
		No. 6 and 13	MWt	10.9/5.0			
		No. 7 and 12	MWt	9.5/4.5			
		No. 8 and 11	MWt	8.1/4.9			
		No. 9 and 10 South	MWt	6.8/5.6			
	2	Receiver Absorbed Power					
		Total at max. insolation (design)	MWt	208			
		Per panel -					
		No. 1 and 18 North	MWt	13.4			
		No. 2 and 17	MWt	13.2			
		No. 3 and 16	MWt	12.7			
		No. 4 and 15	MWt	12.3			
		No. 5 and 14 East and West	MWt	11.8			
		No. 6 and 13	MWt	11.0			
		No. 7 and 12	MWt	10.3			
		No. 8 and 11	MWt	9.9			
		No. 9 and 10 South	MWt	9.4			

FORM 706-A REV. 6-78

sjd:510

ESG-79-30, Vol III

E-24

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

3 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	2		Receiver Absorbed Power - Continued					
			Total at design insolation (operating)	MWt	208			
			Per panel -					
			No. 1 and 18 North	MWt	14.8			
			No. 2 and 17	MWt	14.6			
			No. 3 and 16	MWt	13.7			
			No. 4 and 15	MWt	12.7			
			No. 5 and 14 East and West	MWt	11.8			
			No. 6 and 13	MWt	10.5			
			No. 7 and 12	MWt	9.2			
			No. 8 and 11	MWt	8.6			
			No. 9 and 10 South	MWt	8.1			
			Total at min. operating condition	MWt	145.2			
			Per panel - *					
			No. 1 and 18 North	MWt	6.1/5.0			*Panel Power is Asymmetric
			No. 2 and 17	MWt	7.3/4.4			
			No. 3 and 16	MWt	8.5/4.0			
			No. 4 and 15	MWt	9.8/4.5			
			No. 5 and 14 East and West	MWt	10.2/5.8			
			No. 6 and 13	MWt	10.6/6.9			
			No. 7 and 12	MWt	10.9/8.3			
			No. 8 and 11	MWt	11.2/9.5			
			No. 9 and 10 South	MWt	11.5/10.7			

FSG-79-30, Vol III

E-25

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER
Rev. 0

PREPARED BY

APPROVED BY

PAGE 4 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	B ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	3	Flux Maps					Design point is minimum requirement.
	4	Peak flux absorbed					
		Maximum Design point	MWt/m ² MWt/m ²	See Text Sect. 5.2			Receiver Area - 441 m ²
	5	Average flux absorbed					
		Maximum Design point Minimum operating condition	MWt/m ² MWt/m ² MWt/m ²	0.47 0.47 0.33			
	6	Receiver sodium operating temperatures					
		Inlet Outlet	°C (°F) °C (°F)	228 (550) 593 (1100)			
	7	Receiver sodium operating pressures					
		Inlet Outlet	MPa (psi) MPa (psi)	0.45 (65) 0.24 (35)			
	8	Receiver sodium flow rates					
		Total maximum (design)	kg/hr (lb/hr)	1.93 x 10 ⁶ (4.26 x 10 ⁶)			
		Design (operating)	kg/hr (lb/hr)	1.93 x 10 ⁶ (4.26 x 10 ⁶)			
		Minimum	kg/hr (lb/hr)	1.35 x 10 ⁶ (2.97 x 10 ⁶)			

FORM 706-A REV. 6-78

sjd:510

ESG-79-30, Vol III

E-26

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver
Hybrid Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

5 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	8		Receiver sodium flow rates - Continued					
			Per panel -					
			No. 1 and 18 North -	kg/hr (lb/hr)	1.24 x 10 ⁵			(2.74 x 10 ⁵)
			Design		1.38 x 10 ⁵			(3.03 x 10 ⁵)
			Minimum		0.57 x 10 ⁵ /			(1.25 x 10 ⁵)/(1.02 x 10 ⁵)
			No. 2 and 17		0.46 x 10 ⁵			
			Maximum		1.23 x 10 ⁵			(2.70 x 10 ⁵)
			Design		1.36 x 10 ⁵			(2.99 x 10 ⁵)
			Minimum		0.68 x 10 ⁵ /			(1.49 x 10 ⁵)/(0.90 x 10 ⁵)
			No. 3 and 16		0.41 x 10 ⁵			
			Maximum		1.18 x 10 ⁵			(2.60 x 10 ⁵)
			Design		1.28 x 10 ⁵			(2.81 x 10 ⁵)
			Minimum		0.79 x 10 ⁵ /			(1.74 x 10 ⁵)/(0.82 x 10 ⁵)
			No. 4 and 15		0.37 x 10 ⁵			
			Maximum		1.14 x 10 ⁵			(2.52 x 10 ⁵)
			Design		1.18 x 10 ⁵			(2.60 x 10 ⁵)
			Minimum		0.91 x 10 ⁵ /			(2.00 x 10 ⁵)/(0.92 x 10 ⁵)
			No. 5 and 14 East & West -		0.42 x 10 ⁵			
			Maximum		1.10 x 10 ⁵			(2.42 x 10 ⁵)
			Design		1.10 x 10 ⁵			(2.42 x 10 ⁵)
			Minimum		0.95 x 10 ⁵ /			(2.09 x 10 ⁵)/(1.19 x 10 ⁵)
			No. 6 and 13		0.54 x 10 ⁵			
			Maximum		1.02 x 10 ⁵			(2.25 x 10 ⁵)
			Design		0.98 x 10 ⁵			(2.15 x 10 ⁵)
			Minimum		0.99 x 10 ⁵ /			(2.17 x 10 ⁵)/(1.41 x 10 ⁵)
			No. 7 and 12		0.64 x 10 ⁵			
			Maximum	kg/hr (lb/hr)	0.96 x 10 ⁵			(2.11 x 10 ⁵)
			Design		0.85 x 10 ⁵			(1.88 x 10 ⁵)
			Minimum		1.01 x 10 ⁵ /			(2.23 x 10 ⁵)/(1.70 x 10 ⁵)
					0.77 x 10 ⁵			

ESG-79-30, Vol III

E-27

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

6 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	8		Receiver sodium flow rates - Continued					
			Per panel -					
			No. 8 and 11	kg/hr (lb/hr)	0.92 x 10 ⁵ 0.80 x 10 ⁵ 1.04 x 10 ⁵ / 0.88 x 10 ⁵			(2.03 x 10 ⁵) (1.76 x 10 ⁵) (2.29 x 10 ⁵)/(1.94 x 10 ⁵)
			No 9 and 10 South	kg/hr (lb/hr)	0.88 x 10 ⁵ 0.75 x 10 ⁵ 1.07 x 10 ⁵ / 0.99 x 10 ⁵			(1.93 x 10 ⁵) (1.66 x 10 ⁵) (2.35 x 10 ⁵)/(2.19 x 10 ⁵)
	9		Receiver sodium velocities					
			Per panel -					
			No. 1 and 18 North	m/sec (ft/sec)	2.0 (6.5) 2.2 (7.3) 0.9/0.7 (3.0)/(2.4)			
			No. 2 and 17		2.0 (6.4) 2.2 (7.1) 1.1/.6 (3.5)/(2.1)			
			No. 3 and 16		1.9 (6.1) 2.0 (6.6) 1.2/0.6 (4.1)(1.9)			
			No. 4 and 15	m/sec (ft/sec)	1.8 (6.0) 1.9 (6.1) 1.4/0.7 (4.7)/(2.2)			

ESG-79-30, Vol III

E-28

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

7 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	9		Receiver sodium velocities - Continued					
			Per panel -					
			No. 5 and 14					
			Maximum	m/sec	1.7 (5.7)			
			Design	(ft/sec)	1.7 (5.7)			
			Minimum		1.5/.9 (4.9)/(2.8)			
			No. 6 and 13					
			Maximum		1.6 (5.3)			
			Design		1.6 (5.1)			
			Minimum		1.6/1.0 (5.1)/(3.3)			
			No. 7 and 12					
			Maximum		1.5 (5.0)			
			Design		1.3 (4.4)			
			Minimum		1.6/1.2 (5.3)/(4.0)			
			No 8 and 11					
			Maximum		1.5 (4.8)			
			Design		1.3 (4.2)			
			Minimum		1.6/1.4 (5.4)/(4.6)			
			No. 9 and 10					
			Maximum	m/sec	1.4 (4.6)			
			Design	(ft/sec)	1.2 (3.9)			
			Minimum		1.7/1.6 (5.6)/(5.2)			

ESG-79-30, Vol III

E-29

Rockwell International

Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

8 of 17

WBS NO. Drawing N00100J301

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	10	Receiver losses @ maximum power					% of incident power
		Design point wind speed at receiver elev.	m/sec(MPH)	11.0 (24.6)			
		Reflection	%	5.0			
		Reradiation	%	5.5			
		Combined natural plus forced convection	%	3.0			
		Receiver losses @ design power					Same wind speed as above
		Reflection	%	5.0			
		Reradiation	%	5.5			
		Combined natural plus forced convection	%	3.0			
		Receiver losses @ minimum oper. power					
		Reflection	%	5.0			
		Reradiation	%	7.2			
		Combined natural plus forced convection	%	4.0			
	11	Peak metal temperatures in receiver	°C (°F)	618 (1144)			North panel approx.
		Location					2.5 m from top of panel
	12	Peak working stress in receiver	MPa(psi)	TBD			
		Location					
	13	Receiver fatigue life					
		No. of cycles		15,000			
		Equivalent years of operation		30

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PAGE

9 of 17

DATE

PREPARED BY

APPROVED BY

WBS NO. Drawing N001000301

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	14	Receiver heat transfer coefficients at maximum absorbed power					
		a. Tube wall	$W/M^2-^{\circ}C$ ($Btu/hr-ft^2-^{\circ}F$)	TBD			
		b. Sodium					
		c. Overall					
	14	Receiver heat transfer coefficients at design absorbed power					
		a. Tube wall-hot-593 $^{\circ}C$ (1100 $^{\circ}F$)	$W/M^2-^{\circ}C$ ($Btu/hr-ft^2-^{\circ}F$)	16,700 (2940)			Based on OD - h_{Na}
		Tube wall-mean-441 $^{\circ}C$ (825 $^{\circ}F$)		15,200 (2670)			
		Tube wall-cold-288 $^{\circ}C$ (550 $^{\circ}F$)		13,600 (2400)			Based on OD - h_{Na}
		b. Sodium-North quadrant-hot		45,200 (7950)			Based on OD - $h_{eff. cond.}$
		Sodium-North quadrant-mean		48,600 (8550)			
		Sodium-North quadrant-cold		52,300 (9200)			
		Sodium-East/West quadrant- hot		36,800 (6480)			
		Sodium East/West quadrant-mean		39,900 (7020)			
		Sodium East/West quadrant- cold		43,230 (7610)			
		Sodium South quadrant-hot		30,300 (5340)			
		Sodium-South quadrant-mean		33,300 (5850)			
		Sodium-South quadrant-cold	$W/M^2-^{\circ}C$ ($Btu/hr-ft^2-^{\circ}F$)	36,300 (6380)			Based on OD - $h_{eff. cond.}$

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

10 of 17

WBS NO.

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	14	Receiver heat transfer coefficients at design absorbed power - Continued					
		c. Overall-North quadrant-hot	$W/M^2 - ^\circ C$ ($Btu/hr-ft^2 - ^\circ F$)	12,200 (2150)			
		Overall-North quadrant-mean		11,530 (2030)			
		Overall North quadrant-cold		10,800 (1900)			
		Overall East/West quadrant-hot		11,480 (2020)			
		Overall East/West quadrant-mean		10,970 (1930)			
		Overall East/West quadrant-cold		10,340 (1820)			
		Overall South quadrant-hot		10,800 (1900)			
		Overall South quadrant-mean		10,400 (1830)			
		Overall South quadrant-cold	$W/M^2 - ^\circ C$ ($Btu/hr-ft^2 - ^\circ F$)	9,800 (1740)			

ESG-79-30, Vol III

E-32

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

11 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	14		Receiver heat transfer coefficients at minimum operating condition absorbed power		TBD			
		a.	Tube wall	$\text{W/M}^2\text{-}^\circ\text{C}$ ($\text{Btu/hr-ft}^2\text{-}^\circ\text{F}$)				
		b.	Sodium					
		c.	Overall					
	15		Receiver ramp rate					
			% of maximum absorbed power per minute	%				
	16		Steam generator heat exchanger (HX) discharge rate					
		Total	Maximum	MWt	160.0			
			Design	MWt	260.0			
			Minimum	MWt	145.2			
		Evaporator	Maximum	MWt	146.0			
			Design	MWt	146.0			
			Minimum	MWt	81.5			
		Superheater	Maximum	MWt	74.0			
			Design	MWt	74.0			
			Minimum	MWt	41.4			
		Reheater	Maximum	MWt	40.0			
			Design	MWt	40.0			
			Minimum	MWt	22.3			

ESG-79-30, Vol III

E-33

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

12 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	17		Sodium operating temperatures for each HX unit					
			Evaporator - Inlet	°C (°F)	459 (859)			
			Outlet	°C (°F)	288 (550)			
			Superheater - Inlet	°C (°F)	593 (1100)			
			Outlet	°C (°F)	459 (859)			
			Reheater - Inlet	°C (°F)	593 (1100)			
			Outlet	°C (°F)	459 (859)			
	18		Water/steam operating temperatures for each HX unit					
			Evaporator - Inlet	°C (°F)	251 (483.5)			
			Outlet	°C (°F)	336 (636)			
			Superheater - Inlet	°C (°F)	336 (636)			
			Outlet	°C (°F)	538 (1000)			
			Reheater - Inlet	°C (°F)	308 (586)			
			Outlet	°C (°F)	538 (1000)			

ESG-79-30, Vol III

E-34

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

13 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	19		Sodium operating pressure for each HX unit					
			Evaporator - Inlet	MPa (psia)	0.76 (110)			
			Outlet	MPa (psia)	0.55 (80)			
			Superheater - Inlet	MPa (psia)	0.97 (140)			
			Outlet	MPa (psia)	0.76 (110)			
			Reheater - Inlet	MPa (psia)	0.97 (140)			
			Outlet	MPa (psia)	0.76 (110)			
	20		Water/steam operating pressure for each HX unit					
			Evaporator - Inlet	MPa (psia)	13.8 (2000)			
			Outlet	MPa (psia)	13.4 (1950)			
			Superheater - Inlet	MPa (psia)	13.4 (1950)			
			Outlet	MPa (psia)	12.8 (1850)			
			Reheater - Inlet	MPa (psia)	2.2 (322)			
			Outlet	MPa (psia)	2.1 (300)			

ESG-79-30, Vol III

E-35

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

14 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	21	Sodium flow rates					
		Total - Maximum	kg/hr (lb/hr)	2.4×10^6 (5.32×10^6)			
		Design		2.4×10^6 (5.32×10^6)			
		Minimum		1.3×10^6 (3.0×10^6)			
		Evaporator - Maximum		2.41×10^6 (5.32×10^6)			
		Design		2.41×10^6 (5.32×10^6)			
		Minimum		1.3×10^6 (3.0×10^6)			
		Superheater - Maximum		1.58×10^6 (3.48×10^6)			
		Design		1.58×10^6 (3.48×10^6)			
		Minimum		0.88×10^6 (1.95×10^6)			
		Reheater - Maximum		0.83×10^6 (1.84×10^6)			
		Design		0.83×10^6 (1.84×10^6)			
		Minimum	kg/hr (lb/hr)	0.46×10^5 (1.02×10^5)			

ESG-79-30, VOL III

E-36

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

15 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	22	Water/steam flow rates					
		Total - Maximum	kg/hr (lb/hr)	3.50×10^5 (7.73×10^5)			
		Design		3.34×10^5 (7.36×10^5)			
		Minimum		6.68×10^4 (1.47×10^5)			
		Evaporator - Maximum		3.50×10^5 (7.73×10^5)			
		Design		3.34×10^5 (7.36×10^5)			
		Minimum		6.68×10^4 (1.47×10^5)			
		Superheater - Maximum		3.50×10^5 (7.73×10^5)			
		Design		3.34×10^5 (7.36×10^5)			
		Minimum		6.68×10^4 (1.47×10^5)			
		Reheater - Maximum		2.89×10^5 (6.37×10^5)			
		Design		2.75×10^5 (6.06×10^5)			
		Minimum	kg/hr (lb/hr)	5.5×10^4 (1.21×10^5)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

16 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	23	Steam generator heat transfer coefficients at design power					
		Evaporator X-1					
		Tube side - preheating	$W/M^2-^{\circ}C$ (Btu/hr-ft ² - ⁰ F)	7,782 (1,370)			Uncorrected for dia. ratio
		Tube side - nucleate boiling		70,700 (12,450)			
		Tube side - film boiling		7,380 (1,300)			
		Tube side fouling		18,900 (3,333)			(0.0003 hr-ft ² - ⁰ F/Btu)
		Tube wall		17,488 (3,079)			
		Shell side fouling		Zero			
		Shell side		33,740 (5,940)			
		Overall - preheating		3,060 (540)			
		Overall - nucleate boiling		5,850 (1,030)			
		Overall - film boiling	$W/M^2-^{\circ}C$ (Btu/hr-ft ² - ⁰ F)	3,440 (605)			

ESG-79-30, Vol III

E-38

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

17 of 17

WBS NO. Drawing N001000301

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	23	Steam generator heat transfer coefficients at design power - Continued					
		Superheater X-2 heat transfer coefficients at design power					
		Tube side	$W/M^2-^{\circ}C$ ($Btu/hr-ft^2-^{\circ}F$)	8,640 (1,520)			Uncorrected for dia. ratio (0.0002 hr-ft ² - [°] F/Btu)
		Tube side fouling		28,400 (5,000)			
		Tube wall		5,450 (960)			
		Shell side fouling		Zero			
		Shell side		42,940 (7,560)			
		Overall		2,270 (400)			
		Reheater X-3 heat transfer coefficients at design power					
		Tube side		2,160 (380)			Uncorrected for dia. ratio (0.0002 hr-ft ² - [°] F/Btu)
		Tube side fouling		28,400 (5,000)			
		Tube wall		7,670 (1,350)			
		Shell side fouling		Zero			
		Shell side		25,000 (4,400)			
		Overall	$W/M^2-^{\circ}C$ ($Btu/hr-ft^2-^{\circ}F$)	1,310 (230)			

ESG-79-30, Vol III

E-39

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Storage Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE

1 of 4

WBS NO. Dwg. N001000301

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Storage Subsystem					
	A	Design Characteristics					
	1	Storage Media - Sodium					
		Specific heat - t = 288°C (550°F)	W/m ² -°C	1.77			
		Specific heat - t = 288°C (500°F)	Btu/hr-ft ² -°F	0.312			
		Specific heat - t = 441°C (825°F)	W/m ² -°C	1.73			
		Specific heat - t = 441°C (825°F)	Btu/hr-ft ² -°F	0.304			
		Specific heat - t = 593°C (1100°F)	W/m ² -°C	1.70			
		Specific heat - t = 593°C (1100°F)	Btu/hr-ft ² -°F	0.300			
		Viscosity - t = 288°C (550°F)	MP/S	355			
		Viscosity - t = 288°C (550°F)	(lb/ft-hr)	0.86			
		Viscosity - t = 441°C (825°F)	MP/S	260			
		Viscosity - t = 441°C (825°F)	(lb/ft-hr)	0.63			
		Viscosity - t = 593°C (1100°F)	MP/S	207			
		Viscosity - t = 593°C (1100°F)	(lb/ft-hr)	0.50			
		Density - t = 288°C (550°F)	kg/m ³	883			
		Density - t = 288°C (550°F)	(lb/ft ³)	55.1			
		Density - t = 441°C (825°F)	kg/m ³	846			
		Density - t = 441°C (825°F)	(lb/ft ³)	52.8			
		Density - t = 593°C (1100°F)	kg/m ³	811			
		Density - t = 593°C (1100°F)	(lb/ft ³)	50.6			
	2	Sodium Storage Mass					
		Low Temperature buffer tanks	kg (ton)	64,400 (71)			Tanks 2/3 full
		High Temperature buffer tanks	kg (ton)	31,800 (35)			Tanks 1/3 full

FORM 706-A REV. 6-78

bbd:615

ESG-79-30, Vol III

E-40

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Storage Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE 2 of 4

WBS NO. Dwg. N001000301

DATE

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	3		Tank Characteristics <u>Low-Temperature Buffer Tanks</u>		6			Vertical cylindrical
			Number					
			Type					
			Diameter	m (ft)	2.4 (8)			
			Height	m (ft)	6.4 (21)			
			Wall Thickness	cm (in.)	1.91 (0.75)			
			Tank Volume - total 6 tanks	m ³ (gal)	180 (48,000)			
			Tank Volume - each tank	m ³ (gal)	30 (8,000)			
			Tank Material		CS			
			Tank Design Temperature	°C (°F)	316 (600)			
			Tank Mass - total 6 tanks	kg (ton)	54,500 (60)			
			Tank Mass - each tank	kg (ton)	9,000 (10)			
			Tank Surface Area - total 6 tanks	m ² (ft ²)	351 (3,780)			
			Tank Surface Area - each tank	m ² (ft ²)	59 (630)			
			Tank Insulation Material - External					Calcium silicate with aluminum weather protection
			Insulation Thickness	cm (in.)	10.2 (4)			
			Insulation Mass - total 6 tanks	kg (ton)	7,300 (8)			
			Insulation Mass - each tank	kg (ton)	1,200 (1.3)			
			Electric Preheat - Temperature Maint	KWe	5			
			Ullage Maintenance Unit					
			Ullage Pressure	MPa	0.31			
			Pressurization Media	(Psia)	(30) Argon			

ESG-79-30, Vol III

E-41

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Storage Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

WBS NO. Dwg. N00100C3C1

DATE _____

3 of 4

NEW REV	NO.	A	ITEM	DESIGN POINT		TENTATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	3		Tank Characteristics					
			<u>High-Temperature Buffer Tanks</u>					
			Number		6			
			Type					Vertical cylindrical
			Diameter	m (ft)	2.4 (8)			
			Height	m (ft)	6.4 (21)			
			Wall Thickness	cm (in.)	0.64 (0.25)			
			Tank Volume - total 6 tanks	m ³ (gal)	180 (48,000)			
			Tank Volume - each tank	m ³ (gal)	30 (8,000)			
			Tank Material		304 SS			
			Tank Design Temperature	°C (°F)	607 (1,125)			
			Tank Mass - total 6 tanks	kg (ton)	18,000 (20)			
			Tank Mass - each tank	kg (ton)	3,000 (3.3)			
			Tank Surface Area - total 6 tanks	m ² (ft ²)	351 (3,780)			
			Tank Surface Area - each tank	m ² (ft ²)	59 (630)			
			Tank Insulation Material - External					Calcium silicate with aluminum weather protection
			Insulation Thickness	cm (in.)	20.3 (8)			
			Insulation Mass - total 6 tanks	Kg (ton)	14,500 (16)			
			Insulation Mass - each tank	Kg (ton)	2,400(2.7)			
			Electric Preheat - Temperature Maintenance	KWe	25			
			Ullage Maintenance Unit		Argon			
			Ullage Pressure	MPa Psia	0.0069 (1)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Storage Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE 4 of 4

WBS NO. Dwg. N001000301

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	B	Operating Characteristics					
	1.	Extractable Capacity	MWht (Btu)	N/A			
	5.	Sodium Operating Temperatures					
		Hot Buffer Tanks	°C (°F)	1,100 (593)			
		Cold Buffer Tanks	°C (°F)	550 (288)			
	6.	Storage Tank Operating Pressure					
		Cold Buffer Tanks	MPg (psig)	0.24 (35)			
		Hot Buffer Tanks	MPg (psig)	0.0069 (1)			

ESG-79-30, Vol III

E-43

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0,8

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000301

PAGE 1 of 17

DATE June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	A	Design Characteristics					
	1	Turbine Generator Type and Nameplate Rating					
	1.1	Turbine					
		Type					
		Nameplate Rating	kWe	112,000			
		Last Stage Blade Length	cm (in.)	58.4 (23)			
		Shaft Speed	rpm	3600			
	1.2	Generator					
		Type					
		Rating	kVa	135,000			
		Power Factor		0.9			
		Voltage	volts	13,800			
		Speed	rpm	3600			
		Frequency	Hz	60			
							Tandem-Compound, Double-Flow, Reheat, Extraction, Condensing Turbine
							Synchronous, Hydrogen-Cooled, Static Excitation

ESG-79-30, Vol III

E-44

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N0010003.01

PAGE 2 of 17

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	2.0		Turbine Inlet Conditions					
			Inlet Temperature	°C (°F)	538°C (1000°F)			
			Inlet Pressure	MPa (psia)	12.5 (1815)			
			Inlet Flow Rates (at rated temperature and pressure)					
			Maximum	kg/hr (lb/hr)	350,500 (772,700)			
			Design	kg/hr (lb/hr)	333,800 (735,900)			
			Minimum	kg/hr (lb/hr)	33,400 (73,600)			
	3.0		Turbine Reheat Conditions					
			Reheat Temperature	°C (°F)	538 (1000)			
			Reheat Pressure	MPa (psia)	2.05 (298)			
			Reheat Flow Rate (at rated inlet temperature and pressure)					
			Maximum	kg/hr (lb/hr)	288,800 (636,800)			
			Design		275,100 (606,500)			

ESG-79-30, Vol III

E-45

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000301

PAGE , 3 of 17

DATE June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		FEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Turbine Reheat Conditions (Cont'd.)					
		Minimum	Kg/hr (lb/hr)	27,500 (60,650)			
	4.0	Number and Location of Feedwater Heating Extractions					
		Number of Extractions		6			
		<u>Extraction</u> <u>Location</u>					<u>Heater Description</u>
		1st extraction H.P. turbine					High-Pressure Heater No. 5 (heater above reheat point)
		2nd extraction H.P. turbine exhaust					High-Pressure Heater No. 5 (cold reheat)
		3rd extraction I.P. turbine					High-Pressure Heater No. 4
		4th extraction I.P. turbine exhaust					Deaerator No. 3
		5th extraction L.P. turbine					Low-Pressure Heater No. 2
		6th extraction L.P. turbine					Low-Pressure Heater No. 1
	4.1	Feedwater Heater Descriptions					
	A	Low-Pressure Heaters					
		Quantity		2			

ESG-79-30, Vol III

E-46

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM CO-8

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N0010003 01

PAGE

4 of 17

DATE

June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Feedwater Heaters (Cont'd.)					
		Type					Horizontal, Shell and Tube with Drain Cooler
		Tube Material		Stainless Steel			ASME B and PV Code Section VIII
		Shell Material		Carbon Steel			
		Tube-Side Design Pressure	MPa (psig)	2.1 (300)			
	B	High-Pressure Heaters					
		Quantity		3			
		Type					Horizontal, Shell and Tube with Desuper Heater and Drain Cooler Sections
		Tube Material		Carbon Steel			ASME B and PV Code Section VIII
		Shell Material		Carbon Steel			
		Tube-Side Design Pressure	MPa (psig)	20.7 (3000)			
	C	Deaerator					
		Quantity		1			
		Type					Horizontal, Spray-Tray Type, with Internal Vent Condenser, and Separate Storage Section

ESG-79-30, Vol III
E-47

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000301

PAGE 5 of 17

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Feedwater Heaters (Cont'd.)					
			Rated Capacity	kg/s (lb/hr)	100 (800,000)			ASME B and PV Code Section VIII
			Guar. O ₂ in Effluent (Maximum)	cc/l	0.005			
			Design Pressure	kPa (psig)	345 (50)			
			Shell Material	---	Carbon Steel			
			Tray Material	---	Stainless Steel			
			Vent Condenser Material	---	Stainless Steel			
			Storage Capacity	m ³ (gal)	60 (16,000)			
			Weight, incl. Storage Sect. (Est.)	kg (lb)	20,400 (45,000)			
	5.0		Condenser Type and Configuration					
			Type					Surface Condenser, Two-Pass, Divided Water Boxes, per H.E.I. Standards for Steam Surface Condensers
			Surface	m ² (ft ²)	8175 (88,000)			
			Tube Material					90-10 Cu-Ni; ASTM B111, Alloy 706
			Tube Diameter	cm (in.)	2.54 (1.0)			

ESG-79-30, Vol III

E-48

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Electrical Power Generation
Subsystem. 100 MWe, SM 0.0

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000301

PAGE 6 of 17

DATE June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Condensers (Cont'd.)					
		Tube Length (eff.)	m (ft)	8.54 (28.0)			
		Duty	MWt(Btu/h)	154 (525 x 10 ⁶)			
		Cooling Water Inlet Temperature	°C (°F)	28.9 (84.0)			
		Cooling Water Outlet Temperature	°C (°F)	35.3 (95.6)			
		Cooling Water Flow	m ³ /s(gpm)	5.7 (90,500)			
		Type of Air Removal					Mechanical Vacuum Pump
		Condensing Pressure	MPa(in. Hg)	.0067 (2.0)			
		Weight (Dry)	kg (lb)	252 x 10 ³ (560 x 10 ³)			
	5.1	Cooling Tower					
		Quantity		1			
		Type					Mechanical Draft, Wet, Cross Flow
		Number of Cells	---	5			(Ref. Marley 6616-4-05)
		Fan Motor Size	kW (hp)	5-150 (200)			
		Design Wet Bulb Temperature	°C (°F)	23.0 (73.4)			
		Cold Water Temperature	°C (°F)	28.9 (84.0)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM C.B

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N0010003 01

PAGE

7 of 17

DATE

June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Cooling Tower (Cont'd.)					
		Hot Water Temperature	$^{\circ}\text{C}$ ($^{\circ}\text{F}$)	35.3 (95.6)			
		Circulating Water Flow	m^3/s (gpm)	5.9 (93,100)			
		Heat Rejected	MWt(Btu/h)	158 (540×10^6)			
		Fill Material	---	---			Treated Fir or Redwood
		Overall Dimensions:					
		Width	m (ft)	22 (72)			
		Length	m (ft)	61 (201)			
		Height (Top of Fan Cylinder)	m (ft)	18 (59)			
		Est. Weight (Dry), excl. Basin	kg (lb)	472,000 (1.04×10^6)			
	6.0	Feedwater Pump Stages					
		Number of Stages		1			Single Feedwater Pumping Stage (following deaerator)
		Feedwater Pump					
		Quantity		2			Each Pump Full Capacity
		Type					Horizontal, Centrifugal; Double Case, Barrel Type, 9 Stages, with Variable Speed Hydraulic Coupling & Electric Motor Drive

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 9.8

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N0010003'01

PAGE 8 of 17

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Feedwater Pump Stages (Cont'd.)					
			Capacity, Each	m ³ /s (gpm)	0.11 (1750)			
			Head	m (ft)	1950 (5410)			
			Speed (Pump)	rpm	3440			
			Efficiency	%	80.5			
			Motor Rating	kW (h.p.)	2250 (3000)			4160 volt
			Motor Speed (Synch.)	rpm	3600			
			Outer Case Material	---	Carbon Steel			
			Inner Case Material	---	Alloy Steel			
			Impeller Material	---	Alloy Steel			
			Weights (Est.), Each					
			Pump and Base	kg (lb)	29,500 (65,000)			
			Coupling	kg (lb)	2700 (6000)			
			Motor	kg (lb)	11,800 (26,000)			
	6.1		Circulating Water Pumps					
			Quantity		2			Two Half-Capacity

ESG-79-30, Vol III

E-51

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000301

PAGE

9 of 17

DATE

June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Circulating Water Pumps (Cont'd.)					
			Type					Horizontal, Centrifugal, Single Stage, Double Suction, Electric Motor Drive
			Capacity, Each	m ³ /s (gpm)	3.0 (47,000)			
			Head	m (ft)	23.2 (76.0)			
			Speed	rpm	514			
			Efficiency	%	80			
			Motor Rating	kW (hp)	930 (1250)			
			Casing Material	---	Cast Iron			
			Impeller Material	---	Bronze			
			Weight (Pump and Motor), Each	kg (lb)	18,100 (14,000)			
	5.2		Condensate Hotwell Pump					
			Quantity		2			Two - Full Capacity
			Type					Vertical Turbine Can Type, Centrifugal, with Electric Motor Drive
			Capacity, Each	m ³ /s (gpm)	0.08m ³ /s (1300)			

ESG-79-30, Vol III

E-52

Rockwell International

Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0-8

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N0010003 01

PAGE 10 of 17

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Condensate Hotwell Pump (Cont'd.)					
			Head	m (ft)	136 (446)			
			Speed	rpm	1750			
			Efficiency	%	84			
			Motor	kW (hp)	186 (250)			460 volt
			Casing Material	---	Cast Iron			
			Impeller Material	---	Bronze			
			Can Material	---	Carbon Steel			
			Weight (Pump and Motor), Each	kg (lb)	4100 (9000)			
	7.0		Auxiliary Steam Supply		TBD			
	8.0		Sealing Steam Requirements		TBD			
	9.0		Turbine Startup and Shutdown Characteristics					See Table

ESG-79-30, Vol III

E-53

Atomic International Division
Rockwell International

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO: N001000301

PAGE 11 of 17

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEM- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	10.0		Nonsolar Energy Source Design Interface Sodium Heater/Receiver Configuration					Parallel Flow, Flow Portional to Energy Contribution, Constant Fluid ΔT
			Number of Heaters		1			
			Heated Fluid					Sodium
			Flow Distribution Mechanism					Manual Throttling of Receiver and Heater Control Valves
			Heat Duty	MWt	265			
			Full Load Sodium Flow	Kg/hr	2.4×10^6			
			20% Load Sodium Flow	(lb/hr)	(5.4×10^6) 0.5×10^6 (1.08×10^6)			
	10.1		Heater Height/Width/Depth	m (ft)	48.2/9.1/11.0 (158/30/36)			
	10.2		Heater Working Surface Area	m ² (ft ²)				
			Radiant Section		847 (9120)			Effective at Full Load, 7460 ft ² at 20% Load
			High-Temperature Convection Section		2480 (26,700)			
			Low-Temperature Convection Section		5648 (60,800)			
	10.3		Tube OD/ID/Wall	mm (in.)				
			Radiant Section		31.8/24/2/3.8 (1.25/0.954/ 0.148)			
			High-Temperature Convection Section		63.5/TBD/TBD 2.50/TBD/TBD			
			Low-Temperature Convection Section		63.5/TBD/TBD (2.50/TBD/TBD)			

ESG-79-30, Vol III

E-54

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO.

N001000301

PAGE

12 of 17

DATE

June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	10.4		Tube Length	m (ft)	TBD			
			Radiant Section (Nominal)					
			High-Temperature Convection Section					
			Low-Temperature Convection Section					
	10.5		Number of Tubes	---				
			Radiant Section		900			
			High-Temperature Convection Section		104			
			Low-Temperature Convection Section		176			
	10.6		Heater Materials and Mass (Core Only)					
			Radiant Section					
			Material					2-1/4 Cr - 1 Mo
			Mass	kg (lb)	TBD			
			High-Temperature Convection Section					
			Material					304 Stainless Steel
			Mass	kg (lb)	TBD			
			Low-Temperature Convection Section					
			Material					Carbon Steel
			Mass	kg (lb)	TBD			

ESG-79-30, Vol III

E-55

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000301

PAGE 13 of 17

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	10.7		Heat Pipe Material					Not Applicable
	10.8		Header Material and Mass		TBD			
			Radiant Section Input					
			Material					
			Mass	kg (lb)				
			High-Temperature Convection Input		TBD			
			Material					
			Mass	kg (lb)				
			High-Temperature Convection Output		TBD			
			Material					
			Mass	kg (lb)				
			Low-Temperature Convection Input		TBD			
			Material					
			Mass	kg (lb)				
	10.9		Insulation		TBD			
			Material					
			Mass	kg (lb)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N0010003

PAGE 14 of 17

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	10.		Structure		TBD			
	10		Material					
			Mass	kg (lb)				
	10.		Support		TBD			
	11		Material					
			Mass	kg (lb)				
	10.		Piping		TBD			
	12		Material					
			Mass	kg (lb)				
	10.		Valve (s)		TBD			
	13		Material		CS			
			Number		1			
			Location					Heater Inlet Piping
			Mass					
			Size (Nominal)	cm (in.)	50.8 (20)			
			Type					Drag Valve
	10.		Pump					Not Applicable
	14							

ESG-79-30, Vol III

E-57

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 Mwe, SM 0.8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000301

PAGE 15 of 17

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	10. 15		Total Heater Mass (Misc. Items)	kg (lb)	TBD			
	10. 16		Furnace Volume	m ³ (ft ³)				
			Radiant Section		1716 (60,555)			
			High-Temperature Convection Section		548 (19,320)			
			Low-Temperature Convection Section		860 (30,360)			
	10. 17		Heater Weather Protection Surface Area	m ² (ft ²)	1595 (17,200)			
	10. 18		Fuel Handling Equipment					
			Type					Direct Feed from Pulverizers, One Pulverizer/Burner Row B&W Type EL 76 or Equivalent Ball and Race Pulverizer
			Number		3			
	10. 19		Structural Design					
			Useful Life	years	30			
			Structural Code					UCB Zone 3
			Pressure Vessel Code					ASME Section I (Other Sections as Applicable)
			Piping Code					ANSI B31.1

ESG-79-30, Vol III

E-58

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N00100301

PAGE 16 of 17

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Structural Design (Cont'd.)					
			Sodium Corrosion Allowance	cm (in.)	0.03 (0.01)			
	10. 20		Combustion Equipment					
			Burners					
			Type					Dual Register
			Number		9			
			Burner Arrangement					Three Horizontal Rows Three Burners/Row, Opposed Firing
	10. 21		Environmental Conditions					
			Wind Velocity	m/sec (mph)	3.5 (8 ave., 55 max)			
			Altitude	m (ft)	730 (2400)			
			Ambient Temperature	°C (°F)				
			Minimum		-20 (-30)			
			Maximum		50 (120)			
			Rainfall	cm (in.)	101.6 (40 ave.)			
			Seismic	g	0.2 horizontal 0.1 vertical			

ESG-79-30. Vol III

F-59

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000301

PAGE 17 of 17

DATE June 21, 1979

NEW REV	NO.	A ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	10. 22	Interfaces					
		Sodium Inlet Nozzle	cm (in.)	51 (20)			
		Sodium Outlet Nozzle		51 (20)			
		Vents and Drains (Size and Number)		TBD			
	11.0	Non-solar Emission Levels	lb/mm Btu				
		NO _x		0.5			
		SO ₂		0.1			
		Particulates		0.03

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000301

PAGE 1 of 10

DATE June 25, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	B	Operational Characteristics					
	1.0	EPGS Proper					
	1.1	Receiver Operation					
		Gross Turbine Cycle Efficiency	%	43.1			Generator Output
		Net Turbine Cycle Efficiency	%	38.5			Heat Input to Turbine
		Fraction of Turbine Cycle Heat Input Supplied by Solar	%	80.0			Generator Output-All Aux. Loads
		Supplied by Heater	%	20.0			Heat Input to Turbine
		Gross Cycle Heat Rate	kJ/kW-hr (Btu/kW-h)	8356.8 (7922.6)			
		Net Cycle Heat Rate	kJ/kW-h (Btu/kW-h)	9360.1 (8873.8)			
		Turbine Exhaust Pressure	mm (in.)	50.8 (2.0)			In. of Mercury
		Feedwater Temperature	°C (°F)	251 (484)			
		Flow Rate to Turbine	kg/hr (lb/hr)	334,500 (735,900)			
		Auxiliary Loads	kWe	12,000			
		Heliostats and Controllers					
		Receiver Pump					

ESG-79-30, Vol III

E-61

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000301

PAGE

2 of 10

DATE

June 25, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Auxiliary Loads (Cont'd.)					
			Boiler Feed Pump		2100			
			Condensate Pump		150			
			Auxiliary Power Requirements	kWe				
			Cooling Tower Fans		850			
			Circulating Water Pumps		1870			
			Miscellaneous Accessories		1055			
			Coal Feeders		0			
			Coal Pulverizers		0			
			F.D. Fan		0			
			I.D. Fan		2600			
			P.A. Fan		0			
			G.R. Fan		0			
			SO ₂ and Particulate Removal		150			
			Coal Handling		260			
			Ash Handling		100			
	B 1.2		STORAGE OPERATION		N/A			

ESG-79-30, Vol III

E-62

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000301

PAGE 3 of 10

DATE June 25, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	B							
	1.3		Nonsolar Operation					
			Gross Turbine Cycle Efficiency	%	43.1			
			Net Turbine Cycle Efficiency	%	38.5			
			Fraction of Turbine Cycle Heat Input Supplied by Solar	%	0.0			
			Gross Cycle Heat Rate	kJ/kW-hr (Btu/kW-h)	8356.8 (7922.6)			
			Net Cycle Heat Rate	kJ/kW-hr (Btu/kW-h)	9360.1 (8873.8)			
			Turbine Exhaust Pressure	mm (in.)	50.8 (2.0)			In. of Mercury
			Feedwater Temperature	°C (°F)	251 (484)			
			Flow Rate to Turbine	kg/hr (lb/hr)	334,500 735,900			
			Auxiliary Loads	kWe	12,000			
			Heliostats and Controllers		0			
			Receiver Pump		995			

ESG-79-30, Vol III

E-63

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER
Revision 0

PREPARED BY
W. W. Willcox

APPROVED BY

WBS NO. N001000301

PAGE 4 of 10

DATE June 25, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Auxiliary Loads (Cont'd.)					
			Boiler Feed Pump		2100			
			Condensate Pump		150			
			Cooling Tower Fans		850			
			Circulating Water Pumps		1870			
			Miscellaneous Accessories		1055			
			Coal Feeders					
			Coal Pulverizers					
			F.D. Fan					
			I.D. Fan		3200			
			P.A. Fan					
			G.R. Fan					
			SO ₂ and Particulate Removal		150			
			Coal Handling		260			
			Ash Handling		100			

ESG-79-30, Vol III

E-64

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER
Revision 0

PREPARED BY
W. W. Willcox

APPROVED BY

WBS NO. N001000301

PAGE 5 of 10

DATE June 25, 1979

NEW REV	NO.	B ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	2	Nonsolar Energy Fuels					Primary: Pulverized Coal Backup: Oil/Gas
	3	Fuel Characteristics					Primary Fuel Only
		Design Basis Coal-Ultimate Analysis	wt (%)				
		Moisture		14.5			
		Carbon		55.8			
		Hydrogen		4.2			
		Oxygen		11.5			
		Nitrogen		0.9			
		Sulfur		0.6			
		Ash		12.5			
		Chlorine		0.03			
	4	Fuel Heating Value (as fired)	j/kg (Btu/lb)	23.2 x 10 ⁶ (10,000)			
	5	Fuel Burning Rate	kg/hr (lb/hr)	47,273 104,000			
	6	Nonsolar Discharge Rate	MWt				
		Maximum		TBD			Stack Gas and Other Heat Losses
		Design		33.8			

ESG-79-30, Vol III

E-65

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER
Revision 0

PREPARED BY
W. W. Willcox

APPROVED BY

PAGE 6 of 10

WBS NO. N001000301

DATE June 25, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Nonsolar Discharge Rate (Cont'd.)					
			Minimum		TBD			
	7		Heater Gas Operating Temperature (In/Out)	°C (°F)				
			Maximum		TBD			
			Design		1199/149 (2190/300)			High-Temperature Convection/ Section/Air Heater Exit
			Minimum 20% Load		721/149 (1330/300)			
	8		Working Fluid Operating Temperature (In/Out)	°C (°F)				Sodium Sodium
			Maximum		TBD			
			Design		289/593 (550/1100)			
			Minimum		289/593 (550/1100)			
	9		Working Fluid Operating Pressures (In/Out)	MPa (psia)				
			Maximum		TBD			
			Design		0.73/0.25 (106/36)			
			Minimum		TBD

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000301

PAGE

7 of 10

DATE

June 25, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	10		Working Fluid Flow Rates	kg/hr (lb/hr)				Sodium
			Maximum		2.5×10^6 (5.5×10^6)			
			Design		2.4×10^6 (5.4×10^6)			
			Minimum		409,900 (1.08×10^6)			
	11		Nonsolar Heat Losses	%				
			@ Maximum Power		TBD			
			Radiation					
			Dry Gas					
			Hydrogen and Moisture in Fuel					
			Moisture in Air					
			Unburned Combustible					
			Other					
			@ Design Power	%	13			
			Radiation		0.2			
			Dry Gas		5.3			

ESG-79-30, Vol III

E-67

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000301

PAGE 8 of 10

DATE June 25, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Nonsolar Heat Losses (Cont'd.)					
		Hydrogen and Moisture in Fuel		5.4			
		Moisture in Air					
		Unburned Combustible		0.5			
		Other		1.5			
		@ Minimum Power	%	16.6			
		Radiation		1.2			
		Dry Gas		8.0			
		Hydrogen and Moisture in Fuel		5.4			
		Moisture in Air					
		Unburned Combustible		0.5			
		Other		1.5			
	12	Nonsolar Startup and Shutdown Characteristics		TBD			
	13	Continuously Controllable Heat Output Nonsolar Energy Source (Heater)	MWt	53-265			
	14	Miscellaneous Heater Data					
		Total Maximum Heat Input from Fuel	MWt	304.7			
		Total Air	%	115			

ESG-79-30, Vol III

E-68

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0.8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000301

PAGE 9 of 10

DATE June 25, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	8	Miscellaneous Heater Data (Cont'd.)					
		Minimum Secondary Air Temperature	$^{\circ}\text{C}$ ($^{\circ}\text{F}$)	260 (500)			
		Heat Input/Burner	MWt	33.9			
		Radiant Section Heat Absorption	MWr	132.5			
		Radiant Section Flux Density	MWt/m ²	0.14			
		Convection Section Heat Absorption	MWt	0.14			
		Convection Section Flux Density	MWt/m ²	0.017			
		Air Heater Load	MWt	26.4			
		Hot Gas Flow Rate	kg (hr) (lb/hr)	454,540 ₆ (1 x 10 ⁶)			
		Liberation Rate	kJ/hr-m ³ (Btu/hr-ft ³)	670,000 18,000			
		Flue Gas Temperature:	$^{\circ}\text{C}$ ($^{\circ}\text{F}$)				
		Leaving Radiant Section		1199 (2190)			
		Leaving H.T. Convection		788 (1450)			
		Leaving L.T. Convection		371 (700)			
		Leaving Air Heater		149 (300)			

ESG-79-30, Vol III

E-69

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 0-8

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000301

PAGE 10 of 10

DATE June 25, 1979

NEW REV	NO.	B ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Miscellaneous Heater Data (Cont'd.)					
		Air Temperature:					
		Ambient		28 (83)			
		Leaving Air Heater		204 (400)			
		Sodium Temperature:					
		Inlet		288 (550)			
		Leaving L.T. Convection		402 (755)			
		Leaving Radiant Section		533 (1028)			
		Leaving H.T. Convection		593 (1100)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
EPG Subsystem
100 MWe SM 0.8

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

PAGE 1 of 1

WBS NO. Dwg. N001000301

DATE

NEW REV.	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Recirculating Pump P-2 Pump Material Number of Recirculating Pumps Type Head NPSH avail. Operating Temperature Power ($\eta = 70\%$) Capacity		CS 1 m (ft) m (ft) °C (°F) kWe (hp) m ³ /S (gpm)			Centrifugal

ESG-79-30, Vol I II

E-71

ELECTRIC POWER GENERATION SUBSYSTEM

B.-1. PRELIMINARY AUXILIARY POWER REQUIREMENTS 100 MWe NET 0.8 SOLAR MULTIPLE (NO STORAGE)

	Receiver Operation (80% Solar/20% Fossil), kWe	Non-Solar Operation (0% Solar/100% Fossil), kWe
Collector Subsystem		
Heliostats & Controllers	330	0
Receiver Subsystem		
Receiver Pump	1326	995
Elect. Power Gen. Subsystem		
Boiler Feed Pump	2100	2100
Condensate Pump	150	150
Cooling Tower Fans	850	850
Circ. Water Pumps	1870	1870
Miscellaneous A.C.	1055	1055
Non-Solar Subsystem		
Coal Feeders		
Coal Pulverizers		
F.D. Fan		
I.D. Fan	2600	3200
P.A. Fan		
G.R. Fan		
SO ₂ & Particulate Removal	150	150
Coal Handling	260	260
Ash Handling	<u>100</u>	<u>100</u>
TOTAL AUXILIARY POWER	10791	10730

APPENDIX F

1.4 SOLAR MULTIPLE DESIGN DATA SHEETS

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem
Solar Multiple = 1.4

NUMBER

PREPARED BY

APPROVED BY

D. A. Carey (MDAC)

WBS NO. N001000352

PAGE 1 of 3

DATE June 22, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
New	A	Design Characteristics					
	1	Field Geometry and Size	m (f)				
		North-South		1970.5 (6464.9)		X	
		East-West		2012.5 (6602.7)		X	
		Distance from South Boundary to Tower		922.4 (3026.3)		X	
		Distance from East Boundary to Tower		1006.3 (3301.5)		X	
		Exclusion Radius		113 (370)		X	
	2	Field Layout				X	Heliostats are distributed throughout the field in a radial stagger array. Density and spacing are defined on a cell-by-cell basis (see Figures 5.2-22 through 5.2-25).
	3	Field Oversizing for Dirt on Mirrors, Reliability, etc.					
		Dirt	%	3.1		X	Reflectivity degraded by .97
		Reliability	%	2.0		X	Assumes availability of .98
	4	Beam Pointing Accuracy and Error Budget Versus Environmental Effects	mr 1σ			X	Wind of 10 to 20 knots
		Azimuth					
		Maximum Peak to Peak	mr	1.0 ±0.6			
		Mean	mr	0.4 ±0.4			
		% Time above 1.0 mr	%	1.0

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem
Solar Multiple = 1.4

NUMBER

PREPARED BY

APPROVED BY

D A Carey (MDAC)

WBS NO. N001000352

PAGE 2 of 3

DATE June 22, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Elevation					
		Maximum Peak to Peak	mr	0.5 ±0.4			
		Mean	mr	0.4 ±0.4			
		% Time Above	%	1.0			
	5	Heliostat Beam Quality and Error Budget Versus Environmental Effects					Not analyzed. Three percent degradation for reflectivity assumed in performance calculations. Fifty km visability assumed for atmospheric absorption.
	6	Heliostat Geometry and Size					
		Shape		Square			
		Glass Area	m ² (ft ²)	49.05 (528)		X	See Figures 5.2-1, 5.2-2, 5.2-3
	7	Number of Heliostats		13,521		X	
	8	Operating Characteristics					
	1	Power Required/Heliostat					
		Track		1.7 amps @ 208V			
		Starting		8.8 amps @ 208V			
		Emergency Shutdown		N/A			
		Average Daily Energy	w-h	100

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem
Solar Multiple = 1.4

NUMBER

PREPARED BY

APPROVED BY

D. A. Carey (MDAC)

WBS NO. N001000352

PAGE 3 of 3

DATE June 22, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	2	Heliostat Operating Modes Startup Tracking Emergency Slew Hold Stowing (Inverted)			X	X X X X	
	3	Control System Characteristics					Open loop, automatic with manual override (remote and at heliostat) (see Section 5.2.2)

FORM 706-A REV. 6-78

tmf:627

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER
Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Dwg. N001000352

PAGE 1 of 16

DATE June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
F-6 ESG-79-30, Vol III	A	Design Characteristics					
	1	Receiver height	m (ft)	15.3 (50.2)			
		Receiver diameter	m (ft)	13.0 (42.6)			
		Receiver midpoint elevation	m (ft)	154.0 (505.1)			
	2	Area of working surface	m (ft ²)	624.9 (6,722.5)			
	3	Absorber tube OD	cm (in.)	1.91 (0.75)			
		Absorber tube ID	cm (in.)	1.65 (0.65)			
		Absorber tube wall thickness	cm (in.)	0.127 (0.05)			
	4	Absorber tube length	m (ft)	19.1 (62.75)			
	5	Number of panels		24			
		Number of tubes per panel		89			
	6	Panel material (dry)		304 SS			
		Total mass of panels	kg (ton)	32,727 (36)			
		Mass per panel	kg (ton)	1,364 (1.5)			Excluding headers
	7	Heat pipe material		NA			(Not applicable)
	8	Header material		CS and SS			CS - 288°C (550°F), SS - 593°C (1100°F)
		Total mass of headers	kg (ton)	10,000 (11.0)			
		Mass per header	kg (ton)	416 (0.5)			
	9	Insulation material					Closed pore Fiberglass, 10 lb/ft ³
		Total mass of insulation	kg (ton)	19,733 (21.7)			Calcium silicate, 13 lb/ft ³
		a. Panels		15,278 (16.8)			
		b. Headers		4,476 (4.9)			

FORM 706-A REV. 6-78

714-G.61

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1,4

NUMBER

Revision 0

PAGE 2 of 16

DATE June 21, 1979

PREPARED BY

APPROVED BY

W. W. Willcox

WBS NO. Dwg. N001000352

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
F-7 ESG-79-30, Vol III	10	Structure material Total mass of structure	kg (ton)	91,000 (100)			Excluding riser, downcomer and headers
	11	Support material Total mass of receiver support	kg (ton)	22,727 (25)			
	12	Piping material Total mass of receiver tubing	kg (ton)	22,300 (24.5)			
	13	Receiver valve material Number		CS 24			Receiver proper only 24-20 cm (8 in.) control butterfly valves
		Total mass	kg (1b)	16,400 (18.0)			
	14	Pump material Number of receiver pumps Mass (dry weight pump)	kg (ton)	--			No pumps in receiver proper
	15	Total mass of other miscellaneous items in receiver proper					
		a. Expansion tank	kg (ton)	6,693 (7.3)			Included in 11.
		b. Crane	kg (ton)	8,000 (8.8)			
		c. Roof	kg (ton)	2,800 (3.1)			
		d. Stack	kg (ton)	TBD			
		e. Stack support	kg (ton)	--

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY
W. W. Willcox

APPROVED BY

WBS NO. Dwg. N001000352

PAGE 3 of 16

DATE June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
F-8 ESG-79-30, Vol III	16	Total dry mass on top of tower	kg (ton)	231,700 (255.4)			Sum of Items 6-15
	17	Receiver Subsystem Sodium Inventory	kg (ton)	281,652 (310)			
		a. Receiver Only		45,500 (50)			
	18	Receiver operational seismic load	kg (ton)				Excluding riser/downcomer
		Vertical at tower top	g				See Appendix D
		Horizontal at tower top	g				
	19	Receiver survival seismic load	kg (ton)				See Appendix D
		Vertical at tower top	g				
		Horizontal at tower top	g				
	20	ASME design code for receiver plus additional requirements	Section	VIII			Analysis for Cyclic Events
	21	Receiver surface coating		Pyromark			
		Composition		--			
		Absortivity		0.95			
		Emissivity		0.90

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO. Dwg. N001000352

PAGE 4 of 16

DATE June 21 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	22	Receiver pressure drop correlations a. Pressure drop: $\Delta p = \left(f \frac{L}{D} + K \right) \frac{\rho v^2}{2g}$ b. Reynolds number: $Re = \frac{Dv\rho}{\mu e}$					Δp = differential pressure f = friction factor L = length of receiver pipe in feet D = internal diameter of receiver pipe in feet v = mean velocity of flow, in feet per second g = acceleration of gravity = 32.2 ft/sec ² Re = Reynolds number ρ = weight density of fluid, pounds per ft ³ μe = absolute viscosity in pound mass per foot second K = resistance coefficient

ESG-79-30, Vol III

F-9

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO: Dwg. N0010003 52

PAGE 5 of 16

DATE June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
F-10	23	Receiver heat transfer correlations (for power into receiver working fluid) a. For conduction through tube wall: $q = \frac{2\pi K L \Delta T}{\ln \frac{d_o}{d_i}}$ b. Sodium heat transfer coefficient: $Nu = 7 + \frac{1}{40} (Pr Re)^{0.8}$ $h_{Na} = \frac{Nu K}{d_i}$					<p>q = heat transferred</p> <p>K = thermal conductivity of tube wall (Btu/hr-ft²-°F)</p> <p>d_o = outside diameter of tube wall - inches</p> <p>d_i = inside diameter of tube wall - inches</p> <p>Nu = Nusselt number</p> <p>Pr = Prandtl number</p> <p>Re = Reynolds number</p> <p>Combined conduction through tube wall and sodium heat transfer coefficient</p> <p>L = wall thickness</p> <p>ΔT = differential temperature across wall</p>

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PAGE 6 of 16

DATE June 21, 1979

PREPARED BY

J. Auleta

APPROVED BY

WBS NO. Dwg. N0010003-52

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-11 ESG-79-30, Vol III	24	A	Receiver heat transfer correlation for receiver losses					Nu = Nusselt number
			a. Air natural convection heat transfer coefficient (vertical cylinder):					Gr = Grashof number
								Pr = Prandtl number, air
								K = thermal conductivity, air (Btu/hr-ft ² -°F)
								g = gravitational constant
			$Nu = 0.13 (GrPr)^{1/3}$					$\beta = \frac{1}{T} (^{\circ}R^{-1}) \text{ for air}$
			$Nu = \frac{hL}{K}$					$\rho = \text{density}$
			$Gr = \left(\frac{\rho^2 g \beta}{\mu^2} L^3 \Delta T \right)$					$\mu = \text{viscosity}$
			$Pr = \frac{\mu C_p}{K}$					T = temperature

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER
Revision 0

PREPARED BY

APPROVED BY

J. Auleta

WBS NO. Dwg. N0010003.52

PAGE 7 of 16

DATE June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEM- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	24	<p>b. Forced convection:</p> <p>Extrapolated Achenbach data</p> <p>c. Assumed combined convection heat transfer coefficient:</p> $h_{eff.} = \sqrt{h_{forced}^2 + h_{nat.}^2}$ <p>d. Thermal radiation:</p> $q = \mathcal{F} \epsilon \sigma A (T_1^4 - T_2^4)$					<p>h = heat transfer coefficient (Btu/hr-ft²-°F)</p> <p>q = heat flow rate (Btu/hr-ft²-°F)</p> <p>$\mathcal{F}$ = radiation factor</p> <p>ϵ = surface thermal emissivity</p> <p>σ = Stefan-Boltzmann constant</p> <p>A = radiating surface area</p> <p>T_1 = effective mean radiating surface temperature (°R)</p> <p>T_2 = radiative sink temperature (°R)</p>

FORM 706-A REV. 6-78

714-G.61

F-12
ESG-79-30, Vol III

Atomic International Division
Rockwell International

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE 8 of 16

DATE June 21, 1979

NEW REV.	NO.	A.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-13 ESG-79-30, Vol III	25		Tower construction					Slip formed concrete
			Height to top of tower	m (ft)	139.4 (457)			
			Diameter - base	m (ft)	15.2 (50)			
			Diameter - top	m (ft)	10.4 (34)			
			Wall thickness - base	m (in.)	0.28 (11)			
			Wall thickness - top	m (in.)	0.23 (9)			
			OD- Mat	m (ft)	37.5 (123)			ANSI B31.1
			Thickness - Mat	m (ft)	3.8 (12.5)			
	26		Riser material		CS			
			Outside diameter	cm (in.)	61 (24)			
			Inside diameter	cm (in.)	58.2 (22.9)			
			Wall thickness	cm (in.)	1.44 (0.562)			
			Downcomer material		SS			
			Outside diameter	cm (in.)	32.4 (12.75)			
			Inside diameter	cm (in.)	30.7 (12.09)			
			Wall thickness	cm (in.)	0.8 (0.33)			
			Riser temperature	°C (°F)	371 (700)			
			Riser pressure	MPa (psia)	2.76 (400)			
			Riser maximum flow	kg/S (lb/s)	1020 (2250)			
			Riser maximum velocity	M/S (ft/s)	4.4 (14.3)			
			Downcomer temperature	°C (°F)	621 (1150)			
			Downcomer pressure	MPa (psia)	2.76 (400)			
			Downcomer maximum flow	kg/S (lb/S)	1020 (2250)			
			Downcomer maximum velocity	M/S (ft/S)	17.1 (56.0)			
	27		Riser total length	m (ft)	232 (760)			Piping material Piping material
			Downcomer total length	m (ft)	232 (760)			
	28		Mass of riser	kg (ton)	49,600 (54.6)			
			Mass of downcomer	kg (ton)	15,400 (17.0)			

FORM 706-A REV 2-74

714-G.61

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER
Revision 0

PREPARED BY

W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE
9 of 16

DATE
June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TENTATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
ESG-79-30, Vol III	29	Riser/downcomer insulation material Insulation thickness - riser Insulation thickness - downcomer	cm (in.) cm (in.)	7.6 (3.0) 12.7 (5.0)			Calcium silicate 100, 101* 105, 104
	30	Mass of riser insulation Mass of downcomer insulation	kg (ton) kg (ton)	7,100 (7.8) 6,200 (6.9)			
	31	Mass of miscellaneous items in tower Elevator Stack Stack support		TBD 74,000 (81.4)			
							*Refers to pipe number in referenced P&I diagram

TITLE
Solar Central Receiver Hybrid Receiver Subsystem 100 MWe SM 1.4

NUMBER
Revision 0

PREPARED BY
W. W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE 10 of 16

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TENTATIVE	FIRM	REFERENCES AND REMARKS	
				UNIT	VALUE				
ESG-79-30, Vol III	32		Horizontal piping material						
		OD	cm (in.)	51 (20)			108, 113*	304 SS	
		ID	cm (in.)	48 (19)					
		Wall thickness	cm (in.)	1.3 (0.5)					
		OD	cm (in.)	36 (14)			109, 112	304 SS	
		ID	cm (in.)	34 (13.25)					
		Wall thickness	cm (in.)	1.0 (0.373)					
		OD	cm (in.)	27 (10.75)			110, 111	304 SS	
		ID	cm (in.)	26 (10.14)					
		Wall thickness	cm (in.)	0.8 (0.307)					
		OD	cm (in.)	51 (20)			114	Carbon Steel	
		ID	cm (in.)	48 (19)					
		Wall thickness	cm (in.)	1.3 (0.5)					
		OD	cm (in.)	6.0 (2.375)			201, 203, 205 -	304 SS or carbon steel	
		ID	cm (in.)	5.3 (2.01)					
		Wall thickness	cm (in.)	0.4 (0.154)					
	33			Horizontal piping total lengths					
			51 cm (20 in.)	m (ft)	21.3 (70)			103, 113	
			36 cm (14 in.)	m (ft)	12.2 (40)			109, 112	
			27 cm (10.8 in.)	m (ft)	15.2 (50)			110, 111	
		51 cm (20 in.)	m (ft)	24.4 (80)			114		
		6 cm (2.4 in.)	m (ft)	68.6 (225)					
34			Horizontal piping mass	kg (lb)	9,500 (10.5)			Sum of Item 33

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE 11 of 16

DATE June 21, 1979

NEW REV	NO.	A ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS																																	
			UNIT	VALUE																																				
ESG-79-30, Vol III	35	Horizontal piping insulation material					Calcium silicate with aluminum weather protection																																	
	36	Mass of horizontal piping insulation	kg (ton)	2,640 (2.9)																																				
	37	Valve size, number, and material	cm (in.)				<table><tr><th>Valve No*</th><th>Quantity</th><th>Material</th></tr><tr><td>V100-1, 2</td><td>2</td><td>CS</td></tr><tr><td>V104-1</td><td>1</td><td>CS</td></tr><tr><td>V105</td><td>1</td><td>SS</td></tr><tr><td>V109-1</td><td>1</td><td>SS</td></tr><tr><td>TV300-1-24</td><td>24</td><td>CS</td></tr><tr><td>V201-1</td><td>1</td><td>CS</td></tr><tr><td>V202-1</td><td>1</td><td>CS</td></tr><tr><td>V203-1</td><td>1</td><td>CS</td></tr><tr><td>V203-2</td><td>1</td><td>SS</td></tr><tr><td>V205</td><td>1</td><td>CS</td></tr></table>	Valve No*	Quantity	Material	V100-1, 2	2	CS	V104-1	1	CS	V105	1	SS	V109-1	1	SS	TV300-1-24	24	CS	V201-1	1	CS	V202-1	1	CS	V203-1	1	CS	V203-2	1	SS	V205	1	CS
	Valve No*	Quantity	Material																																					
	V100-1, 2	2	CS																																					
	V104-1	1	CS																																					
	V105	1	SS																																					
	V109-1	1	SS																																					
	TV300-1-24	24	CS																																					
	V201-1	1	CS																																					
	V202-1	1	CS																																					
	V203-1	1	CS																																					
	V203-2	1	SS																																					
	V205	1	CS																																					
		Check valves		51 (20)																																				
	Block		5.1 (2)																																					
	Drag valve		30.5 (12)																																					
	Control		25.4 (10)																																					
	Control		20.3 (8)																																					
	Block		5.1 (2)																																					
	Block		5.1 (2)																																					
	Block		5.1 (2)																																					
	Block		5.1 (2)																																					
	Block		5.1 (2)																																					

*See N001000352

FORM 706-A REV. 6-78

714-G.61

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER
Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

PAGE 12 of 16

WBS NO. Drawing N001000352

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-17 ESG-79-30, Vol III	38		Number and mass of valves	kg (lb)	1,636 (3,600)			Ground level only
	39		Receiver pump material Number of receiver pumps Mass of receiver pump	kg (lb)	1 (44,600)(98,300)			CS Ground level only Dry weight
	40		Pump characteristics Type		-			Centrifugal mixed flow, single stage, inducer type
			Speed	rpm	700,350			Two speed
			Operating range		-			
			Head	m (ft)	242.4 (795)			
			NPSH	m (ft)	12.2 (40)			
			Operating temperature	°C (°F)	288 (550)			
			Power (N = 78%)	kWe (hp)				
			Capacity	m ³ /s (gpm)	1.17 (18,600)			
			Inlet pressure	MPa (psi)	0.08 (11.5)			
			Outlet pressure	MPa (psi)	2.21 (319.5)			
			Pump height w/motor	m (ft)	7.6 (25)			
			Pump tank dimensions	m (ft)	2.3 x 4.2 (7.8 x 14)			
			Inlet nozzle	m (ft)				
			Outlet nozzle		0.76 (2.5)			
			Impeller diameter		0.52 (1.7)			
			Casing diameters		1.7 (5.4)			
			Code					ASME Section VIII, Div. 1

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N001J00352

PAGE 13 of 16

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-18 ESG-79-30, Vol III	41		Pump motor	MWe (hp)	3.1 (4,200)			Tube and shell hockey stick
			Size	m (ft)	1.8 x 3.6			
			Dimensions		(6 x 11)			
			Voltage	V	4160			
			Mass	kg (lb)	11,450 (21,000)			
			No. poles					
			Speed	rpm	725			
			Steam generator heat exchanger characteristics					
			Service - evaporator X-1					
			Number required		1			
			Type		-			
			Orientation		Vertical			
			Number of tube passes		1			
			Number of shell passes		1			
			Tube side fluid		Water			
			Shell side fluid		Sodium			
			Tube material		2-1/4 Cr - 1 Mo			
			Shell material		2-1/4 Cr - 1 Mo			
			Number of tubes		1,250			
			Tube OD	cm (in.)	1.59 (5/8)			
			Tube ID	cm (in.)	1.21 (0.475)			
			Tube wall thickness	cm (in.)	0.190 (0.075)			
			Tube layout and pitch dimension	cm (in.)	TBD			
			Baffle type and spacing	cm (in.)	TBD			
			Unit size - height	m (ft)	29.0 (95)			
			Unit size - width	m (ft)	5.18 (17)			
			Unit size - shell diameter	m (in.)	1.27 (50)			

FORM 706-A REV. 6-78

714-G.61

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE 14 of 16

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-19 ESG-79-30, Vol III	41		Mass per unit	kg (ton)	65,000 (72)			ASME Section VIII, Div. I Tube and shell hockey stick
			Active external surface area per unit	m ² (ft ²)	1,480 (15,900)			
			Inactive external surface area per unit	m ² (ft ²)	150 (1,600)			
			LMTD - preheating	°C (°F)	16 (28)			
			LMTD - nucleate boiling	°C (°F)	18 (33)			
			LMTD - film boiling	°C (°F)	79 (143)			
			Pinch point	°C (°F)	4.4 (8)			
			Sodium nozzle OD/thickness	cm/in.	51/2.5 (20/1.0)			
			Tubesheet diameter/thickness		122/30.5 (48/1.2)			
			Steam nozzle OD/thickness		20.3/3.8 (8/1.5)			
			Sodium pressure	MPa (psig)	2.07 (300)			
			Steam pressure		15.17 (2,200)			
			Steam temperature	°C (°F)	482 (900)			
			Code					
			Service - Superheater X-2					
			Number required		1			
			Type		-			
			Orientation		Vertical			
			Number of tube passes		1			
			Number of shell passes		1			
			Tube side fluid		Steam			
			Shell side fluid		Sodium			
			Tube material		SS			
			Shell material		SS			
			Number of tubes		269			
			Tube OD	cm (in.)	1.91 (3/4)			
			Tube ID	cm (in.)	1.23 (0.486)			
			Tube wall thickness	cm (in.)	0.34 (0.132)			
			Tube layout and pitch dimension	cm (in.)	TBD			
			Baffle type and spacing	cm (in.)	TBD			
			Unit size - height	m (ft)	27.7 (91)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO.

Drawing N001000352

PAGE

15 of 16

DATE

June 21, 1979

NEW REV	NO.	A	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
ESG-79-30, Vol III	41	Unit size - width	m (ft)	4.57 (15)			ASME Section VIII, Div. I Tube and shell hockey stick
		unit size - shell diameter	m (in.)	0.76 (30)			
		Mass per unit	kg (ton)	20,000 (22)			
		Active external surface area per unit	m ² (ft ²)	383 (4,100)			
		Inactive external surface area per unit	m ² (ft ²)	38 (410)			
		LMTD	°C (°F)	85 (153)			
		Pinch point	°C (°F)	NA			
		Sodium nozzle OD/thickness	cm (in.)	45.7/2.54 (18.0/1.0)			
		Tubesheet diameter/thickness		76.2/20.3 (30/8)			
		Steam nozzle OD/thickness		20/3.0 (8/1.2)			
		Sodium pressure	MPa (psig)	2.07 (300)			
		Steam pressure		15.2 (2200)			
		Steam temperature	°C (°F)	593 (1100)			
		Code					
		Service - Reheater X-2					
		Number required		1			
		Type		-			
		Orientation		Vertical			
		Number of tube passes		1			
		Number of shell passes		1			
		Tube side fluid		Steam			
		Shell side fluid		Sodium			
		Tube material		SS			
		Shell material		SS			
		Number of tubes		166			
		Tube OD	cm (in.)	3.81 (1-1/2)			
		Tube ID	cm (in.)	3.27 (1.29)			
		Tube wall thickness	cm (in.)	0.27 (0.107)			
		Tube layout and pitch dimension	cm (in.)	TBD			

FORM 706-A REV. 6-78

714-G.61

Rockwell International

Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE

16 of 16

DATE

June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-21 ESG-79-30, Vol III		A	Baffle type and spacing	cm (in.)	TBD			ASME Section VIII, Div. I
			Unit size - height	m (ft)	20.1 (66)			
			Unit size - width	m (ft)	5.49 (18)			
			Unit size - shell diameter	m (in.)	0.81 (32)			
			Mass per unit	kg (ton)	22,000 (24)			
			Active external surface area per unit	m ² (ft ²)	315 (3,400)			
			Inactive external surface area per unit	m ² (ft ²)	31.5 (340)			
			LMTD	°C (°F)	95.6 (172)			
			Pinch point	°C (°F)	NA			
			Sodium nozzle OD/thickness	cm (in.)	30.5/1.9 (12/.75)			
			Tubesheet diameter/thickness		81.3/12.7 (32/ 5)			
			Steam nozzle OD/thickness		16.8/1.5 (6.6/ .6)			
			Sodium pressure	MPa (psig)	2.07(300)			
			Steam pressure		3.10 (450)			
			Steam temperature	°C (°F)	593 (1100)			
			Code

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE 1 of 17

DATE June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
ESG-79-30, Vol III	B	Operating Characteristics					
	1	Receiver Incident Power					
		Total at max. insolation	MWt	413.0			Solstice Noon
		Per panel -					
		No. 1 and 24 North	MWt	19.2			Starting with No. 1 for north panel, panels numbered in clockwise direction (15° per panel). Vertical centerline of No. 1 panel 7.5° east of north.
		No. 2 and 23	MWt	19.2			
		No. 3 and 22	MWt	18.6			
		No. 4 and 21	MWt	18.3			
		No. 5 and 20	MWt	17.9			
		No. 6 and 19 East and West	MWt	17.8			
		No. 7 and 18	MWt	17.3			
		No. 8 and 17	MWt	16.2			
		No. 9 and 16	MWt	15.7			
		No. 10 and 15	MWt	15.5			
		No. 11 and 14	MWt	15.6			
		No. 12 and 13 South	MWt	15.2			
		Total at design insolation	MWt	401.2			Equinox Noon
		Per panel -					
		No. 1 and 24 North	MWt	20.9			
		No. 2 and 23	MWt	20.8			
		No. 3 and 22	MWt	19.9			
		No. 4 and 21	MWt	19.2			
		No. 5 and 20	MWt	18.3			
		No. 6 and 19 East and West	MWt	17.6			
		No. 7 and 18	MWt	16.5			

F-22

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE 2 of 17

DATE June 21, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-23 ESG-79-30, Vol III			No. 8 and 17	MWt	14.8			10 ⁰ cutoff winter soltice *Panel power is asymmetric
			No. 9 and 16	MWt	13.9			
			No. 10 and 15	MWt	13.2			
			No. 11 and 14	MWt	13.0			
			No. 12 and 13 South	MWt	12.5			
			Total at min. operating condition	MWt	257.8			
			Per panel*-					
			No. 1 and 24 North	MWt	14.1	14.5		
			No. 2 and 23	MWt	13.0	14.4		
			No. 3 and 22	MWt	11.4	14.1		
			No. 4 and 21	MWt	10.4	14.0		
			No. 5 and 20	MWt	9.5	13.7		
			No. 6 and 19 West and East	MWt	8.3	13.5		
			No. 7 and 18	MWt	6.8	13.6		
			No. 8 and 17	MWt	5.8	13.4		
			No. 9 and 16	MWt	5.4	12.3		
			No. 10 and 15	MWt	5.7	10.8		
			No. 11 and 14	MWt	6.7	9.8		
			No. 12 and 13 South	MWt	7.7	8.8		
	2		Receiver Absorbed Power					
			Total at max. insolation (design)	MWt	375.2			
			Per panel -					
			No. 1 and 24 North	MWt	17.5			
			No. 2 and 23	MWt	17.5			
			No. 3 and 22	MWt	17.0			
			No. 4 and 21	MWt	16.6			
			No. 5 and 20	MWt	16.3			

FORM 706-A REV. 6-78

714-G.61

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N0010C0352

PAGE 3 of 17

DATE June 21, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-24 ESG-79-30, Vol III			No. 6 and 19 East and West	MWt	16.2			
			No. 7 and 18	MWt	15.7			
			No. 8 and 17	MWt	14.6			
			No. 9 and 16	MWt	14.2			
			No. 10 and 15	MWt	14.0			
			No. 11 and 14	MWt	14.2			
			No. 12 and 13 South	MWt	13.8			
			Total at design insolation (operating)	MWt	364.0			
			Per panel -					
			No. 1 and 24 North	MWt	19.1			
			No. 2 and 23	MWt	19.0			
			No. 3 and 22	MWt	18.2			
			No. 4 and 21	MWt	17.5			
			No. 5 and 20	MWt	16.7			
			No. 6 and 19 East and West	MWt	16.0			
			No. 7 and 18	MWt	15.0			
			No. 8 and 17	MWt	13.4			
			No. 9 and 16	MWt	12.5			
			No. 10 and 15	MWt	11.9			
			No. 11 and 14	MWt	11.7			
			No. 12 and 13 South	MWt	11.2			
			Total at min. operating concition	MWt	227.9			
			Per panel*-					
			No. 1 and 24 North	MWt	12.8	13.1		
			No. 2 and 23	MWt	11.7	13.0		
			No. 3 and 22	MWt	10.2	12.7		
			No. 4 and 21	MWt	9.2	12.6		
			No. 5 and 20	MWt	8.3	12.3		

*Panel power is asymmetric

FORM 706-A REV. 6-78

714-G.61

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE

4 of 17

DATE

June 21, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			No. 6 and 19 West and East	MWt	7.1 12.1			
			No. 7 and 18	MWt	5.8 12.0			
			No. 8 and 17	MWt	4.7 12.0			
			No. 9 and 16	MWt	4.4 11.0			
			No. 10 and 15	MWt	4.7 9.6			
			No. 11 and 14	MWt	5.7 8.6			
			No. 12 and 13	MWt	6.6 7.6			
	3		Flux Maps					See Figure 5.2-31
	4		Peak flux absorbed					
			Maximum	MWt/m ²	1.438			
			Design point	MWt/m ²	1.438			
	5		Average flux absorbed					
			Maximum	MWt/m ²	0.612			
			Design point	MWt/m ²	0.594			
			Minimum operating condition	MWt/m ²	0.372			
	6		Receiver sodium operating temperatures					
			Inlet	°C (°F)	228 (550)			
			Outlet	°C (°F)	593 (1100)			
	7		Receiver sodium operating pressures					
			Inlet	MPa (psi)	0.45 (65)			
			Outlet	MPa (psi)	0.24 (35)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver
Hybrid Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE 5 of 17

DATE June 21, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
ESG-79-30, Vol III	8		Receiver sodium flow rates					
			Total maximum (design)	kg/hr (lb/hr)	3.68×10^6 (8.11×10^6)			
			Design (operating)	kg/hr (lb/hr)	3.57×10^6 (7.87×10^6)			
			Minimum	kg/hr (lb/hr)	2.23×10^6 (4.93×10^6)			
			Per panel -					
			No. 1 and 24 North -					
			Maximum	kg/hr	171,785 (378,381)			
			Design	(lb/hr)	187,491 (412,976)			
			Minimum		125,649 (276,759)/128,593 (283,245)			
			No. 2 and 23					
			Maximum		171,785 (378,381)			
			Design		186,510 (410,814)			
			Minimum		114,851 (252,975)/127,812 (281,083)			
			No. 3 and 22					
			Maximum		166,877 (367,570)			
			Design		178,657 (393,517)			
			Minimum		100,126 (220,542)/124,667 (274,597)			
			No. 4 and 21					
			Maximum		162,950 (358,921)			
			Design		171,785 (378,381)			
			Minimum		90,310 (198,920)/123,685 (272,434)			
			No. 5 and 20					
			Maximum		160,005 (352,435)			
			Design		163,932 (361,083)			
			Minimum		81,475 (179,461)/120,240 (265,948)			
			No. 6 and 19 West and East					
			Maximum		159,024 (350,273)			
			Design		157,061 (345,949)			
			Minimum		89,696 (195,515)/118,777 (261,624)			

FORM 706-A REV. 6-78

714-G.61

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE 6 of 17

DATE June 21, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-27 ESG-79-30, Vol III			No. 7 and 18	Maximum	kg/hr	154,116 (339,462)		
				Design	(lb/hr)	147,244 (324,327)		
				Minimum		56,934 (125,406)/117,795 (259,462)		
			No. 8 and 17	Maximum	kg/hr	143,318 (315,678)		
				Design	(lb/hr)	131,538 (289,732)		
				Minimum		46,136 (101,622)/117,795 (259,462)		
			No. 9 and 16	Maximum	kg/hr	139,391 (307,029)		
				Design	(lb/hr)	122,703 (270,272)		
				Minimum		43,191 (95,135)/107,979 (237,840)		
			No. 10 and 15	Maximum		137,428 (302,705)		
				Design		116,814 (257,299)		
				Minimum		46,136 (101,622)/92,245 (207,569)		
			No. 11 and 14	Maximum		139,391 (307,029)		
				Design		139,391 (307,029)		
				Minimum		55,952 (123,244)/84,420 (185,947)		
			No. 12 and 13 South	Maximum	kg/hr	135,646 (298,380)		
				Design	(lb/hr)	109,942 (242,164)		
				Minimum		64,788 (142,704)/74,604 (164,326)		
			9 Receiver sodium velocities					
			Per panel -					
			No. 1 and 24 North	Maximum	m/sec	3.0 (9.7)		
				Design	(ft/sec)	3.2 (10.6)		
				Minimum		2.2 (7.1)/2.2 (7.3)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE 7 of 17

DATE June 21, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-28 ESG-79-30, Vol 1 III			No. 2 and 23	Maximum	m/sec 3.0 (9.7)			
				Design	(ft/sec) 3.2 (10.5)			
				Minimum	2.0 (6.5)/2.2			
			No. 3 and 22	Maximum	2.9 (9.4)			
				Design	3.1 (10.1)			
				Minimum	1.7 (5.7)/2.1			
			No. 4 and 21	Maximum	2.8 (9.2)			
				Design	3.0 (9.7)			
				Minimum	1.6 (5.1)/2.1			
			No. 5 and 20	Maximum	2.7 (9.0)			
				Design	2.8 (9.3)			
				Minimum	1.4 (4.6)/2.1			
			No. 6 and 19	Maximum	2.7 (9.0)			
				Design	2.7 (8.9)			
				Minimum	1.2 (3.9)/2.0			
			No. 7 and 18	Maximum	2.7 (8.7)			
				Design	2.5 (8.3)			
				Minimum	1.0 (3.2)/2.0			
			No. 8 and 17	Maximum	2.5 (8.1)			
				Design	2.3 (7.4)			
				Minimum	0.8 (2.6)/2.0			
			No. 9 and 16	Maximum	2.4 (7.9)			
				Design	2.1 (6.9)			
				Minimum	7.3 (2.4)/1.9			

FORM 706-A REV. 6-78

714-G.61

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE 8 of 17

DATE June 21, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-29 ESG-79-30, Vol III	10		No. 10 and 15	Maximum	m/sec 2.4 (7.8)			% of incident power
				Design	(ft/sec) 2.0 (6.6)			
				Minimum	0.8 (2.6)/1.6	(5.3)		
			No. 11 and 14	Maximum	2.4 (7.9)			
				Design	2.4 (7.9)			
				Minimum	1.0 (3.2)/1.5	(4.8)		
			No. 12 and 23	Maximum	2.3 (7.7)			
				Design	1.9 (6.2)			
				Minimum	1.1 (3.7)/1.3	(4.2)		
			Receiver losses @ maximum power					
			Design point wind speed at receiver elev.	m/sec(MPH)	16.3 (36.4)			
			Reflection	%	5			
			Reradiation	%	3.3			
			Combined natural plus forced convection	%	2.7			
			Receiver losses @ design power					
			Reflection	%	5			
			Reradiation	%	3.4			
			Combined natural plus forced convection	%	2.8			
			Receiver losses @ minimum oper. power					
			Reflection	%	5			
			Reradiation	%	6.0			
			Combined natural plus forced convection	%	5.1			

FORM 706-A REV.6-78

714-G.61

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N0010C0352

PAGE

9 of 17

DATE

June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
ESG-79-30, Vol III	11	Peak metal temperatures in receiver Location	$^{\circ}\text{C}$ ($^{\circ}\text{F}$)	649 (1,200)			North panel approx. 2.5 m from top of panel
	12	Peak working stress in receiver Location	MPa(psi)	(30,000)			
		a. Typical thermal expansion/Panel	cm (in.)	12.7 (5)			
	13	Receiver fatigue life No. of cycles Equivalent years of operation		15,000 30			
	14	Receiver heat transfer coefficients at maximum absorbed power					
		a. Tube wall	$\text{W}/\text{M}^2\text{-}^{\circ}\text{C}$ ($\text{Btu}/\text{hr}\text{-}\text{ft}^2\text{-}^{\circ}\text{F}$)	TBD			
		b. Sodium					
		c. Overall					
	14	Receiver heat transfer coefficients at design absorbed power					
		a. Tube wall-hot-593 $^{\circ}\text{C}$ (1100 $^{\circ}\text{F}$)	$\text{W}/\text{M}^2\text{-}^{\circ}\text{C}$ ($\text{Btu}/\text{hr}\text{-}\text{ft}^2\text{-}^{\circ}\text{F}$)	16,700 (2940)			Based on OD - h_{Na}
		Tube wall-mean-441 $^{\circ}\text{C}$ (825 $^{\circ}\text{F}$)		15,200 (2670)			
		Tube wall-cold-288 $^{\circ}\text{C}$ (550 $^{\circ}\text{F}$)		13,600 (2400)			Based on OD - h_{Na}
		b. Sodium-North quadrant-hot		42,500 (7950)			Based on OD - $h_{\text{eff. cond.}}$

FORM 706-A REV. 6-78

714-G.61

F-30

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. Drawing N001000352

PAGE

10 of 17

DATE

June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
F-31 ESG-79-30, Vol III		Sodium-North quadrant-mean		48,600 (8550)			Based on OD - h_{eff} cond.
		Sodium-North quadrant-cold		52,300 (9200)			
		Sodium-East/West quadrant-hot		36,800 (6480)			
		Sodium-East/West quadrant-mean		39,900 (7020)			
		Sodium-East/West quadrant-cold		43,230 (7610)			
		Sodium-South quadrant-hot		30,300 (5340)			
		Sodium-South quadrant-mean		33,300 (5850)			
		Sodium-South quadrant-cold	$W/M^2 - ^\circ C$ ($Btu/hr-ft^2 - ^\circ F$)	36,300 (6380)			
		c. Overall-North quadrant-hot	$W/M^2 - ^\circ C$ ($Btu/hr-ft^2 - ^\circ F$)	12,200 (2150)			
		Overall-North quadrant-mean		11,530 (2030)			
		Overall North quadrant-cold		10,800 (1900)			
		Overall East/West quadrant-hot		11,480 (2020)			
		Overall East/West quadrant-mean		10,970 (1930)			
		Overall East/West quadrant-cold		10,340 (1820)			
		Overall South quadrant-hot		10,800 (1900)			
		Overall South quadrant-mean		10,400 (1830)			
		Overall South quadrant-cold	$W/M^2 - ^\circ C$ ($Btu/hr-ft^2 - ^\circ F$)	9,800 (1740)			

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver subsystem
100 MWe SM 1.4

NUMBER

Rev. 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO. Drawing N0010J0352

PAGE

11 of 17

DATE

June 21, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TER- MINATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
ESG-79-30, Vol III	14		Receiver heat transfer coefficients at minimum operating condition absorbed power		TBD			
		a.	Tube wall	$\text{W/M}^2\text{-}^\circ\text{C}$ ($\text{Btu/hr-ft}^2\text{-}^\circ\text{F}$)				
		b.	Sodium					
		c.	Overall					
	15		Receiver ramp rate					
			% of maximum absorbed power per minute	%	66			
	16		Steam generator heat exchanger (HX) discharge rate					
		Total	Maximum	MWt				
			Design	MWt	260.0			
			Minimum	MWt				
		Evaporator	Maximum	MWt				
			Design	MWt	146.0			
			Minimum	MWt				
		Superheater	Maximum	MWt				
			Design	MWt	74.0			
			Minimum	MWt				
		Reheater	Maximum	MWt				
			Design	MWt	40.0			
			Minimum	MWt				

FORM 706-A REV. 6-78

714-G.61

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Rev. 0

PREPARED BY

APPROVED BY

J. Auleta

WBS NO. Drawing N001000352

PAGE

12 of 17

DATE

June 21, 1979

ESG-79-30, Vol III

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	17	Sodium operating temperatures for each HX unit					
		Evaporator - Inlet	°C (°F)	459 (859)			
		Outlet	°C (°F)	288 (550)			
		Superheater - Inlet	°C (°F)	593 (1100)			
		Outlet	°C (°F)	459 (859)			
		Reheater - Inlet	°C (°F)	593 (1100)			
		Outlet	°C (°F)	459 (859)			
	18	Water/steam operating temperatures for each HX unit					
		Evaporator - Inlet	°C (°F)	251 (483.5)			
		Outlet	°C (°F)	336 (636)			
		Superheater - Inlet	°C (°F)	336 (636)			
		Outlet	°C (°F)	538 (1000)			
		Reheater - Inlet	°C (°F)	308 (586)			
		Outlet	°C (°F)	538 (1000)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Rev. 0

PREPARED BY

J. Auleta

APPROVED BY

PAGE

13 of 17

WBS NO. Drawing N001000352

DATE

June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIR-4	REFERENCES AND REMARKS
			UNIT	VALUE			
ESG-79-30, Vol III F-34	19	Sodium operating pressure for each HX unit					
		Evaporator - Inlet	MPa (psia)	0.76 (110)			
		Outlet	MPa (psia)	0.55 (80)			
		Superheater - Inlet	MPa (psia)	0.97 (140)			
		Outlet	MPa (psia)	0.76 (110)			
		Reheater - Inlet	MPa (psia)	0.97 (140)			
		Outlet	MPa (psia)	0.76 (110)			
	20	Water/steam operating pressure for each HX unit					
		Evaporator - Inlet	MPa (psia)	13.8 (2000)			
		Outlet	MPa (psia)	13.4 (1950)			
		Superheater - Inlet	MPa (psia)	13.4 (1950)			
		Outlet	MPa (psia)	12.8 (1850)			
		Reheater - Inlet	MPa (psia)	2.2 (322)			
		Outlet	MPa (psia)	2.1 (300)			

FORM 706-A, REV. 6-78

714-G.61

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Rev. 0

PREPARED BY

J. Auleta

APPROVED BY

PAGE

14 of 17

DATE

June 21, 1979

WBS NO. Drawing N001000352

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	21	Sodium flow rates					
		Total - Maximum	kg/hr (lb/hr)	2.5×10^6 (5.5×10^6)			
		Design		2.4×10^6 (5.32×10^6)			
		Minimum		1.5×10^6 (3.31×10^6)			
		Evaporator - Maximum		2.5×10^6 (5.5×10^6)			
		Design		2.41×10^6 (5.32×10^6)			
		Minimum		1.5×10^6 (3.31×10^6)			
		Superheater - Maximum		1.62×10^6 (3.59×10^6)			
		Design		1.58×10^6 (3.48×10^6)			
		Minimum		0.99×10^6 (2.17×10^6)			
		Reheater - Maximum		0.86×10^6 (1.90×10^6)			
		Design		0.83×10^6 (1.84×10^6)			
		Minimum	kg/hr (lb/hr)	0.52×10^6 (1.14×10^6)			

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Rev. 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO. Drawing N001000352

PAGE

15 of 17

DATE

June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	22	Water/steam flow rates					
		Total - Maximum	kg/hr (lb/hr)	3.50×10^5 (7.73×10^5)			
		Design		3.34×10^5 (7.36×10^5)			
		Minimum		6.68×10^4 (1.47×10^5)			
		Evaporator - Maximum		3.50×10^5 (7.73×10^5)			
		Design		3.34×10^5 (7.36×10^5)			
		Minimum		6.68×10^4 (1.47×10^5)			
		Superheater - Maximum		3.50×10^5 (7.73×10^5)			
		Design		3.34×10^5 (7.36×10^5)			
		Minimum		6.68×10^4 (1.47×10^5)			
		Reheater - Maximum		2.89×10^5 (1.37×10^5)			
		Design		2.75×10^5 (6.06×10^5)			
		Minimum	kg/hr (lb/hr)	5.5×10^4 (1.21×10^5)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Rev. 0

PREPARED BY

J. Auleta

APPROVED BY

PAGE

16 of 17

WBS NO. Drawing N001000352

DATE

June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	23	Steam generator heat transfer coefficients at design power					
		Evaporator X-1					
		Tube side - preheating	$W/M^2-^{\circ}C$ ($Btu/hr-ft^2-^{\circ}F$)	7,782 (1,370)			Uncorrected for dia. ratio
		Tube side - nucleate boiling		70,700 (12,450)			
		Tube side - film boiling		7,380 (1,300)			(0.0003 $hr-ft^2-^{\circ}F/Btu$)
		Tube side fouling		18,900 (3,333)			
		Tube wall		17,488 (3,079)			
		Shell side fouling		Zero			
		Shell side		33,740 (5,940)			
		Overall - preheating		3,060 (540)			
		Overall - nucleate boiling		5,850 (1,030)			
		Overall - film boiling	$W/M^2-^{\circ}C$ ($Btu/hr-ft^2-^{\circ}F$)	3,440 (605)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
100 MWe SM 1.4

NUMBER

Rev. 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO. Drawing NO01000352

PAGE

17 of 17

DATE

June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	23	Steam generator heat transfer coefficients at design power - Continued					
		Superheater X-2 heat transfer coefficients at design power					
		Tube side	$W/M^2-^{\circ}C$ ($Btu/hr-ft^2-^{\circ}F$)	8,640 (1,520)			Uncorrected for dia. ratio
		Tube side fouling		28,400 (5,000)			($0.0002 \text{ hr-ft}^2-^{\circ}F/Btu$)
		Tube wall		5,450 (960)			
		Shell side fouling		Zero			
		Shell side		42,940 (7,560)			
		Overall		2,270 (400)			
		Reheater X-3 heat transfer coefficients at design power					
		Tube side		2,160 (380)			Uncorrected for dia. ratio
		Tube side fouling		28,400 (5,000)			($0.0002 \text{ hr-ft}^2-^{\circ}F/Btu$)
		Tube wall		7,670 (1,350)			
		Shell side fouling		Zero			
		Shell side		25,000 (4,400)			
		Overall	$W/M^2-^{\circ}C$ ($Btu/hr-ft^2-^{\circ}F$)	1,310 (230)			

FORM 706-A REV. 6-78

714-G.61

F-38

ESG-79-30, Vol III

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

SOLAR CENTRAL RECEIVER HYBRID
STORAGE SUBSYSTEM
100 MWe SM 1.4

NUMBER

REVISION 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 1 of 7

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	A	Design Characteristics					
	1.	Storage Media		Sodium			TDT 12083
		a. Specific Heat @ 288°C (550°F)	Cal/g-°C (Btu/lb-°F)	0.312 (0.312)			
		@ 593°C (1100°F)		0.300 (0.300)			
		b. Viscosity @ 288°C (550°F)	kg/m-s (lb/ft-s)	3.51x10 ⁻⁴ (2.36x10 ⁻⁴)			
		@ 593°C (1100°F)		2.08x10 ⁻⁴ (1.40x10 ⁻⁴)			
		c. Density @ 288°C (550°F)	kg/m ³ (lb/ft ³)	882.88 (55.12)			
		@ 593°C (1100°F)		809.78 (50.55)			
	2.	Storage Media Mass	kg (lb)	7.6x10 ⁶ (16.8x10 ⁶)			
	3.1	Cold Tank Characteristics					
		a. Number of Tanks		1			
		b. Geometry					Cylindrical API Type
		Diameter	m (ft)	30.5 (100)			
		Height	m ₃ (ft)	12.3 (41)			
		c. Volume	m ³ (ft ³)	9,124 (322,014)			
		d. Tank Material					Carbon Steel
		e. Tank Design Temperature	°C (°F)	316 (600)			
		f. Tank Mass (dry)	kg (lb)	233,600 (515,000)			

FORM 706-A REV.6-78

714-G.61

F-39

ESG-79-30, Vol III

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
SOLAR CENTRAL RECEIVER HYBRID
STORAGE SUBSYSTEM
100 MWe SM 1.4

NUMBER
REVISION 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 2 of 7

DATE June 26, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-40 ESG-79-30, Vol III	3.2	A	g. Tank Surface Area					Calcium Silicate with Aluminum Weather Protection, Perlitic Concrete Base Insulation (Base Insulation = 1m (3 ft) (Sides and Top only)
			Top	m ² (ft ²)	803 (8,639)			
			Side	m ² (ft ²)	1,197 (12,881)			
			Bottom	m ² (ft ²)	730 (7,854)			
			Total	m ² (ft ²)	2,730 (29,374)			
			h. Tank Insulation Material					
			i. Insulation Thickness	m (in.)	0.152 (6)			
			j. Insulation Mass	kg (lb)	63,440 (139,900)			
			k. Tank Wall Thickness					
			@ Top	mm (in.)	63.5 (0.25)			
			@ Bottom		264.2 (1.04)			
			l. Preheat Power	kWe	274.0			
			Hot Tank Characteristics					
			a. Number of Tanks					
			b. Geometry					
			Diameter	m (ft)	30.5 (100)			Cylindrical API Type
			Height	m ³ (ft) ³	13.7 (45)			
			c. Volume	m ³ (ft ³)	10,014 (353,430)			Type 304H SS
			d. Tank Material					
			e. Tank Design Temperature	°C (°F)	621 (1,150)			
			f. Tank Mass	kg (lb)	254,000 (560,000)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
SOLAR CENTRAL RECEIVER HYBRID
STORAGE SUBSYSTEM
100 MWe SM 1.4

NUMBER
REVISION 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 3 of 7

DATE June 26, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
ESG-79-30, Vol III F-41			g. Tank Surface Area					
			Top	m ² (ft ²)	803 (8,639)			
			Side	m ² (ft ²)	1,314 (14,137)			
			Bottom	m ² (ft ²)	730 (7,854)			
			Total	m ² (ft ²)	2,847 (30,630)			
			h. Tank Insulation Material					Calcium Silicate with Aluminum Weather Protection, Perlitic Concrete Base Insulation (1m (3 ft) thick)
			i. Insulation Thickness	m (in.)	0.304 (12)			
			j. Insulation Mass	kg (lb)	134,600 (296,100)			(Sides and Top only)
			k. Tank Wall Thickness					
			@ Top	mm (in.)	63.5 (0.25)			
			@ Bottom		269.2 (1.06)			
			l. Preheat Power	kWe	540.0			
	4.		Piping and Valves					
	4.1		Piping					
			a. Material					Carbon Steel
			Low Temperature					304H SS
			High Temperature					
			b. OD/ID/Wall					
			Low Temperature (115)	mm (in.)	7,620/7,468/76 (30.0/29.4/0.3)			(115) refers to pipe no. in P&I Diagram
			High Temperature (105)		3,239/3,112/64 (12.75/12.25/ 0.25)			
			(106)		5,080/4,953/64 (20.0/19.5/ 0.25)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
SOLAR CENTRAL RECEIVER HYBRID
STORAGE SUBSYSTEM
100 MWe SM 1.4

NUMBER
REVISION 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 4 of 7

DATE June 26, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			(107)		5,080/4,953/64 (20.0/19.5/ 0.25)			
ESG-79-30, Vol III	4.2		Valve Size, Number, and Material	cm (in.)				Identi- fication* Quantity Material
			Block		76 (30)			V112 1 C.S.
			Block		51 (20)			V106 1 S.S.
			Block		51 (20)			V104 1 S.S.
	5.		Piping Total Lengths	m (ft)				
			Low Temperature		23.2 (76.1)			(115)
			High Temperature		3.0 (10)			(105)
					24.4 (80)			(106 + 107)
	6.		Mass of Piping	kg (lb)	5,513 (12,154)			
	7.		Piping Insulation Material					Calcium Silicate with Aluminum Weather Protection
		Thickness	mm (in.)	762 (3) 1,281 (5) 1,281 (5)			(115) (105) (106 and 107)	
8.		Mass of Piping Insulation	kg (lb)	1,898 (4,185)				
9.		Storage Pumps						
		a. Number		1			(Steam Generator Pump)	
		b. Material					304H SS	
		c. Mass	kg (lb)	8,600 (19,000)				

FORM 706-A REV. 6-78

714-G.61

F-42

ESG-79-30, Vol III

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

SOLAR CENTRAL RECEIVER HYBRID
STORAGE SUBSYSTEM
100 MWe SM 1.4

NUMBER

REVISION 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 5 of 7

DATE June 26, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-43 ESG-79-30, Vol III	10.		Storage Pump Characteristics					Steam Generator Pump P-2
		a.	Type	rpm	116-1160			Single Stage, Centrifugal
		b.	Speed and Operating Range	m (ft)	76 (250)			Variable
		c.	Head	m (ft)	7.6 (25)			
		d.	NPSH	°C (°F)	593 (1,100)			
		e.	Operating Temperature	kWe (hp)	560 (750)			
		f.	Power	m ³ /s (gpm)	0.95 (15,000)			η = 80%
		g.	Capacity		1			
		h.	Number of Stages	m (ft)	7.3 (24)			
		i.	Height, with Motor	m (ft)	1.00x3.6			ASME Section VIII, Div. I
		j.	Pump Tank Size		(3.50x12)			
		k.	Code	mm (in.)	5,080 (20)			
		l.	Inlet Nozzle	mm (in.)	5,080 (20)			
		m.	Outlet Nozzle					
	11.		Storage Pump Motor					
		a.	Size	kWe (hp)	560 (750)			
		b.	Dimensions with coupling	m (ft)	1.50x3.7			
					(50x12)			
		c.	Voltage	v	4,160			
		d.	Mass	kg (lb)	3,860 (8,500)			
	B		Operating Characteristics					
	1.		Extractable Capacity	MWh _t (Btu)	821 (2.8x10 ⁹)			Includes 41 MWh _t for Startup and Shutdown
	2.		Charging Rate					
		a.	Maximum	MWt	364.0			
		b.	Design	MWt	121.3			
		c.	Minimum	MWt	0

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
SOLAR CENTRAL RECEIVER HYBRID
STORAGE SUBSYSTEM
100 MWe SM 1.4

NUMBER
REVISION 0

PREPARED BY

APPROVED BY

W. W. Willcox

WBS NO. N001000352

PAGE 6 of 7

DATE June 26, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
ESG-79-30, Vol III F-44	3.	Discharging Rate					
		a. Maximum	MWt	300			
		b. Design	MWt	257			
		c. Minimum	MWt	0			
	4.	Duration					
		a. @ Maximum Discharge Rate	hr	2.74			
		b. @ Design Discharge Rate	hr	3.0			
		c. @ Minimum Discharge Rate	hr	-			
	5.	Storage Media Operating Temperatures (Hot/Cold)	°C (°F)	288/593 (550/1100)			
	6.1	Cold Tank Operating Pressure	MPa (PSI)				
		a. Fully Charged					
		@ Top		0.0069 (1)			
		@ Bottom		0.0120 (1.74)			
		b. Fully Discharged					
		@ Top		0.0069 (1)			
		@ Bottom		0.1043 (15.11)			
		c. Media		Argon			
	6.2	Hot Tank Operating Pressures	MPa (PSI)				
		a. Fully Charged					
		@ Top		0.0069 (1)			
		@ Bottom		0.1043 (15.11)			
		b. Fully Discharged					
		@ Top		0.0069 (1)			
		@ Bottom		0.0120 (1.74)			
		c. Media		Argon			

FORM 706-A REV. 6-78

714-G.61

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

SOLAR CENTRAL RECEIVER HYBRID
STORAGE SUBSYSTEM
100 MWe SM 1.4

NUMBER

REVISION 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 7 of 7

DATE June 26, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
ESG-79-30, Vol III F-45	7.1		Cold Tank Heat Loss Rate					
			a. Fully Charged	MWt	0.15			
			b. Fully Discharged	MWt	0.15			
	7.2		Hot Tank Heat Loss Rate					
			a. Fully Charged	MWt	0.30			
			b. Fully Discharged	MWt	0.30			
	8.		Storage Ramp Rate	% max. discharge minute	TBD			
	9.		Storage Pump					Steam Generator Pump
			a. Flow Rate	kg/hr (lb/hr)	2.41×10^6 (5.32×10^6)			
			b. Sodium Volume	m ³ (gal)	5.7 (1,500)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000352

PAGE 1

DATE June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEMP- TATWE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
ESG-79-30, Vol III F-46	A	Design Characteristics					
	1	Turbine Generator Type and Nameplate Rating					
	1.1	Turbine					
		Type					
		Nameplate Rating	kWe	112,000			
		Last Stage Blade Length	cm (in.)	58.4 (23)			
		Shaft Speed	rpm	3600			
	1.2	Generator					
		Type					
		Rating	kVa	135,000			
		Power Factor		0.9			
		Voltage	volts	13,800			
		Speed	rpm	3600			
		Frequency	Hz	60			
							Tandem-Compound, Double-Flow, Reheat, Extraction, Condensing Turbine
							Synchronous, Hydrogen-Cooled, Static Excitation

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000352

PAGE 2

DATE June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
F-47 ESG-79-30, Vol III	2.0	Turbine Inlet Conditions					
		Inlet Temperature	°C (°F)	538°C (1000°F)			
		Inlet Pressure	MPa (psia)	12.5 (1815)			
		Inlet Flow Rates (at rated temperature and pressure)					
		Maximum	kg/hr (lb/hr)	350,500 (772,700)			
		Design	kg/hr (lb/hr)	333,800 (735,900)			
		Minimum	kg/hr (lb/hr)	33,400 (73,600)			
	3.0	Turbine Reheat Conditions					
		Reheat Temperature	°C (°F)	538 (1000)			
		Reheat Pressure	MPa (psia)	2.05 (298)			
		Reheat Flow Rate (at rated inlet temperature and pressure)					
		Maximum	kg/hr (lb/hr)	288,800 (636,800)			
		Design		275,100 (606,500)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000352

PAGE 3

DATE June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Turbine Reheat Conditions (Cont'd.)					
		Minimum	kg/hr (lb/hr)	27,500 (60,650)			
	4.0	Number and Location of Feedwater Heating Extractions					
		Number of Extractions		6			
		<u>Extraction</u> <u>Location</u>					<u>Heater Description</u>
		1st extraction H.P. turbine					High-Pressure Heater No. 6 (heater above reheat point)
		2nd extraction H.P. turbine exhaust					High-Pressure Heater No. 5 (cold reheat)
		3rd extraction I.P. turbine					High-Pressure Heater No. 4
		4th extraction I.P. turbine exhaust					Deaerator No. 3
		5th extraction L.P. turbine					Low-Pressure Heater No. 2
		6th extraction L.P. turbine					Low-Pressure Heater No. 1
	4.1	Feedwater Heater Descriptions					
	A	Low-Pressure Heaters					
		Quantity		2

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000352

PAGE

4

DATE

June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-49 ESG-79-30, Vol III		A	Feedwater Heaters (Cont'd.)					
			Type					Horizontal, Shell and Tube with Drain Cooler
			Tube Material		Stainless Steel			ASME B and PV Code Section VIII
			Shell Material		Carbon Steel			
	B		Tube-Side Design Pressure	MPa (psig)	2.1 (300)			
			High-Pressure Heaters					
			Quantity		3			
			Type					Horizontal, Shell and Tube with Desuper Heater and Drain Cooler Sections
	C		Tube Material		Carbon Steel			ASME B and PV Code Section VIII
			Shell Material		Carbon Steel			
			Tube-Side Design Pressure	PMa (psig)	20.7 (3000)			
			Deaerator					
			Quantity		1			
			Type					Horizontal, Spray-Tray Type, with Internal Vent Condenser, and Separate Storage Section

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000352

PAGE 5

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-50 ESG-79-30, Vol III	5.0	A	Feedwater Heaters (Cont'd.)					ASME B and PV Code Section VIII
			Rated Capacity	kg/s (lb/hr)	100 (800,000)			
			Guar. O ₂ in Effluent (Maximum)	cc/l	0.005			
			Design Pressure	kPa (psig)	345 (50)			
			Shell Material	---	Carbon Steel			
			Tray Material	---	Stainless Steel			
			Vent Condenser Material	---	Stainless Steel			
			Storage Capacity	m ³ (gal)	60 (16,000)			Surface Condenser, Two-Pass, Divided Water Boxes, per H.E.I. Standards for Steam Surface Condensers
			Weight, incl. Storage Sect. (Est.)	kg (lb)	20,400 (45,000)			
			Condenser Type and Configuration					
			Type					
			Surface	m ² (ft ²)	8175 (88,000)			90-10 Cu-Ni, ASTM B111, Alloy 706
			Tube Material					
			Tube Diameter	cm (in.)	2.54 (1.0)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Electrical Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000352

PAGE

6

DATE June 21, 1979

NEW REV	NO.	A ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Condensers (Cont'd.)					
		Tube Length (eff.)	m (ft)	8.54 (28.0)			
		Duty	MWt(Btu/h)	154 (525 x 10 ⁶)			
		Cooling Water Inlet Temperature	°C (°F)	28.9 (84.0)			
		Cooling Water Outlet Temperature	°C (°F)	35.3 (95.6)			
		Cooling Water Flow	m ³ /s(gpm)	5.7 (90,500)			
		Type of Air Removal					Mechanical Vacuum Pump
		Condensing Pressure	MPa(in. Hg)	.0067 (2.0)			
		Weight (Dry)	kg (lb)	252 x 10 ³ (560 x 10 ³)			
	5.1	Cooling Tower					
		Quantity		1			
		Type					Mechanical Draft, Wet, Cross Flow
		Number of Cells	---	5			(Ref. Marley 6616-4-05)
		Fan Motor Size	kW (hp)	5-150 (200)			
		Design Wet Bulb Temperature	°C (°F)	23.0 (73.4)			
		Cold Water Temperature	°C (°F)	28.9 (84.0)

Rockwell International

Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000352

PAGE

7

DATE

June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Cooling Tower (Cont'd.)					
			Hot Water Temperature	$^{\circ}\text{C}$ ($^{\circ}\text{F}$)	35.3 (95.6)			
			Circulating Water Flow	m^3/s (gpm)	5.9 (93,100)			
			Heat Rejected	MWt(Btu/h)	158 (540×10^6)			
			Fill Material	---	---			Treated Fir or Redwood
			Overall Dimensions:					
			Width	m (ft)	22 (72)			
			Length	m (ft)	61 (201)			
			Height (Top of Fan Cylinder)	m (ft)	18 (59)			
			Est. Weight (Dry), excl. Basin	kg (lb)	472,000 (1.04×10^6)			
	6.0		Feedwater Pump Stages					
			Number of Stages		1			Single Feedwater Pumping Stage (following deaerator)
			Feedwater Pump					
			Quantity		2			Each Pump Full Capacity
			Type					Horizontal, Centrifugal, Double Case, Barrel Type, 9 Stages, with Variable Speed Hydraulic Coupling & Electric Motor Drive

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000352

PAGE

8

DATE

June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
ESG-79-30, Vol III F-52		Feedwater Pump Stages (Cont'd.)					
		Capacity, Each	m ³ /s (gpm)	0.11 (1750)			
		Head	m (ft)	1950 (5410)			
		Speed (Pump)	rpm	3440			
		Efficiency	%	80.5			
		Motor Rating	kW (h.p.)	2250 (3000)			4160 volt
		Motor Speed (Synch.)	rpm	3600			
		Outer Case Material	---	Carbon Steel			
		Inner Case Material	---	Alloy Steel			
		Impeller Material	---	Alloy Steel			
		Weights (Est.), Each					
		Pump and Base	kg (lb)	29,500 (65,000)			
		Coupling	kg (lb)	2700 (6000)			
		Motor	kg (lb)	11,800 (26,000)			
	6.1	Circulating Water Pumps					
		Quantity		2			Two Half-Capacity

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000352

PAGE 9

DATE June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
F-54 ESG-79-30, Vol III		Circulating Water Pumps (Cont'd.)					Horizontal, Centrifugal, Single Stage, Double Suction, Electric Motor Drive
		Type					
		Capacity, Each	m ³ /s (gpm)	3.0 (47,000)			
		Head	m (ft)	23.2 (76.0)			
		Speed	rpm	514			
		Efficiency	%	80			
		Motor Rating	kW (hp)	930 (1250)			
		Casing Material	---	Cast Iron			
		Impeller Material	---	Bronze			
		Weight (Pump and Motor), Each	kg (lb)	18,100 (14,000)			
		6.2 Condensate Hotwell Pump					
		Quantity		2			
		Type					
		Capacity, Each	m ³ /s (gpm)	0.08m ³ /s (1300)			
							Two - Full Capacity Vertical Turbine Can Type, Centrifugal, with Electric Motor Drive

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO. N001000352

PAGE 10

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Condensate Hotwell Pump (Cont'd.)					
			Head	m (ft)	136 (446)			
			Speed	rpm	1750			
			Efficiency	%	84			
			Motor	kW (hp)	186 (250)			460 volt
			Casing Material	---	Cast Iron			
			Impeller Material	---	Bronze			
			Can. Material	---	Carbon Steel			
			Weight (Pump and Motor), Each	kg (lb)	4100 (9000)			
	7.0		Auxiliary Steam Supply		N/A			
	8.0		Sealing Steam Requirements		TBD			
	9.0		Turbine Startup and Shutdown Characteristics					See Table Pg F-56a

Table

TYPICAL STARTING AND LOADING PROCEDURE

TYPE OF START	COLD START	WARM START	HOT START
INITIAL PRESSURE	>40% RATED	>40% RATED	>40% RATED
INITIAL TEMPERATURE	371°C (700°F)	371°C (700°F)	MAX. OBTAINABLE
1. ACCELERATE TO 1000 RPM	(250 RPM/MIN.) 4 MIN.	(250 RPM/MIN.) 4 MIN.	(500 RPM/MIN.) 2 MIN.
2. HOLD AT 1000 RPM (CHECK VIBRATION)	10 MIN.	10 MIN.	5 MIN.
3. ACCELERATE TO 3550 RPM	(250 RPM/MIN.) 10 MIN.	(500 RPM/MIN.) 5 MIN.	(500 RPM/MIN.) 5 MIN.
4. SYNCHRONIZE GENERATOR AND APPLY 5 MW LOAD			
5. HOLD AT 5 MW (TO COOL EXHAUST)	30 MIN.	15 MIN.	NOT APPL.
6. LOAD GENERATOR TO RATED LOAD	(½%/MIN.) 190 MIN.	(1½%/MIN.) 63 MIN.	(3%/MIN.) 33 MIN.
7. TOTAL TIME ACCELERATION TO RATED LOAD	244 MIN. (4 HR - 4 MIN.)	97 MIN. (1 HR. - 37 MIN.)	45 MIN.

SOURCE: GENERAL ELECTRIC CO. (GEK - 27064A)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 10

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
ESG-79-30, Vol III F-57	10.0		Nonsolar Energy Source Design Interface Sodium Heater/Receiver Configuration					Parallel Flow, Flow Proportional to Energy Contribution, Constant Fluid ΔT
			Number of Heaters		1			
			Heated Fluid					Sodium
			Flow Distribution Mechanism					
			Heat Duty	Mwt	265			
			Full Load Sodium Flow Rate	Kg/h(1b/h)	$2.4 \times 10^6 (5.4 \times 10^6)$			Manual Throttling of Receiver and Heater Drag Valves
			20% Load Sodium Flow Rate	Kg/h(1b/h)	$0.5 \times 10^6 (1.08 \times 10^6)$			
	10.1		Heater Height/Width/Depth	m (ft)	48.2/9.1/11.0 (158/30/36)			
	10.2		Heater Working Surface Area	m ² (ft ²)				
			Radiant Section		847(9,120) 2480(26,700)			Effective at Full Load 7460 ft ² at 20% Load
			High-Temperature Convection Section					
			Low-Temperature Convection Section		5648 (60,800)			
	10.3		Tube OD/ID/Wall	mm (in.)				
			Radiant Section		31.8/24.2/3.8 (1.25/0.954/ 0.148)			
			High-Temperature Convection Section		63.5/TBD/TBD (2.50/TBD/TBD)			
			Low-Temperature Convection Section		63.5/TBD/TBD (2.50/TBD/TBD)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO.

N001000352

PAGE

11

DATE

June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
ESG-79-30, Vol III F-58	10.4		Tube Length	ft (ft)	TBD			
			Radiant Section (Nominal)					
			High-Temperature Convection Section					
	10.5		Number of Tubes	---				
			Radiant Section		900			
			High-Temperature Convection Section		104			
			Low-Temperature Convection Section		176			
	10.6		Heater Materials and Mass (Core Only)					
			Radiant Section					
			Material					2-1/4 Cr - 1 Mo
			Mass	kg (lb)	TBD			
			High-Temperature Convection Section					
			Material					304 Stainless Steel
			Mass	kg (lb)	TBD			
			Low-Temperature Convection Section					
			Material					Carbon Steel
			Mass	kg (lb)	TBD

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE

12

DATE

June 21, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
ESG-79-30, Vol III F-59	10.7	Heat Pipe Material					Not Applicable
	10.8	Header Material and Mass		TBD			
		Radiant Section Input					
		Material					
		Mass	kg (lb)				
		High-Temperature Convection Input					
		Material		TBD			
		Mass	kg (lb)				
		High-Temperature Convection Output					
		Material		TBD			
		Mass	kg (lb)				
		Low-Temperature Convection Input					
		Material		TBD			
		Mass	kg (lb)				
	10.9	Insulation					
		Material		TBD			
		Mass	kg (lb)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 13

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
ESG-79-30, Vol III F-60	10. 10		Structure		TBD			
			Material					
			Mass	kg (lb)				
	10. 11		Support		TBD			
			Material					
			Mass	kg (lb)				
	10. 12		Piping		TBD			
			Material					
			Mass	kg (lb)				
	10. 13		Valve (s)		TBD			
			Material		CS			
			Number		1			
			Location					Heater Inlet Piping
			Mass					
			Size (Nominal)	cm (in.)	50.8 (20)			
			Type					Drag Valve
	10. 14		Pump					Not Applicable

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 14

DATE June 21, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-61 ESG-79-30, Vol III	10. 15		Total Heater Mass (Misc. Items)	kg (lb)	TBD			
	10. 16		Furnace Volume	m ³ (ft ³)				
			Radiant Section		1716 (60,555)			
			High-Temperature Convection Section		548 (19,320)			
			Low-Temperature Convection Section		860 (30,360)			
	10. 17		Heater Weather Protection Surface Area	m ² (ft ²)	1595 (17,200)			
	10. 18		Fuel Handling Equipment					
			Type					Direct Feed from Pulverizers, One Pulverizer/Burner Row B&W Type EL 76 or Equivalent Ball and Race Pulverizer
			Number		3			
	10. 19		Structural Design					
			Useful Life	years	30			
			Structural Code					UCB Zone 3
			Pressure Vessel Code					ASME Section I (Other Sections as Applicable)
			Piping Code					ANSI B.1.1

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N00100352

PAGE 15

DATE June 21, 1979

NEW REV	NO.	A ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Structural Design (Cont'd.)					
		Sodium Corrosion Allowance	cm (in.)	0.03 (0.01)			
	10. 20	Combustion Equipment					
		Burners					
		Type					Dual Register
		Number		9			
		Burner Arrangement					Three Horizontal Rows Three Burners/Row, Opposed Firing
	10. 21	Environmental Conditions					
		Wind Velocity	m/sec (mph)	3.5 (8 ave., 55 max)			
		Altitude	m (ft)	730 (2400)			
		Ambient Temperature	°C (°F)				
		Minimum		-20 (-30)			
		Maximum		50 (120)			
		Rainfall	cm (in.)	101.6 (40 ave.)			
		Seismic	g	0.2 horizontal 0.1 vertical			

ESG-79-30, Vol III
F-62

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 16

DATE June 21, 1979

NEW REV	NO.	A ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
ESG-79-30, Vol III F-63	10.	Interfaces					
	22	Sodium Inlet Nozzle	cm (in.)	51 (20)			
		Sodium Outlet Nozzle		51 (20)			
		Vents and Drains (Size and Number)		TBD			
	11.0	Non-Solar Emission Levels	lb/mm Btu				
		NO _x		0.5			
		SO ₂		0.1			
		Particulates		0.03

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 1

DATE June 25, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	B	Operational Characteristics					
	1.0	EPGS Proper					
	1.1	Receiver Operation					
		Gross Turbine Cycle Efficiency	%	43.1			Generator Output
		Net Turbine Cycle Efficiency	%	38.5			Heat Input to Turbine
		Fraction of Turbine Cycle Heat Input	%	100.0			Generator Output — All Aux. Loads
		Supplied by Solar					Heat Input to Turbine
		Gross Cycle Heat Rate	kJ/kW-hr (Btu/kW-h)	8356.8 (7922.6)			
		Net Cycle Heat Rate	kJ/kW-h (Btu/kW-h)	9360.1 (8873.8)			
		Turbine Exhaust Pressure	mm (in.)	50.8 (2.0)			in. of mercury
		Feedwater Temperature	°C (°F)	251 (484)			
		Flow Rate to Turbine	kg/hr (lb/hr)	334,500 (735,900)			
		Auxiliary Loads	kWe	12,000			
		Heliostats and Controllers		2350			
		Receiver Pump		3100			

F-64

ESG-70-30, Vol III

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE

2

DATE

June 25, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-65 ESG-79-30, Vol III			Auxiliary Loads (Cont'd.)					
			Steam Generator Pump		530			
			Boiler Feed Pump		2100			
			Condensate Pump		150			
			Auxiliary Power Requirements	kWe				
			Cooling Tower Fans		850			
			Circulating Water Pumps		1870			
			Miscellaneous Accessories		1055			
			Coal Feeders		0			
			Coal Pulverizers		0			
			F.D. Fan		0			
			I.D. Fan		0			
			P.A. Fan		0			
			G.R. Fan		0			
			SO ₂ and Particulate Removal		0			
			Coal Handling		0			
			Ash Handling		0

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE

3

DATE

June 25, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	1.2	Storage Operation					
		Gross Turbine Cycle Efficiency	%	43.1			
		Net Turbine Cycle Efficiency	%	40.6			
		Fraction of Turbine Cycle Heat Input Supplied by Solar	%	100.0			
		Gross Cycle Heat Rate	kJ/kW-hr (Btu/kW-h)	8356.8 (7922.6)			
		Net Cycle Heat Rate	kJ/kW-hr (Btu/kW-h)	8876.7 (8415.6)			
		Turbine Exhaust Pressure	mm (in.)	50.8 (2.0)			
		Feedwater Temperature	°C (°F)	251 (484)			
		Flow Rate to Turbine	kg/hr (lb/hr)	334,500 735,900			
		Auxiliary Loads	kWe	6555			
		Heliostats and Controllers		0			
		Receiver Pump		0			
		Steam Generator Pump		530			
		Boiler Feed Pump		2100			
		Condensate Pump		150

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W..W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE

4

DATE

June 25, 1979

NEW REV	NO.	B ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Auxiliary Power Requirements (Cont'd.)	kWe				
		Cooling Tower Fans		850			
		Circulating Water Pumps		1870			
		Miscellaneous Accessories		1055			
		Coal Feeders		0			
		Coal Pulverizers		0			
		F.D. Fan		0			
		I.D. Fan		0			
		P.A. Fan		0			
		G.R. Fan		0			
		SO ₂ and Particulate Removal		0			
		Coal Handling		0			
		Ash Handling		0

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 5

DATE June 25, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	B							
	1.3		Nonsolar Operation					
			Gross Turbine Cycle Efficiency	%	43.1			
			Net Turbine Cycle Efficiency	%	38.5			
			Fraction of Turbine Cycle Heat Input Supplied by Solar	%	0.0			
			Gross Cycle Heat Rate	kj/kW-hr (Btu/kW-h)	8356.8 (7922.6)			
			Net Cycle Heat Rate	kj/kW-hr (Btu/kW-h)	9360.1 (8873.8)			
			Turbine Exhaust Pressure	mm (in.)	50.8 (2.0)			
			Feedwater Temperature	°C (°F)	251 (484)			
			Flow Rate to Turbine	kg/hr (lb/hr)	334,500 735,900			
			Auxiliary Loads	kWe	12,000			
			Heliostats and Controllers		0			
			Receiver Pump		1600			
			Steam Generator Pump		530

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER
Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 6

DATE June 25, 1979

NEW REV	NO.	B ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Auxiliary Loads (Cont'd.)					
		Boiler Feed Pump		2100			
		Condensate Pump		150			
		Cooling Tower Fans		850			
		Circulating Water Pumps		1870			
		Miscellaneous Accessories		1055			
		Coal Feeders		TBD			Note: 3700 kWe allocated for balance of plant items
		Coal Pulverizers		TBD			
		F.D. Fan		TBD			
		I.D. Fan		TBD			
		P.A. Fan		TBD			
		G.R. Fan		0			
		SO ₂ and Particulate Removal		150			
		Coal Handling		TBD			
		Ash Handling		TBD

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 7

DATE June 25, 1979

NEW REV	NO.	B ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	2	Nonsolar Energy Fuels					Primary: Pulverized Coal Backup: Oil/Gas
	3	Fuel Characteristics					Primary Fuel Only
		Design Basis Coal-Ultimate Analysis	wt (%)				
		Moisture		14.5			
		Carbon		55.8			
		Hydrogen		4.2			
		Oxygen		11.5			
		Nitrogen		0.9			
		Sulfur		0.6			
		Ash		12.5			
		Chlorine		0.03			
	4	Fuel Heating Value (as fired)	j/kg (Btu/lb)	23.2×10^6 (10,000)			
	5	Fuel Burning Rate	kg/hr (lb/hr)	47,273 104,000			
	6	Nonsolar Discharge Rate	MWt				
		Maximum		TBD			Stack Gas and Other Heat Losses
		Design		33.8

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER
Revision 0

PREPARED BY
W. W. Willcox

APPROVED BY

PAGE 8

WBS NO. N001000352

DATE June 25, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
ESG-79-30, Vol III F-71	7		Nonsolar Discharge Rate (Cont'd.)					
			Minimum		TBD			
			Heater Gas Operating Temperature (In/Out)	°C (°F)				
	8		Maximum		TBD			High-Temperature Convection Section Air Heater Exit
			Design		1199/149 (2190/300)			
			Minimum 20% Load		721/149			
	9		Working Fluid Operating Temperature (In/Out)	°C (°F)	(1330/300)			Sodium
			Maximum		TBD			
			Design		289/593 (550/1100)			
	9		Working Fluid Operating Pressures (In/Out)	MPa (psi)	289/593 (550/1100)			
			Maximum		TBD			
			Design		0.73/0.25 (106/36)			
			Minimum		TBD

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 9

DATE June 25, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-72 ESG-79-30, Vol III	10		Working Fluid Flow Rates	kg/hr (lb/hr)				Sodium
			Maximum		2.5×10^6 (5.5×10^6)			
			Design		2.5×10^6 (5.5×10^6)			
			Minimum		409,900 (1.08×10^6)			
	11		Nonsolar Heat Losses	%				
			@ Maximum Power		TBD			
			Radiation					
			Dry Gas					
			Hydrogen and Moisture in Fuel					
			Moisture in Air					
			Unburned Combustible					
			Other					
			@ Design Power	%	13			
			Radiation		0.2			
			Dry Gas		5.3

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE 10

DATE June 25, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Nonsolar Heat Losses (Cont'd.)					
			Hydrogen and Moisture in Fuel	%	5.4			
			Moisture in Air		-			
			Unburned Combustible		0.5			
			Other		1.5			
			@ Minimum Power	%	16.6			
			Radiation		1.2			
			Dry Gas		8.0			
			Hydrogen and Moisture in Fuel		5.4			
			Moisture in Air		-			
			Unburned Combustible		0.5			
			Other		1.5			
	12		Nonsolar Startup and Shutdown Characteristics		TBD			
	13		Continuously Controllable Heat Output Nonsolar Energy Source (Heater)	MWt	53-265			
	14		Miscellaneous Heater Data					
			Total Maximum Heat Input from Fuel	MWt	304.7			
			Total Air	%	115

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS NO. N001000352

PAGE

11

DATE

June 25, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
F-74 ESG-79-30, Vol III			Miscellaneous Heater Data (Cont'd.)					
			Minimum Secondary Air Temperature	$^{\circ}\text{C}$ ($^{\circ}\text{F}$)	260 (500)			
			Heat Input/Burner	MWt	33.9			
			Radiant Section Heat Absorption	MWt	132.5			
			Radiant Section Flux Density	MWt/m ²	0.14			
			Convection Section Heat Absorption	MWt	0.14			
			Convection Section Flux Density	MWt/m ²	0.017			
			Air Heater Load	MWt	26.4			
			Hot Gas Flow Rate	kg (hr) (lb/hr)	454,540 (1 x 10 ⁶)			
			Liberation Rate	kJ/hr-m ³ (Btu/hr-ft ³)	670,000 18,000			
			Flue Gas Temperature:	$^{\circ}\text{C}$ ($^{\circ}\text{F}$)				
			Leaving Radiant Section		1199 (2190)			
			Leaving H.T. Convection		788 (1450)			
			Leaving L.T. Convection		371 (700)			
			Leaving Air Heater		149 (300)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electric Power Generation
Subsystem 100 MWe, SM 1.4

NUMBER

Revision 0

PREPARED BY

W. W. Willcox

APPROVED BY

WBS. NO. N001000352

PAGE 12

DATE June 25, 1979

NEW REV	NO.	B	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
			Miscellaneous Heater Data (Cont'd.)					
			Air Temperature:					
			Ambient		28 (83)			
			Leaving Air Heater		204(400)			
			Sodium Temperature:					
			Inlet		288 (550)			
			Leaving L.T. Convection		402 (755)			
			Leaving Radiant Section		553 (1028)			
			Leaving H.T. Convection		593 (1100)			

HYBRID PROGRAM
STEAEK INPUTS

3.2.1 DATA REQUESTED

3.2.1.1 Collector Subsystem

a. X-Y coordinates of each heliostat or heliostat cell: see grids (TBD). Number of heliostats/cell - see Mid-Term Report (Pages 5-26 and 5-41).

b. Field Efficiency Values $F(\theta_a, \theta_e)$

		θ° elevation					
		5	15	25	45	65	89.5
θ° azi	0	.311	.506	.609	.662	.672	.678
	30	.310	.491	.592	.660	.667	.675
	60	.300	.472	.578	.657	.660	.676
	75	.290	.462	.570	.644	.648	.677
	90	.288	.463	.561	.631	.643	.678
	110	.289	.431	.539	.613	.636	.679

These came from John Raetz for the ACR field - 100 MWe net.

c. Relative wind speed effective values $G(W)$ vs. windspeed W .

$G(W)$	1.005	1.004	1.003	0.998	0.966
$W(m/sec)$	0	3	7	11	16

d. Collector field reflective surface area, S_f (square meters).

	S.M. = .8	S.M. = 1.4
$S_f(m^2)$	416729	663205

e. Maximum and minimum temperatures for heliostat operation:

	$^{\circ}\text{C}$	$^{\circ}\text{F}$
Maximum	50	122
Minimum	0	32

f. Minimum sun elevation for collector field operation = 0°

g. Maximum windspeed for heliostat operation:

16 m/sec (36 mph)

h. Auxiliary power requirements for collector field:

	Standby =	$8.5 \times 10^{-8*}$ $6.12 \times 10^{-7**}$	MWe/m ² of S_f
i.	Tracking =	7.2×10^{-6} $8.97 \times 10^{-7**}$	MWe/m ²
	Starting =	3.73×10^{-5}	MWe/m ²

*Based on 100 watt-hours daily average energy and 24 hours.
**ACR.

3.2.1.2 Receiver Subsystem

- Receiver proportional efficiency, $\epsilon_r = 0.95$.
- Receiver subtractive loss parameter (does not include reflective loss (see ϵ_r)).

L_r (T,W)		Windspeed (m/s)/mph					
$^{\circ}\text{C}$	$(^{\circ}\text{F})$	0/0	3/6.7	7/15.7	11/24.6	16/35.8	
-20	(-4)	4.548E-2	4.548E-2	4.7E-2	5.230E-2	5.932E-2	
Temp. 0	(32)	4.548E-2	4.548E-2	4.7E-2	5.230E-2	5.932E-2	
$^{\circ}\text{C}$ ($^{\circ}\text{F}$) 20	(68)	4.548E-2	4.548E-2	4.7E-2	5.230E-2	5.932E-2	
40	(104)	4.548E-2	4.548E-2	4.7E-2	5.230E-2	5.932E-2	
60	(140)	4.548E-2	0.04548	0.047	5.230E-2	5.932E-2	

- Receiver Size, R_s (MW):

$$SM = 0.8$$

$$SM = 1.4$$

$$R_s = 208 \text{ MWt}$$

$$R_s = 364$$

- Hr, Receiver Heat Capacity Term:

$$Hr = \frac{(\text{MWt-hr})}{Hr \times R_s} = \frac{\text{Energy to heat receiver to operating conditions}}{\Delta t \text{ hrs for cold start x receiver size}}$$

Basis for determination of Hr:

$\Delta \text{time} = 1/2 \text{ hr}$; cooldown to 0°F , heat up to 450°F ; $\Delta \text{temp} = 450^{\circ}\text{F}$

$$Hr = \frac{Q}{\Delta \text{time} \times R_s}$$

$$Q = \frac{M \times Cp \times \Delta \text{temp}}{3.412 \times 10^6} \quad \text{MW}_t\text{-hrs}$$

Mass of receiver to be cycled:*

	SM = 0.8	SM = 1.4
Tubes tons	20	24.5
Panels	10	36
Headers	7.2	11
	30 tons - 60,000 lb	60.5 tons - 121,000 lb

$$C_p = 0.1$$

$$M \times C_p = \quad 6,000 \quad 12,100$$

*Since sodium is drained, only receiver mass to be cycled consists of panels and tubes:

$\Delta \text{temp} (^{\circ}\text{F})$	450	450
$Q(\text{MW}_t\text{-hrs})$	0.7913	1.596
$\Delta \text{time}(\text{hrs})$	0.5	0.5
$R_s \text{ MW}_t$	208	364
$\text{Hr}(\text{MW}_t/\text{MW}_{\text{size}})$	7.608×10^{-3}	8.769×10^{-3}

e. Receiver Cooldown Parameter, α_r (hours⁻¹):

$$\alpha_r = 0.5$$

Note: $X(t) = X_1 \times e^{-\alpha_r(t-t_1)}$, t = time
(t_1 = time of receiver shutdown)

for slower cooldown, $\alpha_r < 0.5$

f. Time required for cold start:

$$T_{cs} = 0.5 \text{ hr}$$

- g. Time between initiation of turbine synchronization with receiver power and completion of startup:

$$(t_3 - t_2) = 0.167 \text{ hr (10 minutes)}$$

- h. Receiver minimum power requirements (% of receiver thermal power) = 0% (Receiver shutdown and drained).

- i. Auxiliary Power Requirements ($\text{MWe}/\text{MW}_{\text{th}}$ of receiver):

	SM = 0.8	SM 1.4
Heliostats & Controllers	330	2,350
Receiver Pump	1,326	3,100
Boiler Feed Pump	2,100	2,100
Condensate Pump	150	150
Cooling Tower Fans	850	850
Circ. H ₂ O Pump	1,870	1,870
Misc Access	1,055	1,055
FD, TD, PA, and GR Fans	2,600	
SO ₂ & Particulates Removal	150	
Steam Generator Pump		530
Coal & Ash Handling	360	
	<u>10,791 KWe</u>	<u>12,005</u>
	10.79 MWe	$\frac{\text{MWe}}{R_s} = \frac{12}{364} = 0.033$
	$\frac{\text{MWe}}{R_s \text{ MWt}} = \frac{208}{208}$	
	$= \frac{10.791}{208} = 0.0518$	

3.1.2.3 Nonsolar Subsystem (Coordinate with B-W)

a.

b.

c.

SM = 0.8

SM = 1.4

$R_s =$

260 MWt

260 MWt

d. Hr

e. α_r

f. T_{cs}

g.

h. Nonsolar minimum

20%

0 to 20%

i. Nonsolar Auxiliary Power

SM = 0.8

SM = 1.4

Mid-Term Report

Total Aux

10.730 MWe

11.855

Page E-73

See Page F-67

$\frac{MWe}{R_s} =$

.0413

.0456

3.2.1.4 Piping

Piping subtractive loss parameter values, $L_p (T)$

$$L_p(T_{amb}) = \frac{\text{Power Loss}}{R_{size}}$$

$$\text{Power Loss} = \sum h A t \quad \text{from all piping}$$

$$A = \pi \left(\frac{d_{\text{outside}} + 2\Delta X_{\text{insulation}}}{12} \right) L$$

$$h = 1 \text{ Btu/hr/42}^{\circ}\text{F}$$

$$\Delta t = 130 = 130^{\circ}\text{F} - 0 = 130^{\circ}\text{F}$$

$$\text{Power Loss} = \frac{\pi h \Delta t}{12 \times 3.412 \times 10^6} \sum (d_o + 2\Delta X) L_{\text{feet}}$$

$$SM = 0.8$$

$$SM = 1.4$$

Downcomer	HT: (20+16)x500 = 18,000	HT: (12.75+10) 760 = 17,290
Riser	LT: (20+10)x500 = 15,000	LT: (24+6) 760 = 22,800
Horizontal		
Piping:	LT: (24+12) 500 = 18,000	HT: (20+16)x70 = 2,520
	HT: (20+16) 700 = 25,200	
	LT: (20+10) 500 = 15,000	LT: (2.4+6)x225 = 1,890
	HT: (14+12) 60 = 1,560	HT: (14+12)x40 = 1,040
	LT: (10+10) 100 = 2,000	LT: (10.8+10)x50 = 1,040
	LT: (8+10) 200 = 3,600	HT: (20+16)x80 = 2,880
	$\sum$ 98,360	$\sum$ 49,460

Ambient Temp	T °C	-20	0	20	40	60
	°F	-4	32	68	104	140

$$q/L = \frac{2\pi(t_{sod} - t_{amb})}{\frac{\ln(r_3/r_2)}{k_{pipe}} + \frac{\ln(r_4/r_3)}{k_{insul}} + \frac{12}{r_4 h_1}}$$

$$q = \left[\frac{1}{\frac{\Delta X_{pipe}}{k_{pipe}} + \frac{\Delta X_{ins}}{k_{ins}} + \frac{1}{I}} \right] \frac{2\pi r_o}{12} L (t_{sod} - t_{amb})$$

can be neglected

$$k_{ins} = 0.5$$

$$SM = 0.8$$

$$SM = 1.4$$

HT:

$$q/(t_{sod} - t_{amb}) = \sum \left[\frac{1}{\frac{\Delta X_{ins}}{12k_{ins}} + 1} \right] \frac{2\pi r_o}{12} L_{ft}$$

Pipe	ΔX_{ins}	r_o	L
Downcomer	8	18	500
Horizontal	8	18	700
	6	18	60

$$\Sigma HT = 840.46$$

Pipe	ΔX_{ins}	r_o	L
Downcomer	5	11.38	760
Horizontal	8	18	70
	6	13	40
	8	18	80

$$\Sigma(q/\Delta t) HT = 608.58$$

LT:

Riser	5	15	500
Horizontal	6	18	500
	5	15	500
	5	10	100
	5	9	200

$$\Sigma LT = 1,426.98$$

	3	15	760
	3	4.2	225
	5	10.4	50

$$\Sigma LT = 1,106.48$$

$$L_p(t_{amb}) = \frac{q_{MW}}{R_s} = \frac{\sum_{HT} \times (1100 - t_{amb}) + \sum_{LT} \times (550 - t_{amb})}{3.412 \times 10^6 R_s}$$

$$SM = 0.8$$

$$R_s = 208 \text{ MWt}$$

t_{amb}	$^{\circ}C =$	-20	0	20	40	60
	$^{\circ}F =$	-4	32	68	104	140
L_p						
(t_{amb})	$=$	2.42×10^{-3}	2.31×10^{-3}	2.19×10^{-3}	2.08×10^{-3}	1.96×10^{-3}

$$SM = 1.4$$

$$R_s = 364 \text{ MWt}$$

t_{amb}	$^{\circ}C =$	-20	0	20	40	60
	$^{\circ}F =$	-4	32	68	104	140
L_p						
(t_{amb})	$=$	1.03×10^{-3}	9.85×10^{-4}	9.35×10^{-4}	8.85×10^{-4}	8.36×10^{-4}

MWt/MWt R_s units of L_p

3.2.1.5 Energy Storage Subsystem

For SM = 1.4 System.

- a. Maximum Chg Rate = 364 MWt.
- b. Maximum Discharge Rate = 300 MWt design maximum.
- c. Maximum Storage Capacity

$$V_{\text{Hot Tank}} = 353430 \text{ ft}^3 \text{ maximum}$$

Assume 5% minimum ullage

$$V_{\text{Na}} = 335758.5 \text{ ft}^3$$

$$M_{\text{Na}} = 17.46 \times 10^6 \text{ lb}$$

$$@ \gamma = 52 \text{ \#/ft}^3$$

$$Q_{\text{MWt-hr}} = \frac{M C_p}{3.412 \times 10^6} (1100 - 550) = \underline{\underline{844.3 \text{ MWt-hr}}}$$

- d. Standby Heat Loss Factor

$$X = 100 \frac{Q_{\text{Lost}}}{Q_{\text{Max Discharge}}} = \frac{.3 \times 100}{300} = 0.1\%$$

- e. Storage Loss Factor

$$\alpha_L = 1 - \frac{.3 \times 15 / 60}{844.3} = .99991$$

- f. Charging Efficiency Quadratic Coefficients for hot tank storage:

$$C_0 = 1$$

$$C_1 = 0$$

$$C_2 = 0$$

g. Discharging Efficiency Quadratic Coefficients:

$$d_0 = 1$$

$$d_1 = 0$$

$$d_2 = 0$$

h. Standby Thermal Power Requirements from Storage - Turbine Sealing Steam and Trace Heating:

$$TSS = 0.381 \text{ MWt}$$

i. $A = B = 0$; Storage Tank

System does not use charging or discharging heat exchangers.

j. Minimum Charge Rate = 10% or 0.10.

k. Minimum Discharge Rate = 10% or 0.10.

3.2.1.6 EPGS

a. Turbine Shell Cooldown Parameters

$$\alpha = .0216 \text{ hr}^{-1}$$

$$\beta = .00571 \text{ hr}^{-1}$$

b. Turbine operating factor

$$\tau_{\text{storage}} = 0$$

$$\tau_{\text{nonsolar}} = 0$$

$$\tau_{\text{receiver}} = 0$$

c. Turbine Synchronization Delays and Ramp Rates

See attached Table.

d. Maximum thermal power to turbine from the receiver 260 MWt.

e. Maximum thermal power to turbine from storage 300 MWt.

f. Maximum thermal power to turbine from nonsolar 265 MWt.

g. Minimum thermal power to turbine from receiver TMFR = 0; 0%.

h. Minimum thermal power to turbine from storage TMFS = 0; 0%.

TABLE FOR SYNCHRONIZATION
DELAYS AND RAMP RATES

<u>Type of Start</u>	<u>Cold Start</u>	<u>Warm Start</u>	<u>Hot Start</u>
Initial Pressure	>40% Rated	>40% Rated	>40% rated
Initial Temperature	371°C (700°F)	371°C (700°F)	Max. Obtainable
1. Accelerate to 1000 rpm	(250 rpm/min.) 4 min	(250 rpm/min.) 4 min.	(500 rpm/min.) 2 min.
2. Hold at 1000 rpm (Check Vibration)	10 min.	10 min.	5 min.
3. Accelerate to 3550 rpm	(250 rpm/min.) 10 min.	(500 rpm/min.) 5 min.	(500 rpm/min.) 5 min.
4. Synchronize Generator and Apply 5MW Load	-	-	-
5. Hold at 5 MW (to Cool Exhaust)	30 min.	15 min.	Not Appl.
6. Load Generator to Rated Load	(1/2%/min.) 190 min.	(1-1/2%/min.) 63 min.	(3%/min.) 33 min.
7. Total Time - Acceleration to Rated Load	244 min. (4 hr-4 min.)	97 min. (1 hr-37 min.)	45 min.

Source: General Electric Co. (GEK 27064A)

i. Minimum Thermal Power to Turbine from Nonsolar

If coal fired - 20% minimum

If oil fired - 10% minimum

j. Auxiliary Power Scale Factors: SM = 0.8 SM

α Receiver .0518 .03
 α Nonsolar .0413 .045
 α Storage DNA; $\frac{Aux = 6.555}{364} = .018$

k. Standby Auxiliary Thermal Power Requirements

7.8 MWt

l. Standby Auxiliary Electrical Power Requirements

Assumed 25% of Auxiliary Power = 3 MWe

m. Gross EPGS efficiency values ϵ_r as a function of T_{wb} (wet bulb temperature) and X mass flow fraction - Operation from receiver:

T_{wb} °C	0	5	10	15	20	25
°F	32	41	50	59	68	77
X						
.25	.404	.401	.396	.388	.378	.367
.5	.433	.433	.430	.424	.418	.410
.75	.437	.437	.436	.434	.431	.424
1.0	.435	.435	.435	.435	.434	.430

n. Same as m.

o. Same as m.

APPENDIX G
ELECTRIC POWER GENERATION SUBSYSTEM P&I DIAGRAM

ESG-79-30, Vol III

G-1

APPENDIX H
0.8 SOLAR MULTIPLE P&ID

ESG-79-30, Vol III

H-1

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

APPENDIX I
1.4 SOLAR MULTIPLE P&ID

ESG-79-30, Vol III

I-1

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Continued
on next
page

T-2
HIGH TEMPERATURE SODIUM TANK
9460 m³ (2.5 x 10⁶ GAL)
593°C (1100°F)
0.0069 MPa (1 PSIG) ULLAGE PRESSURE
AUSTENITIC SS
ASME SECTION VIII, DIV. 1

P-2
STEAM GENERATOR PUMP
76M (250 FT) TDH
0.95 m³/sec (15,000 GPM)
NPSH 9.1M (30 FT)
0.56MW (750 HP)
593°C (1100°F)
1.5 - 3.7M (5 - 12 FT)
AUSTENITIC SS
ASME SECTION VIII - DIV. 1

X-1
EVAPORATOR
HEIGHT 29.7m (95 ft)
SHELL DIAMETER 1.27m (50 in)
376°C (706°F) SATURATED STEAM OUT
13.79 MPa (2000 PSIA) STEAM
146.0 MW (4.98 x 10⁶ BTU/h)
2-1/4 Cr-1 Mo
ASME - SECTION VIII, DIV. 1

X-2
SUPERHEATER
HEIGHT 27.7m (91 ft)
SHELL DIAMETER 0.76m (30 in)
538°C (1000°F) STEAM OUT
13.4 MPa (1950 PSIG) STEAM
74.0 MW (2.53 x 10⁶ BTU/h)
AUSTENITIC SS
ASME - SECTION VIII - DIV. 1

X-3
REHEATER
HEIGHT 20.1m (66 ft)
SHELL DIAMETER 0.81m (32 in)
538°C (1000°F) STEAM OUT
2.07 MPa (300 PSIG) STEAM
40.0 MW (1.36 x 10⁶ BTU/h)
AUSTENITIC SS
ASME - SECTION VIII - DIV. 1

LEGEND	
DESCRIPTION	
2.7 MPa (400 PSI)	
0.84 MPa (125 PSI)	
304 SS	
CARBON STEEL	
POWER PIPING CODE ANSI B31.1	
ASME B & PV CODE SECT. VIII	
AMERICAN PETROLEUM INST. STD.	
TBD

- NOTES: UNLESS OTHERWISE SPECIFIED ON THIS DRAWING:
1. PIPES, VESSELS & EQUIPMENT CONTAINING SODIUM ARE HEAT TRACED.
 2. SODIUM DENSITY;
287°C (550°F) - 881 kg/m³ (55 LB/FT³)
593°C (1100°F) - 809 kg/m³ (50.5 LB/FT³)
 3. STEAM SYSTEM INSTRUMENTATION NOT SHOWN.
 4. FOR LEGEND & SYMBOLS REFER TO STANDARD DWG NP 773-0001.
 5. PROCESSED VALVE NUMBERS REFER TO VALUES GIVEN IN THE DESIGN DATA SHEETS - APPENDIX "A"

Figure I-1. Solar Central Receiver,
Hybrid Power System
(430 MWe - SM 1.4)
(Dwg N001000352)

APPENDIX J
SYSTEM RESPONSE TO LOSS OF P-1 PUMP
AND
LOSS OF SUN TRANSIENTS

ESG-79-30, Vol III

J-1

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

1.0 INTRODUCTION

1.1 SOLAR MULTIPLE = 1.4

Storage subsystem sizing and thermal performance analysis were discussed in Sections 3.4.2 and 3.4.4, respectively, of the main body of the report. For the plant conceptual design incorporating 3 h thermal storage capacity with a 1.4 solar multiple the operation of the plant is always from thermal storage independent of whether the thermal energy is provided from the fossil heater, the receiver, or combinations of both. This is true since the fossil heater and the solar receiver are in parallel. The hot storage tank is effectively located between the thermal energy source and the steam generator system. This arrangement provides complete buffering or isolation of the steam generator system from the fossil heater and/or receiver. This isolation provides for operation of the steam generators free of transients resulting from loss of P = 1 pump or sharp-edged cloud passage. This appendix deals primarily with the 0.8 solar multiple design.

1.2 SOLAR MULTIPLE = 0.8

The plant conceptual design with a solar multiple of 0.8 does not provide thermal storage capacity, as such, but some degree of protection against transients is provided by a buffering system of 6 each T-1 cold tanks at 288°C (550°F) and T-2 hot tanks at 593°C (1100°F). These tanks are each approximately 2.44 m (8 ft) diameter by 6.1 m (20 ft) high and are located in series with the solar receiver as shown in the process diagram of Figure J-1. The sizing of these tanks is determined by consideration of the response required in the event of (1) failure of the P-1 pump; and (2) passage of a sharp-edged cloud (or loss of sun transient). Sizing of these tanks and performance under the transients described above is discussed in more detail in the following sections.

9315-4

Figure J-1. Process Diagram (0.8 SM)

2.0 CONTROL LOOPS — NORMAL OPERATION

The plant is designed for fixed sodium temperatures and variable flow rates to partition the energy flow from the receiver and the fossil-fired sodium heater. The solar insulation sets the ratio between these two energy sources. It is planned to operate the plant primarily in the "base load mode," however, reduced load operation is allowed at dispatcher option. At summer solstice noon, the receiver supplies 80%, and the sodium heater 20% of full power. Referring to Figure J-1, the pump, P-1, runs at a constant speed, and the receiver outlet temperature is maintained constant by modulating the control valves (V-301 through V-318). Each receiver-panel outlet header is equipped with a temperature sensor and control loop for this purpose. For normal operation, the sodium level (Level Control No. 1) in Tank T-2 is fixed by modulating the Control Valve V-105. The signal from the Flowmeter FM-104 sets the furnace heat rate in inverse relation to the flow-through Line 104 at rates of change limited by furnace controls. The heater outlet sodium temperature is fixed by modulating Valve V-112 in accord with the outlet sodium header temperature sensor. For example: incrementally, as the receiver power decreases, the valves, V-301 through V-318, close. The level in T-2 drops signaling V-105 to close restoring the level in T-2. This decreases the flow in FM-104 which signals the heater to increase in heat rate. As the furnace power increases, the furnace outlet temperature increases which opens V-112 restoring the furnace outlet to 1100°F. A reverse sequence takes place on an increase of receiver power.

3.0 TRANSIENTS

3.1 LOSS OF P-1 RECEIVER PUMP

In the event the P-1 pump fails and both the receiver control valves and the heliostats fail neutral, the relative motion of the sun will drift the image off the receiver, reducing the input power with time (Figure J-2). At the same time, the net head difference between the hot and cold buffer tanks continues the flow through the receiver. The flow decreases with time (Figure J-3) and approximately matches the power decrease so that the receiver outlet temperature remains approximately constant without control action. Thus, passive protection against a loss of pump accident is provided for. A more quantitative system performance is discussed in Section 3.1.1 and shown in Figure J-4.

In the more usual case, the receiver control valves will continue to function, and the heliostat field power will be reversed, thus adding additional margin of protection as well as diversity and redundancy to the system. Backflow through the supply line is prevented by means of the stop check valve, V-100. Following the transient, the heater is shut off, and the plant is tripped and secured for extended shutdown.

Figure J-2. Power vs Time

Figure J-3. Flow vs Time

Figure J-4. Buffer System Response to Loss of P-1 Pump

3.1.1 Performance Analysis - T-1/T-2 Buffer System

Referring to Sketch 1,

$$H = \frac{144}{\gamma_{\text{fluid}}} (p_1 - p_2) + h,$$

where H is the net head driving flow through valves and receiver panels.

For mass continuity,

$$-A_1 \frac{dh_1}{dt} = A_2 \frac{dh_2}{dt} = Q$$

$$dh_1 = -\frac{1}{A_1} Q dt$$

$$dh = dh_1 - dh_2$$

$$dh = \left(1 + \frac{A_1}{A_2}\right) dh_1$$

Flow velocity through valves & panels

$$w = \sqrt{2gH}$$

$$Q_{\text{flow}} = aw, \quad a = \text{flow area}$$

$$Q^2 = C_1 H, \quad C_1 = 2ga^2 = \frac{Q^2}{H}$$

$$2Q dQ = C_1 dH$$

$$dH = \frac{2Q}{C_1} dQ$$

$$\text{but } H = C_2 (P_1 - P_2) + h, \quad C_2 = \frac{144}{\gamma_{\text{fluid}}}$$

$$dH = C_2 d(P_1 - P_2) + dh$$

$$2 \frac{Q dQ}{C_1} = C_2 d(P_1 - P_2) + \left(1 + \frac{A_1}{A_2}\right) dh_1$$

$$2 \frac{Q dQ}{C_1} = C_2 d(P_1 - P_2) + \left(1 + \frac{A_1}{A_2}\right) \left(-\frac{1}{A_1} Q dt\right)$$

$$\left\{ \frac{2 dQ}{C_1} = \frac{C_2}{Q} d(P_1 - P_2) - \left(\frac{A_1 + A_2}{A_1 A_2}\right) dt \right\} \quad \underline{\text{EQU 1}}$$

With tanks not vented, P_1 and P_2 are functions of the initial pressure values and the changes in ullage volumes, V_1 and V_2

Assuming adiabatic expansion in tanks 1 and adiabatic compression in tanks 2,

$$pV^k = \text{constant}$$

Differentiating,

$$\frac{dp_1}{dV_1} = -C_3 K V_1^{-(k+1)}, \text{ where } C_3 = (p_1 V_1^k)_0$$

$$\frac{dp_2}{dV_2} = -C_4 K V_2^{-(k+1)}, \text{ where } C_4 = (p_2 V_2^k)_0$$

$$\text{but, } V_1 = V_{1,0} - A_1 dh_1$$

$$V_2 = V_{2,0} - A_2 dh_2$$

$$\text{and } A_1 dh_1 = -Q dt$$

$$A_2 dh_2 = Q dt$$

Substituting,

$$d(p_1 - p_2) = -C_3 K V_1^{-(k+1)} Q dt - C_4 K V_2^{-(k+1)} Q dt$$

$$\frac{C_2}{Q} d(p_1 - p_2) = -C_2 K \left[C_3 V_1^{-(k+1)} + C_4 V_2^{-(k+1)} \right] dt$$

Substituting for $\frac{C_2}{Q} d(p_1 - p_2)$, Equ 1 becomes

$$\boxed{dQ = -\frac{C_1}{2} \left[C_2 K \left\{ C_3 V_1^{-(k+1)} + C_4 V_2^{-(k+1)} \right\} + \frac{A_1 + A_2}{A_1 A_2} \right] dt} \quad \text{EQU 2}$$

With $A_1 = A_2 = \text{constant with tank height}$
(that is, cylindrical tanks as opposed to
shaped tanks), Equ 2 can be integrated
as follows,

$$\Delta Q = -\frac{C_1 C_2 C_3}{2} K \left(\bar{V}_1 \right)^{-(k+1)} \Delta t - \frac{C_1 C_2 C_4}{2} K \left(\bar{V}_2 \right)^{-(k+1)} \Delta t - \frac{C_1}{A_1} \Delta t \quad \text{Eqn 3}$$

Note that,

$$V_1 = V_{1, \text{initial}} + \int Q dt = V_{1_0} + \int \Delta V$$

$$V_2 = V_{2, \text{initial}} + \int Q dt = V_{2_0} - \int \Delta V$$

and,

$$\bar{V}_1 = (V_{1_t} + V_{1_{t+\Delta t}}) \div 2$$

for any t

$$\bar{V}_2 = (V_{2_t} + V_{2_{t+\Delta t}}) \div 2$$

for any t

$$Q = Q_0 - \int dQ = Q_0 - \sum \Delta Q$$

Equation 2 can be integrated using the differentials of Eq 3 with small enough time steps, Δt . This integration has been programmed on the Hewlett-Packard HP-97 for several cases of initial conditions and system assumed sizes.

Table J-1 shows the tabular values describing the cases run. The results are plotted on Figure J-4.

Although this does not represent the final design, it has been demonstrated that such a system is feasible. Final sizing and performance analysis will more precisely match the power drop off and the actual system when implemented will provide for adequate controls to field adjust the performance.

3.2 LOSS OF SUN TRANSIENT

In the loss of sun transient, a sharp-edged cloud is assumed to pass across the field at a velocity of 20 m/s (65 ft/s). This totally shuts off the power to the receiver in about 100 s. To maintain fixed power to the steam generator requires that the sodium heater pick up this load. The maximum ramp rate of the sodium heater is approximately 25% per minute. The heater alone cannot meet the cloud transient requirement. The difference between the steam generator energy requirement and the ability of the heater to delivery it is made up by flowing sodium from Tank T-2 through the steam generator and into Tank T-1.

Incrementally, as the cloud cover traverses the field at 20 m/s and the power level to the receiver drops at a corresponding rate, the valves, V-301, through V-318, close, tending to lower the sodium level in Tank T-2. As the level drops, the Control Valve V-105 closes, the flow in FM-104 decreases, and the heater power ramps up at the maximum rate allowed by its control loop. The maximum closing rate of Valve V-105 is preset to correspond to the maximum allowed heater power ramp. Consequently, this valve is unable to close fast enough to maintain the sodium level in the Tank T-2. When the sodium level in this tank drops about 6 in., the second level device, LIC No. 2, is actuated. When this level device is actuated, it switches the control from FM-104 to FM-100, initiates a pre-programmed heater ramp to full power, and sets the heliostats on the standby. The signal from FM-100 controls V-105 to provide a constant flow through the flowmeter FM-100. As the heater ramps up, Valve V-112 opens to maintain the heater sodium outlet temperature constant. This increases the flow through

TABLE J-1
SYSTEM SIZING PARAMETERS

	Run ①	②	③	④ Isothermal	⑤
$H_0 = \left[\frac{144}{Y} (P_1 - P_2) + h \right]_0$	101.94	93.28	99.24	101.94	88.60
h_0^{ft} = initial fluid level difference	6.67	-1.99	+3.97	6.67	-6.67
$C_1 = Q_0^2 / H_0$	.1096	.120	0.113	.1096	.1261
$C_2 = \frac{144}{Y}$	2.722	2.722	2.722	2.722	2.722
$C_3 = (P_1 V_1^K)_0 \rightarrow \text{C}$	8.25×10^5	16.079×10^5	16.079×10^5	1.67×10^4	2.6246×10^6
$C_4 = (P_2 V_2^K) \rightarrow \text{D}$	7.875×10^5	3.323×10^5	8.46×10^5	1.006×10^4	2.4746×10^5
$C_5 = \frac{C_1 C_2 C_3^K}{2} \text{ argon} \rightarrow \text{E}$	2.055×10^5	4.082×10^5	4.129×10^5	2.5×10^3	7.52×10^5
$C_6 = \frac{C_1 C_2 C_4^K}{2} \rightarrow \text{F}$	1.9617×10^5	8.436×10^4	2.1728×10^5	1.5×10^3	7.09×10^4
$\bar{\gamma}_{Na} = 52.9 \text{ lb/ft}^3$	52.9	52.9	52.9	52.9	52.9
$\frac{C_1}{A_1 - A_2} \rightarrow \text{G}$	2.1802×10^{-3}	2.222×10^{-3}	2.248×10^{-3}	2.2×10^{-3}	2.508×10^{-3}
$Q_0 \rightarrow \text{H} \text{ ft}^3/\text{s}$	3.342	3.342	3.342	3.342	3.342
$Q_0 \text{ gpm/0, 6 tanks}$	1500	1500	1500	1500	1500
$V_{10} \rightarrow \text{I}$	335.27	500	500	335.27	670.5
$V_{20} \rightarrow \text{J}$	670.54	400	700	670.54	335.27
K	1.67	1.67	1.67	1	1.67
KH $\rightarrow \text{K}$	2.67	2.67	2.67	2.0	2.67
$P_{10} \text{ psia}$	50	50	50	50	50
$P_{20} \text{ psia}$	15	15	15	15	15
$\Delta t \text{ increment} \rightarrow \text{L} \text{ (s)}$	4	4	4	4	4

FM-100 which signals V-105 to close, reducing the flow through FM-100 to normal. This process continues until the sodium heater is up to full power and the receiver is drained and secured. Restart of the receiver is at the discretion of the operator and is done manually, because sequencing of the operations depends on the duration of the cloud cover. The sizing diagram for the Tank T-2 is shown in Figure J-4.

The shaded area shown in Figure J-5 and identified as the minimum buffer requirement represents a total volume of 12,600 gal (9,000 gpm for 1.4 min) and translates to a total level change of approximately 5.6 ft for each of the six T-2 hot tanks. The hot tanks normally operate with about 60 to 79% ullage (corresponding to 8 to 6 ft fluid level) and thus contain sufficient sodium to accommodate the loss of sun transient.

4.0 CONCLUSION

The control system as designed provides a constant temperature to the steam generator system under conditions of variable flow (or power) rates.

The buffer system of T-1 and T-2 tanks also provides passive protection against (1) loss of P-1 pump and (2) loss of sun (cloud passage) transients. In the P-1 pump failure case where the power is not lost (except for the pump failure itself) the control system provides a measure of redundancy through the continued operation of the receiver control valves and reversal of the heliostat field power.

Figure J-5. 0.8 5M Thermal Buffer Sizing for Loss of Sun Transient

APPENDIX K
0.8 AND 1.4 SOLAR MULTIPLE STEAEC INPUT DATA

ESG-79-30, Vol III

K-1

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem Solar
Multiples 0.8 & 1.4
STEAEK - Input

NUMBER

PREPARED BY

APPROVED BY

WBS NO.

PAGE 1

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			

3.2.1 DATA REQUESTED - INPUT FOR SOLAR
THERMAL ELECTRIC MANUAL ENERGY
CALCULATOR - STEAEK

Note: For definitions of sym-
bols see SAND 77-8278,
January 1978. See
Note Page 21

3.2.1.1 Collector Subsystem

a. Number of heliostats/cell

See Figures 5.2-8 and 5.2-22

b. Field Efficiency Values $F(\theta_a, \theta_e)$

From J. Raetz for ACR Field -
100 MWe Net

		θ_e^{sun} elevation = θ_e					
		5	15	25	45	65	89.5
θ_a^{sun} azimuths = θ_a	0	.311	.506	.609	.662	.672	.678
	30	.310	.491	.592	.660	.667	.675
	60	.300	.472	.578	.657	.660	.675
	75	.290	.462	.570	.644	.648	.677
	90	.288	.463	.561	.631	.643	.673
	110	.289	.431	.539	.613	.636	.679

c. Relative wind speed effective
values $G(W)$ vs windspeed W

W(m/sec)	$G(W)$
0	1.005
3	1.004
7	1.003
11	0.998
16	0.966

ESG-79-30, Vol III K-2

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem Solar
Multiples 0.8 & 1.4
STEAC - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE

2

WBS NO.

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		d. Collector field reflective surface area, S_f (square meters)					
		S_f for S.M. = .8	m ²	416729			
		S_f for S.M. = 1.4	m ²	663205			
		e. Maximum and minimum temperatures for heliostat operation:					
		Maximum	°C	50			
		Minimum	°C	0			
		f. Minimum sun elevation for collector field operation	degrees	0			
		g. Maximum windspeed for heliostat operation:	m/s	16			
		h. Auxiliary power requirements for collector field:					
		When on Standby =	MWe/m ² of S_f	$8.5 \times 10^{-8*}$ $6.12 \times 10^{-7**}$			
		<p>* Based on 100 watt-hours daily average energy and 24 hours. **ACR.</p>					

ESG-79-30, Vol III

K-3

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem Solar
Multiples 0.8 & 1.4
STEAEC - Input

NUMBER

PREPARED BY

APPROVED BY

WBS NO.

PAGE

3

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEM- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		3.2.1.1 - Continued					
		i. Auxiliary power requirements for collector field when on:					
		Tracking =	MWe/m ²	7.2×10^{-6} $8.97 \times 10^{-7**}$			
		Starting =	MWe/m ²	3.73×10^{-5}			

ESG-79-30, Vol III

K-4

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem Solar
Multiples 0.8 & 1.4
STEAEC - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE

4

WBS NO.

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		3.2.1.2 <u>Receiver Subsystem</u>					
		a. Receiver proportional efficiency	r	0.95			
		b. Receiver subtractive loss parameter (does not include reflective loss (see r))					
		L_r (T,W)	W = Windspeed (m/s)				
		$^{\circ}\text{C}$	0	3	7	11	16
		T = -20	4.548E-2	4.548E-2	4.7E-2	5.230E-2	5.932E-2
		Temp 0	4.548E-2	4.548E-2	4.7E-2	5.230E-2	5.932E-2
		$^{\circ}\text{C}$ ($^{\circ}\text{F}$) 20	4.548E-2	4.548E-2	4.7E-2	5.230E-2	5.932E-2
		40	4.548E-2	4.548E-2	4.7E-2	5.230E-2	5.932E-2
		60	4.548E-2	0.04548	0.047	5.230E-2	5.932E-2

ESG-79-30, Vol III

K-5

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem Solar
Multiples 0.8 & 1.4
STEAE - Input

NUMBER

PREPARED BY

APPROVED BY

WBS NO.

PAGE 5

DATE

NEW
REV

NO.

ITEM

DESIGN POINT

UNIT

VALUE

TEN-
TATIVE

FIRM

REFERENCES AND REMARKS

3.2.1.2 - Continued

c. Receiver Size, R_s (MW):

For SM = 0.8

MWt 208

For SM = 1.4

MWt 264

d. H_r , Receiver Heat Capacity Term:

$$H_r = \frac{(MWt-h)}{Hr \times R_s} = \frac{\text{Energy to heat receiver to operating conditions}}{t \text{ hrs for cold start} \times \text{receiver size}}$$

Basis for determination of H_r :

time = 1/2 hr; cooldown to 0°F, heat up to 450°F; temp = 450°F

$$H_r = \frac{Q}{\text{time} \times R_s}$$

$$Q = \frac{M \times Cp \times \text{temp}}{3.412 \times 10^6} \quad MW_t-h$$

ESG-79-30, Vol III

K-6

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAEK - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE

6

WBS NO.

DATE

NEW
REV

NO.

ITEM

DESIGN POINT

UNIT

VALUE

TEN-
TATIVE

FIRM

REFERENCES AND REMARKS

3.2.1.d - Continued

Mass of receiver to be cycled*

SM = 0.8

Tubes

Panels

Headers

M = Tubes + Panels

kg

18,200

kg

9,100

kg

6,500

kg

27,300

SM = 1.4

Tubes

Panels

Headers

M = Tubes + Panels

kg

22,200

kg

32,700

kg

10,000

kg

54,900

C_p

0.1

M x C_p

6,000

M x C_p

12,100

SM = 0.8

ΔT - Temperature

°C

232

Q

MWt-hrs

0.7913

ΔTime

h

0.5

R_s

MWt

208

R_r

MWt/MW

7.608 x 10⁻³

Size

*Since sodium is drained, only
receiver mass to be cycled
consists of panels and tubes.

SM = 0.8

SM = 1.4

For SM = 1.4

232

1.596

0.5

364

8.769 x 10⁻³

ESG-79-30, Vol III

K-7

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAEK - Input

NUMBER

PREPARED BY

APPROVED BY

WBS NO.

PAGE

7

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		3.2.1.2 - Continued					
		e. Receiver cooldown parameter					
		α_r	(hour ⁻¹)	0.5			
		Note: $X(t) = X_1 \times e^{-\alpha_r(t-t_1)}$, t = time					
		(t ₁ = time of receiver shutdown)					
		for slower cooldown, $\alpha_r < 0.5$					
		f. Time required for cold start					
		t _{cs}	h	0.5			
		g. Time between initiation of turbine synchronization with receiver power and completion of startup					
		(t ₃ -t ₂)	h min.	0.167 10			
		h. Receiver minimum power requirements (% of receiver thermal power)	%	0			Receiver shutdown and drained

ESG-79-30, Vol III K-8

DESIGN DATA SHEET

TITLE

Receiver Subsystem Solar
 Multiples 0.8 & 1.4
 STEAEC - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE 8

WBS NO.

DATE

NEW REV.	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		3.2.1.2 - Continued					
		i. Auxiliary power requirements (MWe/MW _t of receiver power)					Receiver Operation (80% Solar, 20% Fossil)
		SM = 0.8					
		Collector - Heliostats & Controllers	kWe	330			
		Receiver - Receiver Pump	kWe	1,325			
		Boiler Feed Pump	kWe	2,100			
		Condensate Pump	kWe	150			
		EPGS { Cooling Tower Fans	kWe	850			
		Cir. H ₂ O Pump	kWe	1,870			
		Misc. Access	kWe	1,055			
		Pulverizers FD, ID, PA,	kWe	1,350			
		& GR Fans					
		Non-Solar { SO ₂ & Particulates Removal	kWe	150			
		Coal & Ash Handling	kWe	360			
		Total	kWe	9,540			
			MWe	9.54			
				0.459			MWe per MWt of receiver power
		$\frac{MWe}{R_s} = \frac{9.54}{208} =$					

ESG-79-30. Vol III

K-9

Atomics International Division
Rockwell International

DESIGN DATA SHEET

TITLE

Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAE - Input

NUMBER

PAGE 9

DATE

PREPARED BY

APPROVED BY

WBS NO.

NEW REV.	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		3.2.2i - Continued					
		Auxiliary power requirements (MWe/MW _t of receiver)					Receiver Operation (Summer Solstice)
		<u>SM = 1.4</u>					
		Collector - Heliostats & Controllers	kWe	525			
		Receiver - Receiver Pump	kWe	3,400			
		Steam Generator Pump	kWe	610			
		Boiler Feed Pump	kWe	2,100			
		Condensate Pump	kWe	150			
		Cooling Tower Fans	kWe	850			
		Circ. H ₂ O Pump	kWe	1,870			
		Misc. Access	kWe	1,055			
		Non-Solar { Pulverizers FD, ID, PA, & GR Fans					
		SO ₂ & Particulates Removal					
		Coal & Ash Handling					
		Total	kWe	10,560			Fossil Heater Not Operating
		$\frac{MWe}{R_s} = \frac{10.56}{364} =$		0.0290			MWe per MWt of receiver power

ESG-79-30, Vol III K-10

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

FOSSIL-FIRED
SODIUM HEATER

NUMBER

PREPARED BY

W. F. CLANCEY (B&W)

APPROVED BY

PAGE 10

WBS NO.

DATE 8/20/79

NEW
REV

NO.

ITEM

DESIGN POINT

UNIT

VALUE

TEN-
TATIVE

FIRM

REFERENCES AND REMARKS

PARAGRAPH 3.2.1.3

(a) Non-solar proportional efficiency $\epsilon_r = 0.98$

(b) Non-solar subtractive loss parameter

$L_r = 0.0026$ for all conditions specified

(c) Non-solar size $R_s = 0.0280 \text{ MW}_t$ Nominal

(d) Non-solar heat capacity term $H_r = 0.027$

(e) Non-solar cooldown parameter $\alpha_r = 0.17$

(f) Time required for cold startup $T_{cs} = 4.25$ hours

(g) Time between initiation of turbine synchronization with non-solar power and completion of non-solar startup

$(t_3 - t_2) = 1$ hour

PRELIMINARY ESTIMATES

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
FOSSIL-FIRED
SODIUM HEATER

NUMBER

PREPARED BY

APPROVED BY

W. F. CLANCEY (B&W)

PAGE 11

WBS NO.

DATE 8/20/79

NEW REV	NO.	ITEM	DESIGN POINT		TEM- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		<u>PARAGRAPH 3.2.1.3 (continued)</u>					
		(h) Non-solar minimum power requirements (as percent of non-solar power) = 20%					
		(i) Auxiliary power requirements (as MWe per MW _t of non-solar power) = 0.01 MWe /MW _t					
		<u>PRELIMINARY ESTIMATES</u>					

ESG-79-30, Vol III K-12

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAE - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE 12

WBS NO.

DATE

NEW
REV

NO.

ITEM

DESIGN POINT

UNIT

VALUE

TEN-
TATIVE

FIRM

REFERENCES AND REMARKS

3.2.1.4 Piping

Piping subtractive loss parameter values, L_p (T)

$$L_p(T_{amb}) = \frac{\text{Power Loss}}{R_{size}}$$

$$\text{Power Loss} = \sum h A \Delta t$$

from all piping

$$A = \pi \left(\frac{d_{\text{outside}} + 2\Delta X_{\text{insulation}}}{12} \right) L$$

$$h = 1 \text{ Btu/hr/}^{\circ}\text{F}$$

$$\Delta t = 130^{\circ}\text{F} - 0^{\circ}\text{F} = 130^{\circ}\text{F}$$

$$\text{Power Loss} = \frac{\pi h \Delta t}{12 \times 3.412 \times 10^6} \sum (d_o'' + 2\Delta X'') L_{\text{feet}}$$

ESG-79-30, Vol III

K-13

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAEC - Input

NUMBER

PREPARED BY

APPROVED BY

WBS NO.

PAGE 13

DATE

NEW
REV

NO.

ITEM

DESIGN POINT

UNIT

VALUE

TEN-
TATIVE

FIRM

REFERENCES AND REMARKS

3.2.1.4 - Continued

SM = 0.8

SM = 1.4

Downcomer HT: (20+16) x 500 = 18,000
Riser LT: (20+10) x 500 = 15,000
Horizontal
Piping: LT: (24+12) 500 = 18,000
HT: (20+16) 700 = 25,200
LT: (20+10) 500 = 15,000
HT: (14+12) 60 = 1,560
LT: (10+10) 100 = 2,000
LT: (8+10) 200 = 3,600

HT: (12.75+10) 760 = 17,290
LT: (24+6) 760 = 22,800

HT: (20+16) x 70 = 2,520

LT: (2.4+6) x 225 = 1,890
HT: (14+12) x 40 = 1,040
LT: (10.8+10) x 50 = 1,040
HT: (20+16) x 80 = 2,880

Σ 93,360

Σ 49,460

Ambient Temp T °C -20 0 20 40 60

$$q/L = \frac{2\pi(t_{sod} - t_{amb})}{\frac{\ln(r_3/r_2)}{k_{pipe}} + \frac{\ln(r_4/r_3)}{k_{insul}} + \frac{12}{r_4 h_1}}$$

$$q = \left[\frac{1}{\frac{\Delta x_{pipe}}{k_{pipe}} + \frac{\Delta x_{ins}}{k_{ins}} + \frac{1}{h_1}} \right] \frac{2\pi r_c}{12} L (t_{sod} - t_{amb})$$

can be neglected

$k_{ins} = 0.05$

ESG-79-30, Vol III

K-14

DESIGN DATA SHEET

TITLE

Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAEC - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE 14

WBS NO.

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		3.2.1.4 - Continued					
		SM = 0.8		SM = 1.4			
		HT:					
		$q/(t_{sod} - t_{amb}) = \sum \frac{1}{\frac{x_{ins}}{12} + 1} \frac{2 r_o}{12} L_{ft}$					
		Pipe	Δx_{igs}	r_o	L		
		Downcomer	8	18	500		
		Horizontal	8	18	700		
			6	18	60		
		Pipe	Δx_{igs}	r_o	L		
		Downcomer	8	11.38	760		
		Horizontal	8	18	70		
			6	13	40		
			8	18	80		
		$\Sigma HT =$		840.46			$\Sigma(q/\Delta t) HT = 608.58$
		LT:					
		Riser	5	15	500		
		Horizontal	6	18	500		
			5	15	500		
			5	10	100		
			5	9	200		
		$\Sigma LT =$		1,426.98			$\Sigma LT = 1,106.48$

ESG-79-30, Vol III

K-15

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAE - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE 15

WBS NO.

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS	
			UNIT	VALUE				
		3.2.1.4 - Continued						
		$L_p(t_{amb}) = \frac{q_{MW}}{R_s} = \frac{\sum_{HT} \times (1100 - t_{amb}) + \sum_{LT} \times (550 - t_{amb})}{3.412 \times 10^6 R_s}$						
		SM = 0.8		R _s = 208 MWt				
		t _{amb}	°C =	-20	0	20	40	60
			°F =	-4	32	68	104	140
		L _p (t _{amb})		2.42x10 ⁻³	2.31x10 ⁻³	2.19x10 ⁻³	2.08x10 ⁻³	1.96x10 ⁻³
		SM = 1.4		R _s = 364 MWt				
		t _{amb}	°C =	-20	0	20	40	60
		L _p (t _{amb})		1.03x10 ⁻³	9.85x10 ⁻⁴	9.35x10 ⁻⁴	8.85x10 ⁻⁴	8.36x10 ⁻⁴
		MWt/MWt R _s units of L _p						
		3.2.1.5 <u>Energy Storage Subsystem</u>						
		<u>For SM = 1.4 System</u>						
		a.	Maximum chg. rate	MWt	364			
		b.	Maximum discharge rate	MWt	300	Design maximum		

ESG-79-30. Vol III K-16

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAEK - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE 16

WBS NO.

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		3.2.1.4 - Continued					
		c. Maximum storage capacity					
		$V_{\text{Hot Tank}}$	m^3 (ft^3)	10,000 (353,430)			Maximum
		Assume 5% minimum ullage					
		V_{Na}	m^3 (ft^3)	9,502 (335,758)			
		$M_{\text{Na}} = 17.46 \times 10^6 \text{ lb}$	kg (lb)	7.92×10^6 (17.46×10^6)			
		@ $\gamma = 52 \text{ \#/ft}^3$					
		$Q_{\text{Mwt-h}} = \frac{M C_p \Delta t}{3.412 \times 10^6}$	MWt-h	844.3			Temperature Range (593-288) $^{\circ}\text{C}$ (1110-550) $^{\circ}\text{F}$
		d. Standby Heat Loss Factor					
		$X = 100 \frac{Q_{\text{Lost}}}{Q_{\text{Max Discharge}}} = \frac{.3 \times 100}{300} = 0.1\%$					Percent of maximum heat rate
		e. Storage Loss Factor					
		$\alpha_L = 1 - \frac{.3 \times 15 / 60}{844.3} = .99991$					One minus the fraction of energy in storage lost in a 15-minute period

ESG-79-30, Vol III

K-17

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAEAC - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE 17

WBS NO.

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		3.2.1.5 - Continued					
		f. Charging efficiency quadratic coefficients for hot tank storage: $C_0 = 1$ $C_1 = 0$ $C_2 = 0$					
		g. Discharging efficiency quadratic coefficients: $d_0 = 1$ $d_1 = 0$ $d_2 = 0$					
		h. Standby thermal power requirements from storage - turbine sealing steam and trace heating: TSS =	MWt	0.381			
		i. A = B = 0; Storage tank System does not use charging or discharging heat exchangers.					Auxiliary power scale factors
		j. Minimum charge rate	%	10			or 0.10 {fraction of maximum charge rate
		k. Minimum discharge rate	%	10			or 0.10 {fraction of maximum discharge rate

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAEK - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE 18

WBS NO.

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		3.2.1.6 Electric Power Generating Subsystem (EPGS)					
		a. Turbine Shell Cooldown Parameters					
		$\alpha =$	h^{-1}	0.0216			
		$\beta =$	h^{-1}	0.00571			
		b. Turbine operating temperature factor					
		$\tau_{\text{storage}} =$	h	0			
		$\tau_{\text{nonsolar}} =$	h	0			
		$\tau_{\text{Receiver}} =$	h	0			
		c. Turbine Synchronization Delays and Ramp Rates					
		See attached Table on Page					
		d. Maximum thermal power to turbine from the receiver					
			MWt	260			
		e. Maximum thermal power to turbine from storage					
			MWt	260			
		f. Maximum thermal power to turbine from nonsolar					
			MWt	260			

ESG-79-30, Vol III K-19

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAE - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE 19

WBS NO.

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEM- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		3.2.1.6 - Continued					
		g. Minimum thermal power to turbine from receiver					
		TMFR =	%	0			Percent of maximum power
		h. Minimum thermal power to turbine from storage					
		TMFS =	%	0			Percent of maximum power
		i. Minimum Thermal Power to Turbine from Non-Solar					
		If coal fired -	%	20 Minimum			
		If oil fired -	%	10 Minimum			
		j. Auxiliary Power Scale Factors:					
		Mke/MWt					
		α_r (receiver)		SM = 0.8		SM = 1.4	
		α_N (Non-Solar)		.0459		.0290	
		α_S (Storage)		.0392		.0392	
				DNA; $\frac{Aux = 6.635}{260} =$		.0255	
		k. Standby Auxiliary Thermal Power Requirements					
		$P_{SS} =$	MWt	0.381			

ESG-79-30, Vol III
K-20

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAE - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE 20

WBS NO.

DATE

NEW
REV

NO.

ITEM

DESIGN POINT

UNIT

VALUE

TEN-
TATIVE

FIRM

REFERENCES AND REMARKS

3.2.1.6 - Continued

1. Standby Auxiliary Electrical Power Requirements

~~Assumed 25% of Auxiliary Power~~

$$P_{tsb} = MWe \quad \& 1.6$$

- m. Gross EPGS efficiency values ϵ_g as a function of T_{wb} (wet bulb temperature) and X (mass flow fraction) - Operation from receiver:

$T_{wb}^{\circ}C$	0	5	10	15	20	25
X						
.25	.404.403	.401.403	.396.397	.388.389	.378.380	.367.367
.5	.433.437	.433.437	.420.428	.424.428	.418.421	.410.413
.75	.437.438	.437.438	.436.438	.434.438	.431.434	.424.428
1.0	.435.440	.435.440	.435.440	.435.440	.434.438	.430.434

all revised table

- n. Gross EPGS efficiency values, ϵ_g (T_{wb} , X) when operating from storage for all combinations of the following wet bulb temperatures, T_{wb} (degrees C) and mass flow fractions X .

$T_{wb} = 0., 5., 10., 15., 20., 25.$

Same as m.

$X = .25, .5, .75, 1.0$

ESG-79-30, Vol III

K-21

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAEC - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE 21

WBS NO.

DATE

NEW
REV

NO.

ITEM

DESIGN POINT

UNIT

VALUE

TEN-
TATIVE

FIRM

REFERENCES AND REMARKS

3.2.1.6 - Continued

- o. Gross EPGS efficiency values, ϵ_s (T_{wb} , X) when operating from Non-Solar for all combinations of the following wet bulb temperatures, T_{wb} (degrees C) and mass flow fractions X .

$T_{wb} = 0., 5., 10., 15., 20., 25.$

Same as m.

$X = .25, .5, .75, 1.0$

ESG-79-30, Vol III

K-22

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE Receiver Subsystem Solar
Multiples 0.8 & 1.4
STEAEC - Input

NUMBER

PREPARED BY

APPROVED BY

PAGE 22

WBS NO.

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		TABLE FOR SYNCHRONIZATION DELAYS AND RAMP RATES (Refer to Page 19)					
		<u>Type of Start</u>	<u>Cold Start</u>	<u>Warm Start</u>			<u>> Hot Start</u>
		Initial Pressure	>40% Rated	>40% Rated			40% Rated
		Initial Temperature	371 ⁰ C (700 ⁰ F)	371 ⁰ C (700 ⁰ F)			Max. Obtainable
		1. Accelerate to 1,000 rpm	(250 rpm/min) 4 min	(250 rpm/min) 4 min			(500 rpm/min) 2 min
		2. Hold at 1,000 rpm (Check Vibration)	10 min	10 min			5 min
		3. Accelerate to 3,550 rpm	(250 rpm/min) 10 min	(500 rpm/min) 5 min			(500 rpm/min) 5 min
		4. Synchronize Generator and Apply 5 MW Load	-	-			-
		5. Hold at 5 MW (to Cool Exhaust)	30 min	15 min			Not Appl.
		6. Load Generator to Rated Load	(1/2%/min) 190 min	(1-1/2%/min) 63 min			(3%/min) 33 min
		7. Total Time - Acceleration to Rated Load	244 min (4 h-4 min)	97 min (1 h-37 min)			45 min
		Source: -General Electric Company (GEK 27064A)					

ESG-79-30, Vol III
K-23

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Nonsolar Subsystem
STEAECE Definitions

NUMBER

PREPARED BY

APPROVED BY

PAGE 23

WBS NO.

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Note: As far as practical, these definitions are similar to those given in "STEAECE - Solar Thermal Electric Annual Energy Calculator Documentation," by J. B. Woodard and G. J. Miller (SAND 77-8278, January 1978).					
		3.2.1.3 <u>Nonsolar Subsystem</u>					
		a. Nonsolar proportional efficiency, ϵ_r .					
		$P_{wf}(t) = \epsilon_r (\dot{W}H - L) - L_r R_s$					
		$\epsilon_r = \frac{P_{wf} + L_r R_s}{\dot{W}H - L_s}$					
		where:					
		$\dot{W}$ = flow rate of fuel					
		H = high heating value of the fuel					
		L_r = nonsolar subtractive loss parameter (see Item b of this paragraph)					
		L_s = stack loss					
		P_{wf} = power to the working fluid					
		R_s = nameplate rating of the heater

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Nonsolar Subsystem
STEAECE Definitions

NUMBER

PREPARED BY

APPROVED BY

PAGE 24

WBS NO.

DATE

NEW
REV

NO.

ITEM

DESIGN POINT

UNIT

VALUE

TEM-
TATIVE

FIRM

REFERENCES AND REMARKS

3.2.1.3 - Continued

- b. Nonsolar Subtractive Loss Parameter, L_r

$$L_r = \frac{\text{Average thermal power loss from heater surfaces}}{\text{Nameplate rating of the heater } (R_s)}$$

To be given as a function of all combinations of the following wind speeds, $W(\text{m/s})$
and temperatures, $T(^{\circ}\text{C})$

$$T(^{\circ}\text{C}) = -20, 0, 20, 40, \text{ and } 60$$

$$W(\text{m/s}) = 0, 3, 7, 11, 16$$

- c. Nonsolar size, R_s (MW)

- d. Nonsolar heat capacity term, H_r (nondimensional)

$$H_r = \frac{(\text{Sum of products of sodium and heater masses and specific heats}) \times (T_o - T_s)}{(\text{Heater nameplate rating})(\text{time required for a cold startup})}$$

T_o = operating temperature

T_s = standby temperature

ESG-79-30, Vol III

K-25

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Nonsolar Subsystem
STEAEK Definitions

NUMBER

PREPARED BY

APPROVED BY

PAGE 25

WBS NO.

DATE

NEW
REV

NO.

ITEM

DESIGN POINT

UNIT

VALUE

TEN-
TATIVE

FIRM

REFERENCES AND REMARKS

3.2.1.3 - Continued

e. Nonsolar cooldown parameter, $r(h^{-1})$

$$T = T_o e^{-\alpha_r t_n}$$

$$\text{and } \alpha_r = \frac{\ln T/T_o}{t_n}$$

t_h = time (h) to cool from
temperature T_o ($^{\circ}\text{C}$)
to temperature T ($^{\circ}\text{C}$)

T_o = operating temperature ($^{\circ}\text{C}$)

f. Time required for a cold start, T_{cs} (h)

T_{cs} = time from standby to power operation

g. Time between the initiation of turbine synchronization with
nonsolar power and completion ($t_3 - t_2$), (h).

h. Nonsolar minimum power requirements,
% of nonsolar power (%)

This is the minimum firing rate expressed as a fraction of
heater nameplate rating.

ESG-79-30, Vol. III

K-26

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Nonsolar Subsystem
STEAEC Definitions

NUMBER

PREPARED BY

APPROVED BY

PAGE 26

WBS NO.

DATE

NEW
REV

NO.

ITEM

DESIGN POINT

UNIT

VALUE

TEN-
TATIVE

FIRM

REFERENCES AND REMARKS

3.2.1.3 - Continued

i. Auxiliary power requirements (MWe per MWt of nonsolar power)

The heater equipment expressed as a % of the nameplate rating of the heater.

ESG-79-30, Vol 1 III

K-27

APPENDIX L
PLUME-SOLAR INSOLATION STUDY

ESG-79-30, Vol III

L-1

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

6 June 1979

PLUME-SOLAR INSOLATION STUDY

Prepared by

Dr. Charles E. McDade

Rockwell International

**Environmental Monitoring & Services Center
Environmental & Energy Systems Division
2421 West Hillcrest Drive
Newbury Park, CA 91320
(805) 498-6771**

ESG-79-30, Vol III

L-3

PLUME-SOLAR INSOLATION STUDY

1.0 INTRODUCTION

The hybrid solar tower and coal fired power plant proposed near Barstow, California, is designed to use a combination of solar power and coal-derived power to meet total power production needs. When both systems are working simultaneously, however, the power plant plume can absorb and scatter incoming solar radiation, thereby reducing the potential solar power output. This report describes a series of calculations performed to estimate the amount of attenuation of solar radiation by the plume.

The scattering and absorption of light travelling through a known medium are described by Beer's Law:

$$\log \left(\frac{I}{I_0} \right) = - \sum_i \epsilon_i c_i l_i \quad (1)$$

Here, I_0 is the initial light intensity, I is the light intensity at the observer, and ϵ_i , c_i , and l_i are the extinction coefficient, concentration, and length of the light path, respectively, through species i . The extinction coefficient is an inherent property of the material, and is almost always a function of wavelength. Each species has an extinction coefficient for light scattering and one for light absorption. Extinction coefficients are traditionally related to base 10 logarithms, although particle light scattering coefficients are often seen in base e expressions.

In a homogeneous, spatially well-defined system (a laboratory absorption cell, for example), c_i and l_i are well-characterized. The concentration is constant throughout, and l_i is simply the length of the cell. In a power plant plume, however, this is not the case. Concentrations vary across the plume, and since the plume does not have distinct boundaries, l_i is not explicitly defined. Nevertheless, the combined quantity $(cl)_i$ can be calculated for incremental lengths and then integrated across the plume. This procedure will be discussed in the next section.

Worst-case conditions will be used whenever applicable so that the final result will show the maximum expected effect. For example, it will be assumed that the coal furnace is operating at full capacity. During typical daytime furnace operation, however, the coal furnace will be used in conjunction with solar production and will thus normally operate at less than 100% potential. Explicit worst-case assumptions will be mentioned in the text.

2.0 PLUME MODELING

In order to calculate incremental values of $(c1)_i$ within the plume, it is first necessary to determine the spatial characteristics of the plume. A representation of an idealized plume is shown in Figure 1, as taken from Turner (1). The concentration, x , of species i at point (x,y,z) downwind of the stack is given by (1):

$$x(x,y,z) = \frac{Q}{2\pi\sigma_y\sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \left\{ \exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right] \right\} \quad (2)$$

Here, the x -axis is along the wind vector, Q is the stack emission rate for species i , and u is the wind speed. It is estimated that the plume concentration follows a Gaussian distribution along both the y and z axes; σ_y and σ_z are the standard deviations associated with these distributions, and they describe the spread of the plume. Both σ_y and σ_z are functions of downwind distance, x , as well as of atmospheric stability (2). Tables of σ_y and σ_z are available (1), and are considered to be reasonably accurate up to about 1 km downwind of the source. The quantity H is the height of the plume centerline above the ground at downwind distance x . It is equal to the stack height plus the plume rise, and is calculated using the equations of Briggs (3,4).

Once the concentration has been estimated for each incremental cube $dx dy dz$ of the atmosphere above the heliostat field, the effective value of $c1$ can be obtained by integrating:

$$c1 = \frac{\int_{x_{\min}}^{x_{\max}} \int_{y_{\min}}^{y_{\max}} \int_0^{\infty} x(x,y,z) dx dy dz}{A} \quad (3)$$

Here, $x_{\min}$ is the radius of the circle surrounding the tower, $x_{\max}$ is the downwind distance from the stack to the edge of the elliptical heliostat field, $y_{\min}$ and $y_{\max}$ are the y-boundaries of the heliostat field, and A is the area of the ellipse defining the heliostat field minus the area of the circle surrounding the tower. Integration is not explicitly performed at negative values of x (upwind of the source) because all values of x would be zero; nevertheless, division by A (total ellipse area) implies that this region is included. Thus, the calculations estimate the total attenuation of light impinging upon the entire field.

The integration of equation (3) is performed numerically using the computer program SOLAR, which is included as Appendix A. This program uses two subroutines which were obtained from CRSTER, a commonly used dispersion model developed by the EPA. The subroutine SIGMA calculates σ_y and σ_z as a function of downwind distance and stability class. BEH072 calculates plume rise using Briggs' equations (3,4). The algorithm of SOLAR incorporates two worst case assumptions: 1) The wind is from the south, so the plume covers a maximum area of the heliostat field due to the position of the tower within the ellipse, and 2) The sun is due south of the tower at 56° from horizontal (Barstow latitude is approximately 34°) so that mid-day conditions are modeled.

SOLAR uses three nested DO-loops to perform the integration along the x, y, and z axes; the increments are calculated in 10 meter cubes. The outer loop processes the x-axis, with the ground-level value of x varying from 100 m (the circle radius) to 840 m (the distance from the stack to the northern edge of the ellipse). The next loop increments Z from 0 to 1250 m (the estimated upper limit of appreciable concentration). Each time z is incremented by 10 meters, x is reduced by 10 times the cotangent of 56° to account for the slanted path of the light rays from the sun to the ground. This allows

a ray to slice through the plume at a 56° angle. In addition, the resultant value of c_l is divided by the sine of 56° to account for the extra length of a light path from elevation z at 56° compared to one at 90° . The innermost loop increments y from zero to the edge of the ellipse at the particular ground level value of x ; this result is then multiplied by two due to the horizontal symmetry of the problem. The total integral is divided by the area of the ellipse minus the center circle to yield an effective value of c_l for the entire heliostat field.

The plant specifications used as inputs to the model are listed in Table 1. A number of meteorological inputs (wind speed and stability class) were tried, and it was found that the worst case to be expected for the Barstow area is a wind speed of 2 m/sec with B stability. Higher wind speeds resulted in lower values of c_l (hence, less attenuation), and lower wind speeds from the south are highly unlikely, as can be seen from Table 2 (5). Using an emission rate of 1 g/sec with B stability and a 2 m/sec wind resulted in a value of c_l of 0.00023 g/m^2 .

Upper and lower boundary effects along the z -axis were not included because their effects should be negligible. Maximum plume spread will occur at the x -axis boundary of the ellipse, or 840 meters from the source. Here, σ_z is approximately 100 meters. The plume centerline, however, is about 400 meters (four standard deviations) above the ground. The mixing height (upper level boundary) is typically well over 1000 meters in the desert at mid-day, and should thus be of no consequence.

3.0 EXTINCTION COEFFICIENTS

Each molecule and each particle has an extinction coefficient for light absorption and one for light scattering. For atmospheric estimates such as the one being performed here, molecular absorption and particle scattering are the predominant processes. Thus, extinction coefficients for molecular scattering and for particle absorption will not be tabulated since they can be assumed to be negligible.

The gaseous coal furnace effluent is composed of molecular nitrogen,
ESG-79-30, Vol III

carbon dioxide, water vapor, molecular oxygen, and sulfur dioxide. The absorption spectra of these compounds from 0.35 μ to 5.0 μ were obtained from Sadtler (6) (carbon dioxide, sulfur dioxide) and from McClatchey et al. (7) (nitrogen, water, oxygen). Nitrogen has a very weak continuum absorption between 3.8 and 4.7 μ . Carbon dioxide exhibits strong, sharp absorption peaks at 2.8 μ and at 4.3 μ . Water vapor has a few very weak bands below 0.7 μ , and has a very complex spectrum of weak to moderately strong bands between 0.7 and 5.0 μ . Oxygen and sulfur dioxide each have only one significant absorption band, oxygen having a weak band at 0.8 μ , and sulfur dioxide a strong, sharp band at 4.0 μ .

The particle light scattering extinction coefficient is not as well-characterized as molecular absorption coefficients, but can be estimated with reasonable accuracy. It is a function of both particle size and the wavelength of the light being scattered. The maximum value of ϵ in the visible region occurs for a particle diameter of 0.5 μ , and has been estimated (8) to be 4 m²/g for unit density particles. As a worst-case assumption, it will be assumed here that all emitted particles have a diameter of 0.5 μ . Various functions of ϵ with wavelength have been proposed, none of which has been proven to be completely correct. As a worst-case assumption, the following relation will be used:

$$\epsilon = 14.2 \exp(-\lambda) , \quad (4)$$

where ϵ is in m²/g and λ is in μ . This is worst-case because it tends to over-estimate ϵ in the vicinity of 1 μ . One further worst-case assumption is that all scattered light is scattered completely out of the heliostat field. This is probably not the actual case, so the true attenuation should be somewhat less than that reported here.

4.0 RESULTS

The attenuation of incident light can be calculated using Beer's Law, equation (1). For each species, ϵ_i is obtained as discussed in Section 3.0. To get $(c1)_i$, the previously mentioned value of 0.00023 gm⁻² for an emission

rate of 1 g/sec must be scaled according to the mass emission rate of each species. Both the percent by volume in the total flow and the mass emission rate of each species are listed in Table 3. The total flow rate is 256000 SCFM, of which 226400 SCFM is effluent flow from the furnace and the remainder is leakage into the lines. The quantity ϵ_1 is a function of wavelength, whereas $(c1)_1$ is not.

Table 4 shows I/I_0 as a function of wavelength from 0.35 to 5.0 μ , as calculated by equation (1). The transmittance (I/I_0) values are averaged over 0.1 μ spans ($\pm 0.05 \mu$ on either side of the reported wavelength) except below 0.7 μ , where this increment is halved. Two very important points should be emphasized. First, as mentioned previously, the reported transmittances apply to light impinging upon the entire heliostat field. Second, no correction has been made for the wavelength dependence of the intensity of incoming solar radiation. In other words, the reported transmittance values give a ratio of intensity above the plume to intensity below the plume at a specified wavelength.

Below about 2.0 μ , virtually all of the reported light attenuation results from scattering by particles. Above 2.0 μ , light absorption by water vapor becomes significant, contributing about 10% to the total $\epsilon c1$ at 2.5 μ and increasing to about 50% at 5.0 μ as the particle scattering coefficient decreases with increasing wavelength. Nitrogen, oxygen, and sulfur dioxide do not make appreciable contributions to the total attenuation at any wavelength. The greatest attenuation occurs around 2.8 μ and around 4.3 μ . These bands are due to molecular absorption by carbon dioxide.

REFERENCES

1. D. Bruce Turner, "Workbook of Atmospheric Dispersion Estimates," Office of Air Programs Publication No. AP-26, EPA (1970).
2. F. Pasquill, "The Estimation of the Dispersion of Windborne Material," Meteorol. Mag. 90, 1063, 33-49 (1961).
3. Gary A. Briggs, "Some Recent Analyses of Plume Rise Observations," Proc. Second Intl. Clean Air Congress, 1029-1032, (1971).
4. Gary A. Briggs, "Discussion on Chimney Plumes in Neutral and Stable Surroundings," Atmos. Environ. 6, 507-510 (1972).
5. California Department of Water Resources, "Wind in California," DWR Bulletin No. 185 (1978).
6. The Sadtler Standard Spectra, Sadtler Research Laboratories, Philadelphia, (1966).
7. R. A. McClatchey, R. W. Fenn, J.E.A. Selby, F. E. Volz, and J. S. Garing, "Optical Properties of the Atmosphere (Third Edition)," Air Force Cambridge Research Laboratories, AFCRL-72-0497 (1972).
8. Glen R. Cass, "The Relationship Between Sulfate Air Quality and Visibility at Los Angeles," Caltech EQL Memorandum No. 18 (1976).

Figure 1. Plume Dispersion

Table 1. Power Plant Specifications

Stack Height = 137.0 m

Stack Gas Temperature = 348.5 K

Stack Gas Exit Velocity = 34.7 m sec⁻¹

Stack Inside Top Diameter = 2.438 m

Stack Gas Volume Flow Rate = 162.2 m³ sec⁻¹

Ambient Temperature = 301.1 K

Ambient Pressure = 937.9 mb

Table 2

SURFACE WINDS

PERCENTAGE FREQUENCY OF WIND
DIRECTION AND SPEED
(FROM HOURLY OBSERVATIONS)

23161

STATION

Daggett, CA FAA

STATION NAME

1955 - 1964

YEARS

ALL

MONTH

ALL

MOUSE (L.S.T.)

ALL WEATHER

CLASS

34 52', 116 47', 1,929'

LOCATION

HEIGHT ABOVE GROUND

SPEED MPH DIR.	1-3	4-6	7-10	11-16	17-21	> 21							%	MEAN WIND SPEED
N	0.1	0.6	0.5	0.2	0.0	0.0							1.4	7.5
NNE	0.1	0.4	0.4	0.2	0.1	0.0							1.2	8.5
NE	0.1	1.0	1.0	0.2	0.0								2.4	7.4
ENE	0.1	0.7	0.9	0.3	0.0	0.0							1.9	7.7
E	0.1	1.3	1.6	0.6	0.1	0.0							3.7	8.0
ESE	0.1	0.7	0.7	0.3	0.1	0.0							1.9	8.1
SE	0.1	0.8	0.4	0.1	0.0	0.0							1.4	6.7
SSE	0.0	0.3	0.1	0.0	0.0	0.0							0.5	6.8
S	0.0	0.3	0.1	0.0	0.0	0.0							0.6	6.9
SSW	0.0	0.2	0.1	0.1	0.1	0.0							0.5	9.9
SW	0.1	0.5	0.6	0.8	1.0	0.4							3.3	14.1
WSW	0.1	0.9	2.1	3.4	3.8	1.3							11.6	15.1
W	0.1	2.7	8.7	6.3	3.3	1.4							22.5	12.1
WNW	0.1	3.2	11.0	8.1	2.0	0.5							24.9	10.8
NW	0.1	1.9	4.2	2.2	0.2	0.0							8.6	9.2
NNW	0.1	0.6	0.7	0.3	0.0	0.0							1.7	8.0
Avg.	2.8	5.1	8.8	13.0	18.8	25.0								
CALA													11.8	9.8
11.8	1.3	16.0	33.4	23.0	10.8	3.7							100.0	

DATA FROM NATIONAL CLIMATIC CENTER
FEDERAL BUILDING - ASHEVILLE, N.C., 28801

TOTAL NUMBER OF OBSERVATIONS 87,556

ESG-79-30, Vol III
L-13

Table 3. Emission Rates

Species	% by Volume	Mass Emission Rate (g/sec)
N ₂	68.12	1.028×10^5
CO ₂	18.63	4.416×10^4
H ₂ O	8.46	8.209×10^3
O ₂	4.77	8.224×10^3
SO ₂	6.09×10^{-3}	2.379×10^1
Particulate	-	0.56

Table 4. Transmittance vs Wavelength

$\lambda(\mu)$	I/I_0	$\lambda(\mu)$	I/I_0
0.35	0.981	2.5	0.997
0.40	0.982	2.6	0.996
0.45	0.982	2.7	0.923
0.50	0.983	2.8	0.935
0.55	0.984	2.9	0.964
0.60	0.985	3.0	0.998
0.65	0.986	3.1	0.998
0.70	0.986	3.2	0.998
0.8	0.987	3.3	0.999
0.9	0.989	3.4	0.999
1.0	0.990	3.5	0.999
1.1	0.991	3.6	0.999
1.2	0.992	3.7	0.999
1.3	0.992	3.8	0.999
1.4	0.993	3.9	0.999
1.5	0.994	4.0	0.999
1.6	0.994	4.1	0.999
1.7	0.995	4.2	0.879
1.8	0.995	4.3	0.741
1.9	0.996	4.4	0.796
2.0	0.996	4.5	0.953
2.1	0.997	4.6	0.999
2.2	0.997	4.7	0.999
2.3	0.997	4.8	0.999
2.4	0.997	4.9	0.999
		5.0	0.999

Appendix A


```

C
C PROGRAM SOLAR
C
C THIS PROGRAM CALCULATES AVERAGE CONCENTRATION TIMES DISTANCE THROUGH
C A PLUME IN A SOUTH-TO-NORTH WIND FOR A SOLAR ANGLE OF 56 DEGREES
C FROM HORIZONTAL. SPECIFIC APPLICATION IS TO THE BARSTOW SOLAR TOWER.
C
C HF=STACK HEIGHT (M)
C TS=STACK GAS TEMPERATURE (K)
C VS=STACK GAS EXIT VELOCITY (M/S)
C D=STACK INSIDE TOP DIAMETER (M)
C VF=STACK GAS VOLUME FLOW RATE (M**3/S)
C T=AMBIENT TEMPERATURE (K)
C P=AMBIENT PRESSURE (MB)
C X=DOWNWIND DISTANCE FOR INITIAL PLUME RISE CALCULATION (KM)
C G=MASS FLOW RATE (G/S)
0001 DATA HP/137./,TS/348.6/,VS/34.7/,D/2.438/,VF/162.2/,
      1 I/301.1/,P/937.9/,X/0.2/,Q/1.0/
0002 WRITE(5,9000)
0003 9000 FORMAT('STABILITY CLASS (A=1,F=6)>')
0004 READ(5,9010)KST
0005 9010 FORMAT(I1)
0006 WRITE(5,9020)
0007 9020 FORMAT('WIND SPEED (M/SEC)>')
0008 9 READ(5,9030)U
0009 9030 FORMAT(F10.5)
C ASSIGN LAPSE RATE ACCORDING TO STABILITY; FROM CRSTER
0010 IF(KST-5)1771,1775,1776
0011 1771 DTHDZ=0.
0012 GO TO 1777
0013 1775 DTHDZ=0.02
0014 GO TO 1777
0015 1776 DTHDZ=0.035
0016 1777 CONTINUE
C CALCULATE EFFECTIVE PLUME HT (FROM CRSTER)
0017 CALL BEH072(HF,HX,HMW,F,DELHF,DISTF,DELHX,HP,
      1 TS,VS,D,VF,KST,U,X,DTHDZ,T,P)
C WRITE SEVERAL QUANTITIES INTO THE OUTPUT FILE.
0018 CALL ASSIGN(4,'SOLAR.DAT')
0019 WRITE(4,8000)KST
0020 8000 FORMAT(' STABILITY CLASS=',I1)
0021 WRITE(4,8010)U
0022 8010 FORMAT(' WIND SPEED (M/SEC)=',F10.5)
0023 WRITE(4,9040)HF
0024 9040 FORMAT(' HF (METERS)=',F10.5)
0025 WRITE(4,9050)DISTF
0026 9050 FORMAT(' DISTF (KM)=',F10.5)
C CALCULATE TRIG FUNCTIONS FOR LATER USE.

```

```

0007      TAN56=SIN(0.9774)/COS(0.9774)
0028      COT56=COS(0.9774)/SIN(0.9774)
0029      TENCOT=10.*COT56
0030      SIN56=SIN(0.9774)
0031      TENSIN=1000./SIN56
0032      C INITIALIZE SUM
          SUM=0.0
0033      C LOOP OVER X VALUES IN 10 METER STEPS FROM EDGE OF INNER CIRCLE
          C TO EDGE OF ELLIPSE.
          DO 30 IX=100,840,10
0034              WRITE(5,2000)IX
0035      2000      FORMAT(' IX=',14)
0036              XNEW=IX
          C CALCULATE THE LIMIT ON Y INTEGRATION AT THE GROUND LEVEL VALUE
          C OF X. USE THE STANDARD ELLIPSE EQUATION. OFFSET BY 66 IS NECESSARY
          C BECAUSE THE TOWER IS NOT IN THE CENTER OF THE ELLIPSE.
0037              YMAX=805.*((SQRT(1.-(((XNEW-66.)*2.)/(600625.))))
          C TRUNCATE YMAX TO THE NEAREST INTEGRAL MULTIPLE OF 10.
0038              YMAX=YMAX/10.
0039              IYMAX=YMAX
0040              IYMAX=10*IYMAX
          C LOOP OVER Z VALUES FROM GROUND TO 1250 METERS IN 10 METER STEPS.
0041              DO 20 IZ=0,1250,10
0042                  Z=IZ
0043                  IF(IZ.EQ.0)GO TO 50
          C WITH EACH INCREMENT OF Z, SUBTRACT 10*COT(56) TO ACCOUNT FOR SUN
          C ANGLE.
0045                  XNEW=XNEW-TENCOT
0046      50          IF(XNEW.LE.0.0)GO TO 20
          C CONVERT FROM M TO KM.
0048                  XNEW=XNEW/1000.
          C CALCULATE SIGMAS AND PLUME RISE.
0049                  CALL SIGMA(XNEW,KST,SY,SZ)
0050                  CALL BEH072 (HF,HX,HMW,F,DELHF,DISTF,DELHX,
          1                      HP,TS,VS,D,VF,KST,U,XNEW,DTHDZ,T,P)
0051                  XNEW=XNEW*1000.
          C CALCULATE Y-INDEPENDENT PART OF PLUME DISPERSION EQUATION.
0052                  CONST=(Q/(6.2832*SY*SZ*U))*
          1                      (EXP(-0.5*(((Z-HX)/SZ)**2.))+
          2                      EXP(-0.5*(((Z+HX)/SZ)**2.)))
          C LOOP OVER Y VALUES AT EACH VALUE OF (X,Z).START AT 0, SO ONLY
          C INTEGRATE OVER HALF OF THE PLUME.
0053      60          DO 10 IY=0,IYMAX,10
0054                  Y=IY
          C CALCULATE PLUME CONCENTRATION AT (X,Y,Z).
0055                  CHI=CONST*(EXP(-0.5*(((Y/SY)**2.)))
          C MULTIPLY CHI BY INCREMENTAL VOLUME (1000 M**3) AND DIVIDE BY
          C SIN(56) TO ACCOUNT FOR LENGTHENED PATH THROUGH PLUME.

```

FORTRAN IV VC2.04C
CORE=29K, UTC=[100,107]

WED 06-JUN-79 15:46:54

PAGE 003
SOLAR,SOLAR/-SP=SOLAR

```
0 5 70                                CHIXYZ=CHI*TENSIN
C ADD INCREMENTAL CONCENTRATION TIMES VOLUME TO TOTAL SUM.
0057                                SUM=SUM+CHIXYZ
0058 10                                CONTINUE
0059 20                                CONTINUE
0060 30                                CONTINUE
C    FOR EFFECTIVE CL, MULTIPLY SUM BY 2 (SYMMETRY IN Y),
C    AND DIVIDE BY TOTAL AREA OF ELLIPSE MINUS CENTER CIRCLE.
0061                                AREA=1926178.
0062                                CL=2.*SUM/AREA
C WRITE OUT INFORMATION TO OUTPUT FILE.
0063                                WRITE(4,9060)Q
0064 9060    FORMAT(' EMISSION RATE (G/SEC)=',F10.5)
0065                                WRITE(4,9070)CL
0066 9070    FORMAT(' EFFECTIVE CL(G/M**2)=',F10.5)
0067                                WRITE(5,9080)
0068 9080    FORMAT(' EXIT')
0069                                CALL EXIT
0070                                END
```

```

0. 1      SUBROUTINE SIGMA (X,KST,SY,SZ)
C          SUBROUTINE SIGMA CALCULATES HORIZONTAL AND VERTICAL STANDARD
C          DEVIATIONS OF CONCENTRATION. THE HORIZONTAL STD. DEV., SY IS
C          OBTAINED FROM THE ANGLE BETWEEN A LINE DRAWN FROM THE SOURCE
C          IN THE DOWNWIND DIRECTION AND THE BOUNDARY OF THE PLUME AS IS
C          SUGGESTED BY PASQUILL. PASQUILL'S DISCUSSION ACTUALLY USES
C          TWO TIMES THIS ANGLE. THE VERTICAL STD. DEV., SZ, IS
C          CALCULATED FROM A SET OF EQUATIONS DEPENDENT UPON STABILITY
C          CLASS AND DOWNWIND DISTANCE OF THE RECEPTOR.
C          THE VARIABLES USED IN SUBROUTINE SIGMA ARE...
C          X      DISTANCE RECEPTOR IS DOWNWIND OF SOURCE (KM)
C          XY     X+VIRTUAL DISTANCE USED FOR AREA SOURCE APPROX. (KM)
C          KST    STABILITY CLASS, SEE PAGE 209 OF PASQUILL, ATMOSPHERIC
C                  DISPERSION
C                  1  IS PASQUILL STABILITY CLASS A
C                  2  IS PASQUILL STABILITY CLASS B
C                  3  IS PASQUILL STABILITY CLASS C
C                  4  IS PASQUILL STABILITY CLASS D2
C                  5  IS PASQUILL STABILITY CLASS E
C                  6  IS PASQUILL STABILITY CLASS F
C                  7  IS PASQUILL STABILITY CLASS D1
C                  41 IS PASQUILL STABILITY CLASS D1
C                  42 IS PASQUILL STABILITY CLASS D2
C          SY     SIGMA Y, THE STANDARD DEVIATION OF CONCENTRATION IN THE
C                  Y-DIRECTION (M)
C          SZ     SIGMA Z, THE STANDARD DEVIATION OF CONCENTRATION IN THE
C                  Z-DIRECTION (M)
C          GC TO PROPER SET OF EQUATIONS FOR THIS STABILITY CLASS TO
C          CALCULATE TH FOR THE GIVEN XY, AND CALCULATE SZ FOR THE GIVEN
C          X. THEN GC TO 80 WHERE SZ IS LIMITED TO 5000 AND SY IS
C          CALCULATED FROM XY AND TH. RETURN.
0002      XY=X
0003      GO TO (10,30,40,42,52,60),KST
C          STABILITY A (10)
0004      10 TH = (24.167 - 2.5334*ALOG(XY))/57.2958
0005      IF (X-0.15)11,12,12
0006      11 SZ = 158.08 *X ** 1.0542
0007      GO TO 80
0008      12 IF (X-0.20)13,13,14
0009      13 SZ = 170.22 *X ** 1.0932
0010      GO TO 80
0011      14 IF (X-0.25)15,15,16
0012      15 SZ = 179.52 *X ** 1.1262
0013      GO TO 80
0014      16 IF (X-0.30)17,17,18
0015      17 SZ = 217.41 *X ** 1.2644
0016      GO TO 80
0017      18 IF (X-0.40)19,19,20

```

```

0018      19 SZ = 258.89 *X ** 1.4094
0019      GC TC 80
0020      20 IF (X-0.50)21,21,22
0021      21 SZ = 346.75 *X ** 1.7283
0022      GC TC 80
0023      22 IF (X-3.11)23,23,24
0024      23 SZ = 453.85 *X ** 2.1166
0025      GC TC 80
0026      24 SZ = 5000.
0027      GC TC 80
      C      STABILITY B (30)
0028      30 TH = (18.333 - 1.8096*ALOG(XY))/57.2958
0029      IF (X-0.2)31,31,32
0030      31 SZ = 90.673 *X ** 0.93198
0031      GC TC 80
0032      32 IF (X-0.4)33,33,34
0033      33 SZ = 98.483 *X ** 0.98332
0034      GC TC 80
0035      34 SZ = 109.30 *X ** 1.0971
0036      GC TC 80
      C      STABILITY C (40)
0037      40 TH = (12.5 - 1.0857*ALOG(XY))/57.2958
0038      SZ = 61.141 *X ** 0.91465
0039      GC TC 80
      C      STABILITY D2 OR D (42)
0040      42 TH = (8.3333-0.72382*ALOG(XY))/57.2958
0041      IF (X-0.3)41,41,39
0042      41 SZ = 34.459 *X ** 0.86974
0043      GC TC 80
0044      39 IF (X-1.0)43,43,44
0045      43 SZ = 32.093 *X ** 0.81066
0046      GC TC 80
0047      44 IF (X-3.0)45,45,46
0048      45 SZ = 32.093 *X ** 0.64403
0049      GC TC 80
0050      46 IF (X-10.)47,47,48
0051      47 SZ = 33.504 *X ** 0.60486
0052      GC TC 80
0053      48 IF (X-30.)49,49,50
0054      49 SZ = 36.650 *X ** 0.56589
0055      GC TC 80
0056      50 SZ = 44.053 *X ** 0.51179
0057      GC TC 80
      C      STABILITY E (52)
0058      52 TH = (6.25 - 0.54287*ALOG(XY))/57.2958
0059      IF (X-0.3)53,53,54
0060      53 SZ = 23.331 *X ** 0.81956
0061      GC TC 80
  
```

```

0002 54 IF (X-1.)55,55,56
0063 55 SZ = 21.628 *X ** 0.75660
0064 GO TC 80
0065 56 IF (X-2.)57,57,58
0066 57 SZ = 21.628 *X ** 0.63077
0067 GO TC 80
0068 58 IF (X-4.)59,59,60
0069 59 SZ = 22.534 *X ** 0.57154
0070 GO TC 80
0071 60 IF (X-10.)61,61,62
0072 61 SZ = 24.703 *X ** 0.50527
0073 GO TC 80
0074 62 IF (X-20.)63,63,64
0075 63 SZ = 26.970 *X ** 0.46713
0076 GO TC 80
0077 64 IF (X-40.)65,65,66
0078 65 SZ = 35.420 *X ** 0.37615
0079 GO TC 80
0080 66 SZ = 47.618 *X ** 0.29592
0081 GO TC 80
C STABILITY F (68)
0082 68 TH = (4.1667 - 0.36191*ALOG(XY))/57.2958
0083 IF (X-0.2)69,69,70
0084 69 SZ = 15.209 *X ** 0.81558
0085 GO TC 80
0086 70 IF (X-0.7)73,73,74
0087 73 SZ = 14.457 *X ** 0.78407
0088 GO TC 80
0089 74 IF (X-1.)75,75,76
0090 75 SZ = 13.953 *X ** 0.68465
0091 GO TC 80
0092 76 IF (X-2.)77,77,78
0093 77 SZ = 13.953 *X ** 0.63227
0094 GO TC 80
0095 78 IF (X-3.)79,79,82
0096 79 SZ = 14.823 *X ** 0.54503
0097 GO TC 80
0098 82 IF (X-7.)83,83,84
0099 83 SZ = 16.187 *X ** 0.46490
0100 GO TC 80
0101 84 IF (X-15.)85,85,86
0102 85 SZ = 17.836 *X ** 0.41507
0103 GO TC 80
0104 86 IF (X-30.)87,87,88
0105 87 SZ = 22.651 *X ** 0.32681
0106 GO TC 80
0107 88 IF (X-60.)89,89,90
0108 89 SZ = 27.074 *X ** 0.27436

```

FORTRAN IV V02.04C
CURE=29K, UIC=(100,107)

WED 06-JUN-79 15:47:24

PAGE 004
SIGMA,SIGMA/-SP=SIGMA

```
0109      GO TC 80
0110      90 SZ = 34.219 *X ** 0.21716
0111      80 IF (SZ-5000.)96,96,95
0112      95 SZ = 5000.
0113      96 SY = 1000.*XY*SIN(TH)/(2.15*COS(TH))
0114      RETURN
0115      END
```

C 1 SUBROUTINE BEH072 (HF,HX,HMW,F,DELHF,DISTF,DELHX,HP,TS,VS,D,VF,
1 KSI,U,X,DTHDZ,T,P)
C BEH072 (BRIGGS EFFECTIVE HEIGHT) OCTOBER 1972
C THIS DIFFERS FROM THE AUGUST 1972 VERSION IN STATEMENT 24 + 1
C THE CONSTANT 2.4 PREVIOUSLY WAS 2.9, AND IN STATEMENT 27
C THE CONSTANT 3.14159 PREVIOUSLY WAS 2.4 .
C D. B. TURNER, RESEARCH METEOROLOGIST* MODEL DEVELOPMENT BRANCH,
C DIVISION OF METEOROLOGY, ENVIRONMENTAL PROTECTION AGENCY,
C ROOM 314B, NCHS BUILDING, RTP. PHONE (919) 549-8411 EXT 4564
C MAILING ADDRESS- DM, EPA, RESEARCH TRIANGLE PARK, NC 27711
C * ON ASSIGNMENT FROM NATIONAL OCEANIC AND ATMOSPHERIC
C ADMINISTRATION, DEPARTMENT OF COMMERCE.
C FROM A SINGLE SOURCE IS BASED ON
C THIS VERSION OF BRIGGS EFFECTIVE HEIGHT TO CALCULATE PLUME RISE
C 1) BRIGGS, GARY A., 1971 SOME RECENT ANALYSES OF PLUME RISE
C OBSERVATION. PP 1029 - 1032 IN PROCEEDINGS OF THE SECOND
C INTERNATIONAL CLEAN AIR CONGRESS, EDITED BY H. M. ENGLUN
C AND W. T. BEERY. ACADEMIC PRESS, NEW YORK.
C 2) BRIGGS, GARY A., 1972 DISCUSSION ON CHIMNEY PLUMES IN
C NEUTRAL AND STABLE SURROUNDINGS. ATMOS. ENVIRON. 6, 507
C - 510. (JUL 72).
C OUTPUT VARIABLES ARE...
C HF FINAL EFFECTIVE PLUME HEIGHT (METERS)
C HX EFFECTIVE PLUME HEIGHT FOR DISTANCE X (METERS)
C HMW HEAT OUTPUT OF SOURCE (MW)
C F BUOYANCY FLUX (M**4/SEC**3)
C DELHF FINAL PLUME RISE (METERS)
C DISTF DISTANCE OF FINAL PLUME RISE FROM SOURCE (KM)
C DELHX PLUME RISE AT DISTANCE X (METERS)
C INPUT VARIABLES ARE...
C HP PHYSICAL STACK HEIGHT (METERS)
C TS STACK GAS TEMPERATURE (DEG K)
C VS STACK GAS EXIT VELOCITY (M/SEC)
C D INSIDE STACK DIAMETER (METERS)
C VF STACK GAS VOLUMETRIC FLOW RATE (M**3/SEC)
C KST STABILITY (CLASS), SEE PAGE 209 OF PASQUILL,
C ATMOSPHERIC DISPERSION, CLASSES DEFINED BY...
C 1 IS PASQUILL STABILITY CLASS A
C 2 IS PASQUILL STABILITY CLASS B
C 3 IS PASQUILL STABILITY CLASS C
C 4 IS PASQUILL STABILITY CLASS D
C 5 IS PASQUILL STABILITY CLASS E
C 6 IS PASQUILL STABILITY CLASS F
C U WIND SPEED (M/SEC)
C X DOWNWIND DISTANCE (KM)
C DTHDZ POTENTIAL TEMPERATURE LAPSE RATE (DEG K/METER)
C T AMBIENT AIR TEMPERATURE (DEG K)
C P AMBIENT AIR PRESSURE (MB)


```

C      THANKS TO DALE COVENTRY FOR HIS HELPFUL DISCUSSION ON
C      PROGRAMMING PLUME RISE, TO RUGER THOMPSON FOR THE COMMENT
C      CARDS, AND TO RUSS LEE WHO REVISED THIS ACCORDING TO REFERENCE
0002  IF(T)1,1,2
C      T = 0. MEANS NO AMBIENT TEMPERATURE GIVEN. USE T = 293.
0003  1 T = 293.
0004  2 IF(P)3,3,4
C      P = 0. MEANS NO AMBIENT AIR PRESSURE GIVEN. USE P = 960.
0005  3 P = 960.
C      IF VF IS NOT GIVEN, CALCULATE IT FROM STACK DATA.
0006  4 IF(VF)5,5,6
0007  5 VF = 0.785398*VS*D*D
C      THE CONSTANT 0.785398 = PI/4
0008  6 F = 3.12139*VF*(TS-T)/TS
C      THE CONSTANT 3.12139 IS THE ACCELERATION DUE TO GRAVITY / PI.
0009  HMW = 0.00011217*F*P
C      THE CONSTANT 0.00011217 = PI TIMES THE SPECIFIC HEAT OF AIR AT
C      CONSTANT PRESSURE (0.24 CAL/GM*DEG K) TIMES MOLECULAR WEIGHT
C      OF AIR (28.966 GM/GM.MOLE) DIVIDED BY IDEAL GAS CONSTANT
C      (0.0831 MB*M**3/GM.MOLE*DEG K) AND ACCELERATION DUE TO GRAVITY
C      (9.80616 M/SEC*SEC) AND THEN MULTIPLIED BY (4.1855E-06 MW/CAL
C      PER SEC) TO CONVERT THE ANSWER TO MEGAWATTS.
C      GO TO APPROPRIATE BRANCH FOR STABILITY CONDITION GIVEN.
C      IF UNSTABLE OR NEUTRAL GO TO 7, IF STABLE GO TO 20.
0  GO TC (7,7,7,7,20),KST
C      DETERMINE APPROPRIATE FORMULA FOR CALCULATING XST, DISTANCE AT
C      WHICH TURBULENCE BEGINS TO DOMINATE. THE FORMULA USED DEPENDS
C      UPON BUOYANCY FLUX. STATEMENTS 8 AND 9 ARE EQUATION (7).
0011  7 IF(F-55.)8,9,9
0012  8 XST=14.*F**.625
0013  GO TC 10
0014  9 XST=34.*F**.4
0015  10 DISTF=3.5*XST
0016  DELHF=1.6*F**0.333333*DISTF**0.666667/U
0017  IF(X)29,29,32
C      IF X = 0.0, CALCULATE FINAL RISE ONLY, IF X IS GREATER THAN
C      0.0, CALCULATE RISE FOR DISTANCE = X ALSO.
0018  32 XM = 1000.* X
C      XM IS X IN METERS.
C      STATEMENT 14 IS EQUATION (6), REFERENCE 1.
0019  14 DELHX = 1.6*F**0.333333*XM**0.666667/U
0020  IF(DELHX.GT.DELHF)DELHX=DELHF
0022  GO TC 30
0023  20 IF(DTHDZ)21,21,24
C      IF DTHDZ IS NEGATIVE OR ZERO ASSIGN TO IT A VALUE OF 0.02 OR
C      0.035 IF STABILITY IS SLIGHTLY STABLE OR STABLE, RESPECTIVELY.
0024  21 GO TC (7,7,7,7,22,23),KST
0025  22 DTHDZ = 0.02

```

```

0000      GO TC 24
0027      23 DTHDZ = 0.035
0028      24 S = 9.80616*DTHDZ/T
      C      THE CONSTANT 9.80616 IS THE ACCELERATION DUE TO GRAVITY.
      C      S IS A STABILITY PARAMETER.
      C      CALCULATE PLUME RISE ACCORDING TO EQUATION (4), REFERENCE 1.
0029      DHA = 2.4*(F/(U*S))**0.333333
      C      CALCULATE PLUME RISE BY EQUATION (5), REFERENCE 1 FOR LIGHT
      C      WIND CONDITIONS ACCORDING TO MORTON, TAYLOR, AND TURNER.
0030      DELHF = 5.0*F**0.25/S**0.375
0031      IF(DHA-DELHF) 25,25,27
0032      25 DELHF = DHA
      C      DISTANCE TO FINAL PLUME RISE IS GIVEN BY THE FOLLOWING
0033      27 DISTF = 3.14159*U/S**0.5
      C      IF X = 0.0, CALCULATE FINAL RISE ONLY, IF X IS GREATER THAN
      C      0.0, CALCULATE RISE FOR DISTANCE = X ALSO.
      C      IF X IS ZERO OR LESS, GO TO 29 AND SET PLUME RISE AND DIST. TO
      C      MAXIMUM PLUME RISE EQUAL TO ZERO.
0034      IF(X)29,29,33
0035      33 XM = 1000.*X
      C      XM IS X IN METERS.
      C      IF XM IS GREATER THAN THE DISTANCE TO THE POINT OF FINAL PLUME
      C      RISE, SET PLUME RISE EQUAL TO FINAL PLUME RISE, OTHERWISE,
      C      CALCULATE PLUME RISE FROM EQUATION (6), REFERENCE 1.
      C      IF(XM-DISTF)14,14,28
0036      28 DELHX = DELHF
0037      GO TC 30
0038      29 DELHX = 0.
0039      HX = 0.
0040      GO TC 31
      C      CALCULATE EFFECTIVE HEIGHT AT DISTANCE X.
0042      30 HX = HP + DELHX
      C      CALCULATE FINAL EFFECTIVE HEIGHT.
0043      31 HF = HP + DELHF
0044      DISTF = DISTF/1000.
0045      RETURN
0046      END

```

APPENDIX M

1.44 SOLAR MULTIPLE PREFERRED COMMERCIAL PLANT DESIGN DATA SHEETS

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem
Preferred Commercial Systems

NUMBER

PREPARED BY

D. A. Carey (MDAC)

APPROVED BY

WBS NO.

PAGE 1

DATE Sept. 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
New	A	Design Characteristics					
	1	Field Geometry and Size	m (f)				Field is made up of a grouping of 369.0 square cells which are trimmed on the perimeter of the field to form a pseudocircular shape of the given dimensions (see Figure 5.2-32).
		North-South		3966 (13012)		X	
		East-West		4058 (13314)		X	
		Distance from South Boundary to Tower		1568 (5144)		X	
		Distance from East Boundary to Tower		2029 (6657)		X	
	2	Field Layout				X	Heliostats are distributed throughout the field in a radial stagger array. Density and spacing are defined on a cell-by cell basis (see Figures 5.2-33 through 5.2.36).
	3	Field Oversizing for Dirt on Mirrors, Reliability, etc.					
		Dirt	%	3.1		X	Reflectivity degraded by .97
		Reliability	%	2.0		X	Assumes availability of .98
	4	Beam Pointing Accuracy and Error Budget Versus Environmental Effects	mr 1σ			X	Wind of 10 to 20 knots
		Azimuth					
		Maximum Peak to Peak	mr	1.0 + 0.6			
		Mean	mr	0.4 ± 0.4			
		% Time above 1.0 mr	%	1.0

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem
Preferred Commercial System

NUMBER

PREPARED BY

D. A. Carey (MDAC)

APPROVED BY

WBS NO.

PAGE 2

DATE Sept, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Elevation					
		Maximum Peak to Peak	mm	0.5 + 0.4			
		Mean	mm	0.4 ± 0.4			
		% Time Above	%	1.0			
	5	Heliostat Beam Quality and Error Budget Versus Environmental Effects					Not analyzed. Three percent degradation for reflectivity assumed in performance calculations. Fifty km visibility assumed to atmospheric absorption.
	6	Heliostat Geometry and Size					
		Shape		Square			
		Glass Area	m ² (ft ²)	49.05 (528)		X	See Figure 5.2-1, 5.2-2, 5.2-3
	7	Number of Heliostats		60,676		X	
	B	Operating Characteristics					
	1	Power Required/Heliostat					
		Track		1.5 amps @ 480V			
		Starting		3.0 amps @ 480V			
		Emergency Shutdown		N/A			
		Average Daily Energy	w-h	100

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Collector Subsystem
Preferred Commercial System

NUMBER

PREPARED BY

D. A. Carey (MDAC)

APPROVED BY

WBS NO.

PAGE 3

DATE Dept. 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	2	Helio-stat Operating Modes Startup Tracking Emergency Slew Hold Stowing (Inverted)			X	X X X X	
	3	Control System Characteristics					Open loop, automatic with manual override (remote and at helio-stat) (see Section 5.2.2).

ESG-79-30, Vol 111

M-4

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE 1 of 14

DATE August 30, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	A		Design Characteristics					
	1		Receiver height	m (ft)	28.5 (93.5)			
			Receiver diameter	m (ft)	25.0 (82.0)			
			Receiver mdipoint elevation	m (ft)	334.0 (1095.5)			
			EXCLUSION RADIUS	m (ft)	275.0			
	2		Area of working surface	m ² (ft ²)	2238.4 (24,081.4)			
	3		Absorber tube OD	cm (in.)	3.18 (1.25)			
			Absorber tube ID	cm (in.)	2.92 (1.15)			
			Absorber tube wall thickness	cm (in.)	0.127 (0.05)			
	4		Absorber tube length	m (ft)	28.5 (93.5)			
	5		Number of panels		36			
			Number of tubes per panel		69			
	6		Panel material (dry)		304 SS			
	7		Heat pipe material		NA			(Not applicable)
	8		Header material		CS and SS			CS - 288°C (550°F), SS - 593°C (1100°F)
	9		Insulation material					Closed pore Fiberglass, 10 lb/ft ³ Calcium silicate, 13 lb/ft ³
	13		Receiver valve material		CS			Receiver proper only
			Number		36			36-20 cm (8 in.) control butterfly valves

ESG-79-30, Vol III

M-5

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE 2

DATE August 30, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	14		Pump material Number of receiver pumps Mass (dry weight pump)	kg (ton)	--			No pumps in receiver proper
	16		Total dry mass on top of tower	kg (ton)	989,090 (1088)			Sum of Items 6-15
	17		Receiver Subsystem Sodium Inventory a. Receiver only	kg (ton)	564,000 (620) 94,500 (104)			
	18		Receiver operational seismic load Vertical at tower top Horizontal at tower top	kg (ton) g g	TBD			Excluding riser/downcomer
	19		Receiver survival seismic load Vertical at tower top Horizontal at tower top	g g	TBD			
	20		ASME design code for receiver additional requirements	Section	VIII			
	21		Receiver surface coating Composition Absortivity Emissivity		Pyromark -- 0.95 0.90			

ESG-79-30, Vol I II

M-6

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE 3

DATE August 30, 1979

NEW REV	NO.	A. ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	22	Receiver pressure drop corrections a. Pressure drop: $\Delta p = \left(f \frac{L}{D} + K \right) \frac{\rho v^2}{2g}$ b. Reynolds number: $Re = \frac{Dv\rho}{\mu_e}$					<p>Δp = differential pressure</p> <p>f = friction factor</p> <p>L = length of receiver pipe in feet</p> <p>D = internal diameter of receiver pipe in feet</p> <p>v = mean velocity of flow, in feet per second</p> <p>g = acceleration of gravity = 32.2 ft/sec²</p> <p>Re = Reynolds number</p> <p>ρ = weight density of fluid, pounds per ft³</p> <p>μ_e = absolute viscosity in pound mass per foot second</p> <p>K = resistance coefficient</p>

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE 4

DATE August 30, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEM- PERATURE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	23	Receiver heat transfer correlations (for power into receiver working fluid) a. For conduction through tube wall: $q' = \frac{2\pi K L \Delta T}{\ln \frac{d_o}{d_i}}$ b. Sodium heat transfer coefficient: $Nu = 7 + \frac{1}{40} (Pr Re)^{0.8}$ $h_{Na} = \frac{Nu K}{d_i}$					q = heat transferred K = thermal conductivity of tube wall (Btu/hr- ft ² -F) d_o = outside diameter of tube wall - inches d_i = inside diameter of tube wall - inches Nu = Nusselt number Pr = Prandtl number Re = Reynolds number Combined conduction through tube wall and sodium heat transfer coefficient L = wall thickness ΔT = differential temperature across wall

ESG-79-30, Vol III

M-8

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe SM 1.44

NUMBER
Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE 5

DATE August 30, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	24	<p>Receiver heat transfer correlation for receiver losses</p> <p>a. Air natural convection heat transfer coefficient (vertical cylinder):</p> $Nu = 0.13 (GrPr)^{1/3}$ $Nu = \frac{hL}{K}$ $Gr = \left(\frac{\rho^2 g \beta}{\mu^2} L^3 \Delta T \right)$ $Pr = \frac{\mu C_p}{K}$					<p>Nu = Nusselt number</p> <p>Gr = Grashof number</p> <p>Pr = Prandtl number, air</p> <p>K = thermal conductivity, air (Btu/hr-ft²-F)</p> <p>g = gravitational constant</p> <p>$\beta = \frac{1}{T} (^{\circ}R^{-1})$ for air</p> <p>ρ = density</p> <p>μ = viscosity</p> <p>T = temperature</p>

ESG-79-30, Vol III

M-9

Rockwell International

Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE 6

DATE August 30, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	24	<p>b. Forced convection:</p> <p>Extrapolated Achenbach data</p> <p>c. Assumed combined convection heat transfer coefficient:</p> $h_{eff.} = \sqrt{h_{forced}^2 + h_{nat.}^2}$ <p>d. Thermal radiation:</p> $q = \mathcal{F} \epsilon \sigma A (T_1^4 - T_2^4)$					<p>h = heat transfer coefficient (Btu/hr-ft²-°F)</p> <p>q = heat flow rate (Btu/hr-ft²-F)</p> <p>$\mathcal{F}$ = radiation factor</p> <p>ϵ = surface thermal emissivity</p> <p>σ = Stefan-Boltzmann constant</p> <p>A = radiating surface area</p> <p>T_1 = effective mean radiating surface temperature (°R)</p> <p>T_2 = radiative sink temperature (°R)</p>

FORM 700-A REV. 8-78

714-G.61

ESG-79-30, Vol III

M-10

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE 7

DATE August 30, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	25	Tower construction Height to top of tower Diameter - base Diameter - top Wall thickness - base Wall thickness - top OD ID Thickness	m (ft) m (ft) m (ft) m (ft) m (ft) m (ft) m (ft) m (ft) m (ft)	TBD 316 (1031)			Slip formed concrete
	26	Riser material Outside diameter Inside diameter Wall thickness Downcomer material Outside diameter Inside diameter Wall thickness Riser temperature Riser pressure Riser maximum flow Riser maximum velocity Downcomer temperature Downcomer pressure Downcomer maximum flow Downcomer maximum velocity	cm (in.) cm (in.) cm (in.) cm (in.) cm (in.) cm (in.) cm (in.) cm (in.) °C (F) MPa (psia) kg/S (lb/s) M/S (ft/s) °C (°F) MPa (psia) kg/S (lb/s) M/S (ft/s)	CS 121.9 (48) 111.8 (44) 5.1 (2.0) SS 76.2 (30.00) 73.0 (28.75) 1.6 (.625) 371 (700) 5.52 (800) 4,370 (9,600) 5.0 (16.48) 621 (1150) 4.14 (600) 4,370 (9,600) 12.8 (42.1)			ANSI B31.1
	27	Riser total length Downcomer total length	m (ft) m (ft)	543.8 (1,783.5) 543.8 (1,783.5)			
	28	Mass of riser Mass of downcomer	kg (ton) kg (ton)	795,700 (875.3) 158,800 (174.7)			Piping material Piping material

Rockwell International
Energy Systems Group

DES GN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe SM 1.44

NUMBER
Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE 8

DATE August 30, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	29		Riser/downcomer insulation material Insulation thickness - riser Insulation thickness - downcomer	cm (in.) cm (in.)	7.6 (3.0) 12.7 (5.0)			Calcium silicate
	30		Mass of riser insulation Mass of downcomer insulation	kg (ton) kg (ton)	31,600 (34.7) 32,900 (36.2)			
	31		Mass of miscellaneous items in tower Elevator Stack Stack support		TBD			

ESG-79-30, Vol III

M-12

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

APPROVED BY

J. Auleta

WBS NO.

DATE August 30, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	32	Horizontal piping material					
		OD 107 (42)	cm (in.)	107 (42)			304 SS
		ID 102.2 (40.25)	cm (in.)	102.2 (40.25)			2.22 (2.815)
		Wall thickness 2.22 (2.815)	cm (in.)	91 (36)			304 SS
		OD	cm (in.)	1.91 (0.75)			
		ID	cm (in.)	87.6 (34.5)			
		Wall thickness	cm (in.)	61 (24)			304 SS
		OD	cm (in.)	1.27 (.5)			
		ID	cm (in.)	58.4 (23)			
		Wall thickness	cm (in.)	107 (42)			
		OD	cm (in.)	1.59 (.625)			
		ID	cm (in.)	103.5 (40.75)			
		Wall thickness	cm (in.)	76.2 (30)			304 SS
		OD	cm (in.)	1.59 (0.625)			
		ID	cm (in.)	73 (28.75)			
		Wall thickness	cm (in.)				
	33	Horizontal piping total lengths					
		107 cm (42 in.)	n (ft)	43 (140)			304 SS
		91 cm (36 in.)	n (ft)	24 (80)			304 SS
		61 cm (24 in.)	n (ft)	30 (100)			304 SS
		107 cm (42 in.)	n (ft)	49 (160)			Carbon Steel
		76 cm (30 in.)	n (ft)	12 (40)			304 SS
		6 cm (2.4 in.)	n (ft)	137 (450)			
	34	Horizontal piping mass	kg (ton)	29,300 (32.2)			Sum of Item 33
	35	Horizontal piping insulation material					Calcium silicate with aluminum weather protection
	36	Mass of horizontal piping insulation	kg (ton)	7,900 (8.7)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe SM 1.44

NUMBER
Revision 0

PREPARED BY

APPROVED BY

J. Auleta

WBS NO.

PAGE 10

DATE August 30, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS																																						
				UNIT	VALUE																																									
	37		Valve size, number, and material	cm (in.)				<table><tr><th>Valve No.</th><th>Quantity</th><th>Material</th></tr><tr><td>Check valves</td><td>122 (48)</td><td>TBD</td><td>2</td><td>CS</td></tr><tr><td>Block</td><td>15 (6)</td><td>TBD</td><td>1</td><td>CS</td></tr><tr><td>Drag valve</td><td>76 (30)</td><td>TBD</td><td>1</td><td>SS</td></tr><tr><td>Control</td><td>61 (24)</td><td>TBD</td><td>1</td><td>SS</td></tr><tr><td>Control</td><td>20 (8)</td><td>TBD</td><td>36</td><td>CS</td></tr><tr><td>Block</td><td>15 (6)</td><td>TBD</td><td>4</td><td>CS</td></tr><tr><td>Block</td><td>15 (6)</td><td>TBD</td><td>1</td><td>SS</td></tr></table>	Valve No.	Quantity	Material	Check valves	122 (48)	TBD	2	CS	Block	15 (6)	TBD	1	CS	Drag valve	76 (30)	TBD	1	SS	Control	61 (24)	TBD	1	SS	Control	20 (8)	TBD	36	CS	Block	15 (6)	TBD	4	CS	Block	15 (6)	TBD	1	SS
Valve No.	Quantity	Material																																												
Check valves	122 (48)	TBD	2	CS																																										
Block	15 (6)	TBD	1	CS																																										
Drag valve	76 (30)	TBD	1	SS																																										
Control	61 (24)	TBD	1	SS																																										
Control	20 (8)	TBD	36	CS																																										
Block	15 (6)	TBD	4	CS																																										
Block	15 (6)	TBD	1	SS																																										
	38		Number and mass of valves	kg (lb)	4,500 (10,000)			Ground level only																																						
	39		Receiver pump material P-1					CS																																						
			Number of receiver pumps		1			Ground level only																																						
			Mass of receiver pump	kg (lb)				Dry weight																																						
	40		Pump characteristics P-1					Centrifugal mixed flow, double stage, inducer type double																																						
			Type																																											
			Speed	rpm	1067																																									
			Operating range																																											
			Head	m (ft)	409 (1340)																																									
			NPSH	m (ft)	9.1 (30)																																									
			Operating temperature	°D (°F)	288 (550)																																									
			Power (N = 82%)	kW (hp)	16,400 (22,000)																																									
			Capacity	m ³ /s (gpm)	0.88 (74,000)			4.67																																						
			Inlet pressure	MPa (psi)	0.08 (11.5)																																									
			Outlet pressure	MPa (psi)	3.66 (524)																																									
			Pump height w/motor	m (ft)																																										
			Pump tank dimensions	m (ft)																																										

DESIGN DATA SHEET

TITLE	1
-------	---

Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE 11

DATE August 30, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	40		Pump characteristics (Continued)					
			Inlet nozzle	m. (ft)	1.21 (4)			
			Outlet nozzle		1.21 (4)			
			Impeller diameter		0.95 (3.13)			
			Casing diameters					
			Code					ASME Section VIII Div. 1
			Pump motor					
			Size	MWe (hp)				
			Dimensions	m (ft)				
			Voltage	V				
			Mass	kg (lb)				
			No. poles					
			Speed	rpm				
	41		Steam generator heat exchanger characteristics					
			Service - evaporator X-1					
			Number required		2			
			Type		-			
			Orientation		Vertical			Tube and shell hockey stick
			Number of tube passes		1			
			Number of shell passes		1			
			Tube side fluid		Water			
			Shell side fluid		Sodium			
			Tube material		2-1/4 Cr -			
					1 Mo			
			Shell material		2-1/4 Cr -			
					1 Mo			
			Number of tubes		2,810			Per unit
			Tube OD	cm (in.)	1.59 (5/8)			
			Tube ID	cm (in.)	1.21 (0.475)			
			Tube wall thickness	cm (in.)	0.21 (0.082)			
			Unit size - height	m (ft)	29.0 (95)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE

12

DATE

August 30, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
	41		Steam generator heat exchanger characteristics (Continued)					
			Unit size - width	m (ft)	6.4 (21)			
			Unit size - shell diameter	m (in.)	1.96 (77)			
			Mass per unit	kg (ton)	148,000 (163)			
			Active external surface area per unit	m ² (ft ²)	3,335 (35,900)			
			Inactive external surface area per unit	m ² (ft ²)	335 (3,600)			
			LMTD - preheating	°C (°F)	15 (27)			
			LMTD - nucleate boiling	°C (°F)	14 (26)			
			LMTD - film boiling	°C (°F)	59 (107)			
			Pinch point	°C (°F)	4 (7)			
			Sodium nozzle OD/thickness	cm/in.	TBD			
			Tubesheet diameter/thickness		TBD			
			Steam nozzle OD/thickness		TBD			
			Sodium pressure	MPa (psia)	2.07 (300)			
			Steam pressure	MPa (psia)	17.93 (2600)			
			Steam temperature	°C (°F)	482 (900)			
			Code					
			DUTY	MWt	214.5 -			ASME Section VIII Div. I PER UNIT TOTAL DUTY = 589 MWt
	41		Service - Superheater X-2					
			Number required		1			
			Type		-			
			Orientation		Vertical			Tube and shell hockey stick
			Number of tube passes		1			
			Number of shell passes		1			
			Tube side fluid		Steam			
			Shell side fluid		Sodium			
			Tube material		SS			
			Shell material		SS			
			Number of tubes		1779			
			Tube OD	cm (in.)	1.59 (5/8)			
			Tube ID	cm (in.)	0.91 (0.355)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE

13

DATE

August 30, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	41	Service - Superheater X-2 (Continued)					
		Unit size - height	m (ft)	27.7 (91)			
		Unit size - width	m (ft)	5.79 (19)			
		Unit size - shell diameter	m (in.)	1.63 (64)			
		Mass per unit	kg (ton)	95,300 (105)			
		Active external surface area per unit	m ² (ft ²)	1514 (16,300)			2100 (22,500)
		Inactive external surface area per unit	m ² (ft ²)	TBD			
		LMTD	°C (°F)	77 (139)			
		Sodium pressure	MPa (psig)	2.07 (300)			
		Steam pressure		TBD			
		Steam temperature	°C (°F)	593 (1100)			
		Code					
		DUTY					
	41	Service - Reheater X-2	MWt	301			ASME Section VIII Div. I
		Number required		1			
		Type		-			
		Orientation		Vertical			
		Number of tube passes		1			
		Number of shell passes		1			
		Tube side fluid		Steam			
		Shell side fluid		Sodium			
		Tube material		SS			
		Shell material		SS			
		Number of tubes		166 775			
		Tube OD	cm (in.)	3.49 (1-3/8)			
		Tube ID	cm (in.)	2.93 (1.155)			
		Tube wall thickness	cm (in.)	0.028 (0.110)			
		Unit size - height	m (ft)	20.1 (66)			
		Unit size - width	m (ft)	6.7 (22)			
		Unit size - shell diameter	m (in.)	1.75 (69)			
							Tube and shell hockey stick

ESG-79-30, Vol III

M-17

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Receiver Subsystem
430 MWe WM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE 14

DATE August 30, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
				UNIT	VALUE			
41			Service - Reheater X-2 (Continued)					
			Mass per unit	kg (ton)	104,300 (115)			
			Active external surface area per unit	m ² (ft ²)	1514 (16,300)			
			Inactive external surface area per unit	m ² (ft ²)	TBD			
			LMTD	°C (°F)	77 (139)			
			Sodium pressure	MPa (psig)	207 (300)			
			Steam pressure		3.10 (450)			
			Steam temperature	°C (°F)	593 (1100)			
			Code					
			DUTY	MWt	165			ASME Section VIII Div. I

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Storage Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE 1 of 7

DATE August 30, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	A	Design Characteristics					
	1.	Storage Media					TDT 12083
		a. Specific Heat @ 288°C (550°F)	Cal/g-°C (Btu/lb-°F)	Sodium 0.312 (0.312)			
		@ 593°C (1100°F)		0.300 (0.300)			
		b. Viscosity @ 288°C (550°F)	kg/m-s (lb/ft-s)	3.51x10 ⁻⁴ (2.36x10 ⁻⁴)			
		@ 593°C (1100°F)		2.08x10 ⁻⁴ (1.40x10 ⁻⁴)			
		c. Density @ 288°C (550°F)	kg/m ³	882.88 (55.12)			
		@ 593°C (1100°F)	(lb/ft ³)	809.78 (50.55)			
	2.	Storage Media Mass	kg (lb)	41.1 x 10 ⁶ (90.5 x 10 ⁶)			
	3.1	Cold Tank Characteristics					
		a. Number of Tanks		1			
		b. Geometry					Cylindrical API Type
		Diameter	m (ft)	67 (220)			
		Height	m ₃ (ft) ₃	25.5 (56)			
		c. Volume	m ³ (ft ³)	60,320 (2.13 x 10 ⁶)			
		d. Tank Material					Carbon Steel
		e. Tank Design Temperature	°C (°F)	316 (600)			
		f. Tank Mass (dry)	kg (lb)	982,636 (2.16 x 10 ⁶)			

61-W

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Storage Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE 2

DATE August 30, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	3.1	Cold Tank Characteristics (Continued)					
		g. Tank Surface Area					
		Top	m ³ (ft ²)	3,887 (41,815)			
		Side	m ² (ft ²)	3,598 (38,704)			
		Bottom	m ² (ft ²)	3,533 (38,013)			
		Total	m ² (ft ²)	11,018 (118,532)			
		h. Tank Insulation Material					Calcium Silicate with Aluminum Weather Protection, Perlite Concrete Base Insulation (Base Insulation = 1m (3 ft))
		i. Insulation Thickness	m (in.)	0.152 (6)			
		j. Insulation Mass	kg (lb)	237,414 (522,310)			
		k. Tank Wall Thickness					
		@ Top	mm (in.)	95.3 (.375)			
		@ Bottom		347.5 (1.368)			
		l. Preheat Power	kWe	1025			
	3.2	Hot Tank Characteristics					
		a. Number of Tanks	1				
		b. Geometry					Cylindrical API Type
		Diameter	m (ft)	67 (220)			
		Height	m ³ (ft ³)	25.5 (56)			
		c. Volume	m ³ (ft ³)	60,320 (2.13 x 10 ⁶)			
		d. Tank Material					Type 304H SS
		e. Tank Design Temperature	°C (°F)	621 (1,150)			
		f. Tank Mass	kg (lb)	1.07 x 10 ⁶ (2.35 x 10 ⁶)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Storage Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE

3

DATE August 30, 1979

NEW REV	NO.	A ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	3.2	Hot Tank Characteristics (Continued)					
		g. Tank Surface Area					
		Top	m ² (ft ²)	3,887 (41,815)			
		Side	m ² (ft ²)	3,598 (38,704)			
		Bottom	m ² (ft ²)	3,533 (38,013)			
		Total	m ² (ft ²)	11,018 (118,532)			
		h. Tank Insulation Material					Calcium Silicate with Aluminum Weather Protection, Perlitic Concrete Base Insulation (1m (3 ft) thick)
		i. Insulation Thickness	m (in.)	0.304 (12)			
		j. Insulation Mass	kg (lb)	474,827 (1.045 x 10 ⁶)			(Sides and Top only)
		k. Tank Wall Thickness					
		@ Top	mm (in.)	95.3 (.375)			
		@ Bottom		347.5 (1.368)			
		l. Preheat Power	kWe				
	4.	Piping and Valves					
	4.1	Piping					
		a. Material					
		Low Temperature					
		High Temperature					
		b. OD/ID/Wall					
		Low Temperature	mm (in.)	1220/1200/17 (48.0/46.75/.625)			Carbon Steel 304H SS
		High Temperature		1220/1170/25.4 (48.0/46.0/1.0)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Storage Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE

4

DATE August 30, 1979

NEW REV	NO.	A	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS									
				UNIT	VALUE												
	4.2		Valve Size, Number, and Material	cm (in.)				<table><tr><th>Identi- fication</th><th>Quantity</th><th>Material</th></tr><tr><td>Block</td><td>1</td><td>CS</td></tr><tr><td>Block</td><td>2</td><td>SS</td></tr></table>	Identi- fication	Quantity	Material	Block	1	CS	Block	2	SS
Identi- fication	Quantity	Material															
Block	1	CS															
Block	2	SS															
	5.		Piping Total Lengths	m (ft)													
			Low Temperature		45.7 (150)												
			High Temperature		54.9 (180)												
	6.		Mass of Piping	kg (lb)	16,000 (36,000)												
	7.		Piping Insulation Material					Calcium Silicate with Aluminum Weather Protection									
			Thickness - Low Temperature	mm (in.)	762 (3)												
			High Temperature		1,281 (5)												
	8.		Mass of Piping Insulation	kg (lb)	5,500 (12,000)												
	9.		Storage Pumps														
		a.	Number		1			(Steam Generator Pump)									
		b.	Material					304H SS									
		c.	Mass	kg (lb)													

ESG-79-30, Vol III

M-22

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Storage Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

j. Auleta

APPROVED BY

WBS NO.

PAGE

5

DATE

August 30, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	10.	Storage Pump Characteristics					
		a. Type	rpm	TBD			Single Stage, Centrifugal Variable
		b. Speed and Operating Range	m (ft)	76 (250)			
		c. Head	m (ft)	7.6 (25)			ASME Section VIII Div. I
		d. NPSH	°C (°F)	593 (1,100)			
		e. Operating Temperature	kWe (hp)	3,000 (4,000)			
		f. Power	m ³ /s (gpm)	3.53 (56,000)			
		g. Capacity		1			
		h. Number of Stages	m (ft)	TBD			
		i. Height, with Motor	m (ft)	TBD			
		j. Pump Tank Size					
		k. Code					
		l. Inlet Nozzle	mm (in.)	1,220 (48)			
		m. Outlet Nozzle	mm (in.)	1,070 (42)			
	11.	Storage Pump Motor					
		a. Size	kWe (hp)				
		b. Dimensions with coupling	m (ft)				
		c. Voltage	v				
		d. Mass	kg (lb)				
	B	Operating Characteristics					
	1.	Extractable Capacity	MWh _t (Btu)	4,460 (1.52 x 10 ¹⁰)			
	2.	Charging Rate					
		a. Maximum	MWt	1,600.0			
		b. Design	MWt	485.0			
		c. Minimum	MWt	0

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Storage Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE

6

DATE

August 30, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		3. Discharging Rate					
		a. Maximum	MWt	1,115			
		b. Design	MWt	1,115			
		c. Minimum	MWt	0			
	4.	Duration					
		a. @ Maximum Discharge Rate	hr	4.0			
		b. @ Design Discharge Rate	hr	4.0			
		c. @ Minimum Discharge Rate	hr	-			
	5.	Storage Media Operating Temperatures (Hot/Cold)	°C (°F)	288/593 (550/1100)			
	6.1	Cold Tank Operating Pressure	MPa (psi)				
		a. Fully Charged					
		@ Top		0.0069 (1)			
		@ Bottom		0.0120 (1.74)			
		b. Fully Discharged					
		@ Top		0.0069 (1)			
		@ Bottom		0.1043 (15.11)			
		c. Media		Argon			
	6.2	Hot Tank Operating Pressures	MPa (psi)				
		a. Fully Charged					
		@ Top		0.0069 (1)			
		@ Bottom		0.1043 (15.11)			
		b. Fully Discharged					
		@ Top		0.0069 (1)			
		@ Bottom		0.0120 (1.74)			
		c. Media		Argon			

ESG-79-30, Vol III

M-24

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Storage Subsystem
430 MWe SM 1.44

NUMBER

Revision 0

PREPARED BY

J. Auleta

APPROVED BY

WBS NO.

PAGE 7

DATE August 30, 1979

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	7.1	Cold Tank Heat Loss Rate					
		a. Fully Charged	MWt	0.5			
		b. Fully Discharged	MWt	0.5			
	7.2	Hot Tank Heat Loss Rate					
		a. Fully Charged	MWt	1.0			
		b. Fully Discharged	MWt	1.0			
	8.	Storage Ramp Rate	% max. discharge minute	TBD			
	9.	Storage Pump					Steam Generator Pump
		a. Flow Rate	kg/hr (lb/hr)	10.2×10^6 (22.53×10^6)			
		b. Sodium Volume	m ³ (gal)	TBD			
		c. NPSH	m (ft)	9.1 (30)			

ESG-79-30, Vol 1 III

M-25

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electrical Power Generation
Subsystem 430 MWe SM 1.44

NUMBER

PAGE 1 of 5

PREPARED BY

A. W. McKenzie
S-R

APPROVED BY

WBS NO.

DATE 9-5-79

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	1	<u>Turbine</u>					
		Type					Tandem Compound, Four Flow, Extraction, Condens- ing Turbine
		Rating	kWe	480,000			
		Heater Extractions	-	7			
		Last Stage Blade Length	cm(in)	11.8(30)			
		Shaft Speed	rpm	3600			
		Rated Inlet Pressure	MPa(psia)	16.6(2415)			
		Rated Inlet Temperature	°C(°F)	538(1000)			
		Rated Reheat Temperature	°C(°F)	538(1000)			
		Rated Exhaust Pressure	kPa(in. Hg)	6.8(2.0)			
		Rated Inlet Flow	kg/s(lb/lb)	403(3,200,000)			
		Est. Net Turbine Heat Rate	kJ/kWh (BTU/kWh)	8229 (7800)			
	2	<u>Generator</u>					
		Type					Synchronous, Hydrogen- Cooled, Static Excitation
		Rating	kVA	557,300

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electrical Power Generation
Subsystem 430 MW SM 1.44

NUMBER

PREPARED BY

APPROVED BY

WBS NO.

PAGE 2 of 5

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	2	<u>Generator, cont'd.</u>					
		Power Factor		0.90			
		Volts	V				
		Speed	rpm	3600			
		Frequency	Hz	60			
	3	<u>Condenser</u>					
		Type					Surface Condenser, 1-pass, Divided Water Boxes, per HEI Standards for Steam Surface Condensers
		Surface	m ² (ft ²)	31,500 (338,800)			
		Tube Material	-	90-10 Cu-Ni			ASTM B111, Alloy 706
		Tube o.d.	mm (in)	25.4 (1.00)			20BWG
		Tube Length (Effective)	m (ft)	17.7 (58)			
		Duty	MW _e (BTU/h)	617 (2106 x 10 ⁶)			
		Condensing Pressure	kPa (in. Hg)	6.8 (2.00)			
		Inlet Water Temperature	°C (°F)	28.3 (83)

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electrical Power Generation
Subsystem 1-30 MW 5/11/44

NUMBER

PREPARED BY

APPROVED BY

WBS NO.

PAGE 3 of 5

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	3	<u>Condenser, Cont'd.</u> Cooling Water Flow Condenser Air Removal	m ³ /s (gpm) -	21 (335,000) -			Mechanical Vacuum Pump (Two Full Capacity)
	4	<u>Cooling Tower</u> Quantity Type Number of cells (Each) Fan Motor Size Design Wet Bulb Temp. Cold Water Temp. Hot Water Temp. Circ. Water Flow (Total) Heat Rejected (Total) Construction	 kW (HP) °C (°F) °C (°F) °C (°F) m ³ /s (gpm) MWe (Btu/h)	 2 10 150 (200) 23 (73.4) 28.3 (83) 35.3 (95.6) 21.7 (344,400) 635.8 (2170 x 10 ⁶)			Mech. Draft, Wet, Cross-Flow Incl. 3% For Aux. Cooling Treated Fir or Redwood
	5	<u>Circulating Water Pumps</u> Quantity Type		4			Vertical, Wet Pit, Mixed Flow

ESG-79-30, Vol III

M-28

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electrical Power Generation
Subsystem 4.30MW_e SM1.44

NUMBER

PREPARED BY

APPROVED BY

WBS NO.

PAGE 4 of 5

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	5	<u>Circulating Water Pumps, Cont'd.</u>					
		Capacity, Each	m ³ /s (gpm)	5.4 (86,100)			
		Head	m (ft)	27.4 (90)			
		Efficiency	%	80			
		Speed	rpm	514			
		Motor Size	kW (hp)	1820 (2500)			
	6	<u>Feedwater Heaters</u>					
	6.1	<u>Low Pressure Heaters</u>					
		Quantity		3			
		Type		-			Horizontal, Shell & Tube
		Tube Material		Stain. Stl.			ASME Sect. VIII
	6.2	<u>High Pressure Heaters</u>					
		Quantity		3			
		Type					Horizontal, Shell & Tube
		Tube Material		Carbon Stl.			ASME Sect. VIII
	6.3	<u>Degenerator</u>					
		Quantity		1			
		Type					Horiz., Tray Type w/ Horiz. Storage Section

ESG-79-30, Vol III

M-29

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

Solar Central Receiver Hybrid
Electrical Power Generation
Subsystem 430MW_e SM1.44

NUMBER

PAGE 5 of 5

PREPARED BY

APPROVED BY

WBS NO.

DATE

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	7	<u>Boiler Feed Pump</u>					
		Quantity		2			Half Capacity.
		Type					Horizontal, centrifugal,
		Capacity (Each)	m ³ /s (gpm)	0.24 (3775)			barrel type with
		Head		2194 (7200)			steam turbine drive
		Speed		5200			
		Turbine Rating (Each)	kW (hp)	6350 (8510)			
	8	<u>Startup Boiler Feed Pump</u>					
		Quantity		1			
		Type					Horizontal, centrifugal,
		Capacity	m ³ /s (gpm)	0.087 (1400)			barrel type w/
		Head	m (ft)	757 (2500)			electric motor drive
		Speed	rpm	3600			
		Motor Size	kW (hp)	932 (1250)			
	9	<u>Condensate Hotwell Pump</u>					
		Quantity		3			Each Half Capacity.
		Type					Vert, Centrif, Can Type
		Capacity (Each)		0.20 (3200)			
		Head		130 (425)			
		Motor Size		373 (500)			

ESG-79-30, Vol III

M-30

APPENDIX N

1.44 SOLAR MULTIPLE PREFERRED COMMERCIAL PLANT P&ID

ESG-79-30, Vol III

N-1

R-1
SODIUM COOLED RECEIVER
28.5m (93.5 ft) HEIGHT
25.0m (82.0 ft) DIAMETER
1.5 MW/m² (0.47 x 10⁶ BTU/m²·h) PEAK POWER DENSITY
0.0069 MP (g) (1.0 PSIG) ULLAGE PRESSURE
AUSTENITIC SS
ASME SECTION VIII-DIV 1
1600 MW (5.46 x 10⁹ BTU/h) SOLAR POWER ABSORBED

T-3
HIGH TEMPERATURE SODIUM EXPANSION TANK
0.0069 MP (g) (1.0 PSIG) ULLAGE PRESSURE
49 m³ (13,000 GAL)
593 °C (1100 °F)
AUSTENITIC SS
ASME SECTION VIII - DIV 1

H-1
FOSSIL FIRED SODIUM HEATER
1.5 MW (5.3 x 10⁹ BTU/h)
593 °C (1100 °F)
2.07 MP (300 PSIA)
AUSTENITIC SS
ASME SECTION VIII-DIV 1

P-1
RECEIVER PUMP
459m (1505 FT) TDH
4.67 m³/s (74,000 GPM)
NPSH 9.1m (30 FT)
6.4 MW (22,000 HP)
288 °C (550 °F)
CARBON STEEL
ASME SECTION VIII, DIV 1

T-1
LOW TEMPERATURE SODIUM TANK
62.7 m (205.5 ft) DIAMETER
288 °C (550 °F)
0.0069 MP (g) (1.0 PSIG) ULLAGE PRESSURE
MILD STEEL
ASME SECTION VIII, DIV 1

Continued on next page

APPENDIX O

0.8 SOLAR MULTIPLE 1ST PLANT COST DATA

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 0.8 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

1ST COMMERCIAL PLANT

SUB-ACCOUNT 5100

CONT. NO. ET-78-C-03-2233

MADE BY W. WILLCOX

PROJECT SOLAR CENTRAL LAND AND SITE PREPARATION
RECEIVER HYBRID POWER SYSTEM

APPROVED.

[illegible]DATE AUGUST 1977 REVISION NO. _____ REVISION DATE _____ PAGE NO. 1 OF 8

ternational

JOB NO. 2175 PROJECT POWER SYSTEM LOCATION FARFIDE CLIENT JOE SANDIN
 DATE 8-13-79 TAKE-OFF PRICED RHF CALC. CHKD APPROVED SHEET 1 OF 3

ESG-79-30, Vol III

0-4

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5100 LAND AND GENERAL SITE PREPARATION									
A EXCAVATION AND CIVIL									
A1 LAND (MDAC - SR)	496	AC						442000	442000
\$8.70 / ACRE									
A2 SITE CLEARING (MDAC - SR)	2,375	SF						356000	356000
\$0.15 / SQUARE YARD									
A3 SITE GRADING (MDAC - SR)	800,000	CY						440000	440000
\$0.55 / CUBIC YARD									
A4 SITE FENCING (MDAC)	19,700	LF						158000	158000
\$8.00 / LINEAR FOOT									
A5 GENERAL ROAD + SIDE WALKWAY (SR)	17800	CY						36000	36000
EXCAVATION 1200 LF X 2.0' MAX. DEPTH									
A6 EVAPORATION POND \$5000 / ACRE INCLUSIVE	30	AC						1500000	1500000
A CIVIL TOTAL								2932000	2932000
B CONCRETE + ASPHALT SIDEWALKS	5000	SF						4500	4500
\$0.88 / SF 1000 FT X 5 FT WIDE									
B1 GENERAL ROAD + PARKING (SR)	25000	SF						84000	84000
\$3.00 / SF									
PARKING 1000 SF + ROADWAY 24000 SF									
B CONCRETE TOTAL								88500	88500
CODE									
5100

JOB NO.

PROJECT

0.8 SOLAR MULTIPLE FIRST
COMMERCIAL HYBRID POWER SYSTEM

LOCATION

WALTON

CLIENT

DRE/DAWNA

DATE

8/16/19

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

2

OF

3

ESG-79-30, Vol III

0-5

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5100	LAND AND GENERAL SITE PREP.									
F	PIPING									
F1	SITE WATER SUPPLY (SR)	5080	LF				32000	21000		53000
	#10/ET (DISTRIBUTION ONLY)									
	F PIPING TOTAL						32000	21000		53000
G	ELECTRICAL									
G1	SITE UTILITY ELECTRICAL SUPPLY (SR)						53000	43000		96000
	G ELECTRICAL TOTAL						53000	43000		96000
L	TEMPERARY CONSTRUCTION FAC.	INCLUDED IN DIRECT								
	(MDAC - SR)				FIELD COST					
M	CONSTRUCTION SERVICES, SUPPLIES & EXPENSE (MDAC - SR)									
N	FIELD STAFF, SUBSISTENCE & EXPENSE (MDAC - SR)									
P	CRATE BENEFITS, PAYROLL BURDENS & INSURANCE (MDAC - SR)									
Q	EQUIPMENT RENTAL (MDAC - SR)									
R	ENGINEERING (MDAC - SR)								190000	190000
CODE										
5100

JOB NO.

PROJECT

0.8 SOLAR MULTIPLE FIRST
COMMERCIAL HYBRID POWER
SYSTEM

LOCATION

BANDON, CA

CLIENT

DOE/SAND

DATE

8/13/79

TAKE-OFF

PRICED

CALC. CKD

APPROVED

SHEET

3

OF

3

ESG-79-30, Vol III

0-6

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5100 UND GENERAL SITE PREPARATION										
T	CONSTRUCTION MANAGEMENT (MDAC-SR)							95000		95000
U	LABOR PRODUCTIVITY (MDAC-SR)									
V	CONTINGENCY (MDAC-SR)									
W	FEE (MDAC-SR)									173000
5100 TOTAL							85000	159000	3210500	3627500

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 0.8 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

1ST COMMERCIAL PLANT

CONT. NO. ET-78-C-03-2233

SUB-ACCOUNT 5200

MADE BY W. WILLCOX

PROJECT SOLAR CENTRAL

ADMINISTRATIVE AREAS

APPROVED _____

RECEIVER HYBRID POWER SYSTEM

A/C NO.	ITEM & DESCRIPTION	ESTIMATED COST \$ x 10 ³				TOTALS
		MANHOURS	LABOR	SUBCONTRACTS	MATERIALS	
	SUMMARY -					
A	Excavation & Civil			14		14
B	Concrete		38		47	86
C	Structural Steel					- 0 -
D	Buildings		120		180	300
E	Machinery & Equipment		145		1142	1287
F	Piping		15		23	38
G	Electrical		62		37	99
H	Instruments					- 0 -
J	Painting			8		8
K	Insulation					- 0 -
	DIRECT FIELD COSTS		380	22	1429	1832
L	Temporary Construction Facilities		8		11	19
M	Construction Services, Supplies & Expense				50	50
N	Field Staff, Subsistence & Expense		46			46
P	Craft Benefits, Payroll Burdens & Insurances		34			34
Q	Equipment Rental			- 0 -		
	INDIRECT FIELD COSTS		88		61	149
	TOTAL FIELD COSTS		468	22	1490	1781
R	Engineering Plant Design 5 % of TFC			100		100
S	Major Equipment Procurement					
T	Construction Management 3% of TFC		59			59
	TOTAL FIELD & ENGR. COSTS		527	122	1490	2149
U	Labor Productivity					
V	Contingency Construction Design			25		25
W	Fee 5% of (A thru V)		107	25		132
	ESG-79-30, Vol. III	0-7				
	TOTAL CONSTRUCTION COST		634	147	1490	2271

DATE AUGUST 1979 REVISION NO.

REVISION DATE

PAGE NO. 2 OF 8

JOB NO.

Jnal

SOLAR CENTRAL RECEIVER

PROJECT PIENID POWER SYSTEMLOCATION PAKSTON, CA CLIENTZUC/SANDIADATE AUGUST 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

1

OF

4

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5200 ADMINISTRATIVE AREAS										
A	EXCAVATION AND CIVIL									
A1	ADMINISTRATION BUILDING FOUNDATION (SR)	12,700	CY			\$0.51/cy			7000	7000
A2	WAREHOUSE/MAINTENANCE BUILDING FOUNDATIONS (SR)	11,800	CY			\$0.55/cy			6500	6500
A3	GUARD HOUSE FOUNDATIONS (SR)	700	CY			\$0.55/cy			100	100
	A CIVIL TOTAL									13600
B	CONCRETE									
B1	ADMINISTRATION BUILDING FOUNDATION (SR)	300	CY	\$70/cy	6 ^{MH} / _{cy}		22000	18000		40000
B2	WAREHOUSE/MAINTENANCE BUILDING FOUNDATION (SR)	570	CY	\$35/cy	3 ^{MH} / _{cy}		20000	16000		36000
B3	GUARD HOUSE FOUNDATION (SR)	11	CY	\$70/cy	6 ^{MH} / _{cy}		800	700		1500
B4	MISCELLANEOUS (SR)	63	CY	\$70/cy	6 ^{MH} / _{cy}		4400	3600		8000
	B CONCRETE TOTAL						47200	38300		85500
D	BUILDINGS									
D1	ADMINISTRATION BUILDING (SR)	1		\$19,000	1.2 ^{MH} / _{hr}		90000	60000		150000
D2	WAREHOUSE/MAINTENANCE BUILDING (SR)	15000	SF	\$10	2.4 ^{MH} / _{hr}		27000	58000		145000
D3	GUARD HOUSE (SR)	400	SF	\$12.50	1.5 ^{MH} / _{hr}		3000	2000		5000
	D BUILDINGS TOTAL						180000	120000		300000
E	MACHINERY & EQUIPMENT									
E1	TRANSPORTATION & LIFTING EQUIPMENT (SR)						520000	130000		650000
E2	COMMUNICATIONS EQUIPMENT (SR)						29000	7000		36000
CODE										
5200

tional

SOUTH CENTRAL RECEIVER

JOB NO.

PROJECT

SOUTH CENTRAL RECEIVER

LOCATION

FARMINGTON, CA.

CLIENT

DOE /
LANDIA

DATE

AUGUST 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

2

OF

A

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5200 ADMINISTRATIVE AREAS										
E	MACHINERY & EQUIPMENT (CONT.)									
E3	MISCELLANEOUS MAINTENANCE EQUIPMENT						32000	8000		40000
	E3 MAINTENANCE EQUIPMENT						561000			561000
	E3 MAINTENANCE EQUIPMENT TOTAL						1143000	145000		1288000
F	PIPING									
F1	ADMINISTRATION WATER AND UTILITY SUPPLY & SEWER (SR)						12000	8000		20000
F2	WAREHOUSE / MAINTENANCE WATER AND UTILITY SUPPLY & SEWER (SR)						10000	7000		17000
F3	GUARD HOUSE WATER AND UTILITY SUPPLY & SEWER (SR)						600	400		1000
	F PIPING TOTAL						22600	15400		38000
G	ELECTRICAL									
G1	ADMINISTRATION ELECTRICAL SUPPLY (SR)						16500	25500		42000
G2	WAREHOUSE / MAINTENANCE ELECTRICAL SUPPLY (SR)						19000	33000		52000
G3	GUARD HOUSE ELECTRICAL SUPPLY (SR)						1700	3400		5100
	G ELECTRICAL TOTAL						37200	61900		99100
J	PAINTING									
J1	ADMINISTRATION BUILDING								4000	4000
J2	WAREHOUSE / MAINTENANCE BUILDING								3500	3500
CODE										
5200

Rc
En

onal

JOB NO.

PROJECT

SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

LOCATION

HARTON, CA

CLIENT

DOE/
SANDIA

DATE

AUGUST 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

3

OF

4

ESG-79-30, Vol III

0-10

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5200 ADMIN. SERVICE AREAS									
J PAINTING (CONT)									
J3 GUARD HOUSE (SR)								200	200
J PAINTING TOTAL								7700	7700
L TEMPORARY CONSTRUCTION FACILITIES (SR)						11300	7700		19000
M CONSTRUCTION SERVICES, SUPPLIES & EXPENSE (SR)						50000			50000
N FIELD STAFF, SUBSISTENCE & EXPENSE (SR)							46000		46000
P CRAFT BENEFITS, PAYROLL BURDENS & INSURANCE (SR)							34000		34000
Q EQUIPMENT RENTAL (SR)							-0-		
R ENGINEERING (SR)									100000
T CONSTRUCTION MANAGEMENT (SR)									59000
V LABOR PRODUCTIVITY (SR)									
CODE									
5200

tional

JOB NO.

PROJECT

CENTRAL RECEIVING
STATION

LOCATION

SANTO, CA.

CLIENT

205

C. H. H.

DATE

JULY 1977

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

4

OF

4

ESG-79-30, Vol III

0-11

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5200 ADMINISTRATIVE AREAS										
V	CONTINGENCY (SR)									25000
W	FEE (SR)									25000
	(ESB)									107000
CODE										
5200	SUB TOTALS						1490000	634000	172000	2295900

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 0.8 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

1ST COMMERCIAL PLANT

SUB. ACCOUNT 5300

CONT. NO. ET-78-G-03-2233

MADE BY W. WILLCOX

PROJECT SOLAR CENTRAL

COLLECTOR SUBSYSTEM

APPROVED _____

RECEIVER HYBRID POWER SYSTEM

A/C NO.	ITEM & DESCRIPTION	ESTIMATED COST \$ X 10 ³			
		MANHOURS	LABOR	SUBCONTRACTS	TOTALS
	SUMMARY-				
A	Excavation & Civil		536		536
B	Concrete		1397		4583
C	Structural Steel				
D	Buildings				
E	Machinery & Equipment		536		29121
F	Piping				
G	Electrical		241		1864
H	Instruments		10		117
J	Painting				
K	Insulation				
	DIRECT FIELD COSTS		2720		36223
L	Temporary Construction Facilities		73		73
M	Construction Services, Supplies & Expense		55		55
N	Field Staff, Subsistence & Expense		451		
P	Craft Benefits, Payroll Burdens & Insurances		611		611
Q	Equipment Rental				940
	INDIRECT FIELD COSTS		1190		2130
	TOTAL FIELD COSTS		3910		34443
R	Engineering Plant Design				
S	Major Equipment Procurement				34
T	Construction Management 3% of IFC		1151		1151
	TOTAL FIELD & ENGR. COSTS				34523
U	Labor Productivity		896		896
V	Contingency Construction Design				
W	Fee 5% of (A thru V)				2022
	ESG-79-30, Vol III		0-12		
	TOTAL CONSTRUCTION COST		5958		34477
					42457

DATE AUGUST 1979 REVISION NO.

REVISION DATE

PAGE NO. 3 OF 8

SOLAR CENTRAL RECEIVED

JOB NO.

PROJECT

HYBRID POWER SYSTEM

LOCATION

EASTON, CA

CLIENT

DOE/SAN

DATE

AUGUST 1997

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

1

OF

2

ESG-79-30, Vol III

0-13

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5300 COLLECTOR SUBSYSTEM										
A	EXCAVATION AND CIVIL									
AI	HELIOSTAT FOUNDATIONS	43.3	K HRS		12.37			536058		536058
	A CIVIL TOTAL							536058		536058
B	CONCRETE									
BI	HELIOSTAT FOUNDATIONS						3186000			3186000
		113.K	HRS		12.37			1397332		1397332
	B CONCRETE TOTAL						3186000	1397332		4583332
C	STRUCTURAL STEEL (INCLUDED IN E1 & E2)									
E	MACHINERY & EQUIPMENT									
E1	REFLECTOR PANELS INCLUDING MIRROR BACKING STRUCTURE						11330500			11330500
E2	DRIVE UNIT (PEDESTAL, DRIVE, SHORT MAIN BEAM ASSY, ELECTRONICS)						17254500			17254500
	FIELD ASSY, C/O, ALIGNMENT	43.3	K HRS		12.37			535561		535561
	E MACHINERY & EQUIPT. TOTAL						28585000	535561		29120561
G	ELECTRICAL									
GI	ELECTRICAL DISTRIBUTION						1623000			1623000
	ASSEMBLE, INSTALL, C/O	19.5	K HRS		12.37			241215		241215
	G ELECTRICAL TOTAL						1623000	241215		1864215
CODE										
5300

SOLAR CENTRAL RECEIVER

JOB NO. _____ PROJECT HYPERION POWER SYSTEM LOCATION BARSTOW, CA CLIENT DOE/ 2111-1ADATE AUGUST 1979 TAKE-OFF _____ PRICED _____ CALC. CHKD _____ APPROVED _____ SHEET 2 OF 2

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5300 COLLECTOR SUBSYSTEM										
H	INSTRUMENTS									
HI	SENSOR/CALIBRATION EQ						109000			109000
	INSTALL, CALIBRATE	.8 K	HRS		1237			10449		10449
	H INSTRUMENT TOTAL						109000	10449		119449
J	PAINING (HELIOSTATS SHIPPED TO SITE PREFINISHED)									—
L	TEMPORARY CONST. FACILITIES							72608		72608
M	CONST. SERVICES, SUPPLIES, EXPENSE							54954		54954
N	FIELD STAFF, SUBSISTANCE, EXPENSE							451669		451669
P	CRAFT BENEFITS, PAYROLL BURDENS, INS.							611046		611046
Q	EQUIPMENT RENTAL						939633			939633
R	ENGINEERING	N/A	AT FIELD SITE							—
S	MAJOR EQUIPMENT PROCUREMENT									
	INITIAL SPARES						34000			34000
T	CONSTRUCTION MGMT.							1151000		1151000
U	LABOR PRODUCTIVITY							896474		896474
V	CONTINGENCY									—
W	FEE									2022000
CODE										
5300	5300 TOTAL						4476633	5958366		42457000

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 0.8 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

1ST COMMERCIAL PLANT

SUB ACCOUNT 5400

CONT. NO. ET-78-G-03-2233

MADE BY W. WILLCOX

PROJECT SOLAR CENTRAL

RECEIVER SUBSYSTEM

APPROVED _____

RECEIVER HYBRID POWER SYSTEM

A/C NO.	ITEM & DESCRIPTION	ESTIMATED COST \$ X 10 ³				TOTALS
		MANHOURS	LABOR	SUBCONTRACTS	MATERIALS	
	SUMMARY -					
A	Excavation & Civil			18		18
B	Concrete		408	1098	377	1862
C	Structural Steel		298	176	367	841
D	Buildings			535		535
E	Machinery & Equipment		1749	992	7919	10660
F	Piping		3090	782	4911	8983
G	Electrical		46	31		77
H	Instruments			702		702
J	Painting			INC		
K	Insulation			INC		
	DIRECT FIELD COSTS					23698
L	Temporary Construction Facilities		18	118		136
M	Construction Services, Supplies & Expense		15	371		386
N	Field Staff, Subsistence & Expense		109	930		1039
P	Craft Benefits, Payroll Burdens & Insurances		81			81
Q	Equipment Rental			177		177
	INDIRECT FIELD COSTS					1839
	TOTAL FIELD COSTS					25537
R	Engineering Plant Design		1548			1548
S	Major Equipment Procurement		16			16
T	Construction Management		838			838
	TOTAL FIELD & ENGR. COSTS					27940
U	Labor Productivity					
V	Contingency Construction			298		298
	Design					
W	Fee					1386
	ESG-79-30, Vol III		0-15			
	TOTAL CONSTRUCTION COST					29623

DATE AUGUST 1979 REVISION NO. _____ REVISION DATE _____ PAGE NO. 4 OF 8

DATE AUGUST, 1979 TAKE-OFF PRICED CALC. CHKD APPROVED SHEET 1 OF 5

[illegible]

JOB NO. _____

PROJECT _____

SOLAR THERMAL POWER SYSTEM

LOCATION EARTHSTON, CA

CLIENT DOE

DRAWING

DATE AUGUST 1979 TAKE-OFF _____

PRICED _____

CALC. CHKD _____

APPROVED _____

SHEET 2 OF 5

ESG-79-30, VOL III

0-17

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5400 RECEIVER SUBSYSTEM										
E	EQUIPMENT									
E1	ABSORBER UNIT	18	ea	41000	1000	2332	747328	1513080	41994	2302902
E2	EXPANSION TANK	SEE	SUB-ACCOUNT			5700				-0-
E3	RECEIVER PUMP	1	ea				173200	51200		224400
E4	RECEIVER COOLANT - SODIUM	792,000	lb	\$0.40			316800			316800
E5	EVAPORATOR	1	ea				3457755	11200		3468955
E6	SUPERHEATER	1	ea				1012798	5120		1017918
E7	REHEATER	1	ea				1156669	5120		1161789
E8	STEAM DRUM	1	ea						200000	200000
E9	CRANES	2	ea				600000	160000	400000	1160000
E10	TOWER ELEVATOR (S-R)	1	ea						350000	350000
E11	SODIUM/WATER REACTION RELIEF EQUIP						259000	3200		262200
E12	DRAIN TANK	1	ea				194650			194650
E13	TOWER	1	ea				INCLUDED IN ITEM B-4			-0-
	TOTAL									10659644
F	PIPING									
F1	SODIUM PIPING-HORIZONTAL						3967904	940576	569600	5480080
F2	RISER						893000	1902432	712160	3157592
F3	DOWNCOMER						INCLUDED IN F2			
F4	FITTINGS						INCLUDED IN F1 & 2			
F5	VALVES									
F6	MANUAL									
F7	CONTROL									
F8	ANTI-SIPHON									
F9	HANGERS & SUPPORTS						75186	247040		345226
F10	MIXING TEE						INCLUDED IN F1 & 2			
	* INCLUDES PURIFICATION SYSTEM									
	* INCLUDES COVER & GROUND SYSTEM									
CODE	TOTAL									8952898
5400	PAGE TOTAL									19642542

ational

SOLAR CENTRAL RECEIVED
H 1000 POWER SYSTEM

LOCATION PARSONS, CA CLIENT DOE ANDAL

DATE AUGUST 279 TAKE-OFF _____ PRICED _____ CALC. CHKD _____ APPROVED _____ SWEET 3 OF 1

[illegible]

ational

JOB NO.

PROJECT

SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

LOCATION

BARSTON, CA

CLIENT

DSE/
SANDIA

DATE

AUGUST 1977 TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

4

OF

5

ESG-79-30, Vol III

0-19

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5400 RECEIVER SUBSYSTEM										
K	INSULATION	INCLUDED IN PIPING								
K1	SEDIUM PIPING, FITTINGS & VALVES	& COMPONENT COST								
K2	RECEIVER PUMP	UNLESS NOTED								
K3	STEAM GENERATORS & STEAM DRUM									
K4	ABSORBER UNIT									
K5	EXPANSION TANK	SEE SUB ACCOUNT 5700								
K6	TOWER (S-R)									
	TOTAL									-0-
L	TEMPORARY CONSTRUCTION FACILITIES									
L1	ALL EXCEPT TOWER (ESG)								91000	91000
L2	TOWER (S-R)							18000	27100	45100
M	CONSTRUCTION SERVICES, SUPPLIES & EXPENSES									
M1	ALL EXCEPT TOWER (ESG)								261000	261000
M2	TOWER (S-R)							15000	110000	125000
N	FIELD STAFF, SUBSISTENCE & EXPENSE									386000
N1	ALL EXCEPT TOWER (ESG)								930000	930000
N2	TOWER (S-R)							109000		109000
P	CRaft BENEFITS, PAYROLL BURDENS & INSURANCE									1039000
P1	ALL EXCEPT TOWER (ESG)	INCLUDE IN DIRECT						-0-		
P2	TOWER (S-R)							81000		81000
Q	EQUIPMENT RENTAL									
Q1	ALL EXCEPT TOWER (ESG)								197000	197000
Q2	TOWER (S-R)								-0-	
CODE										
5400		PAGE TOTAL								
										1839100

JOB NO. .

ional

SOLAR CENTRAL RECEIVER

PROJECT HYBRID POWER SYSTEM

LOCATION BARSTOW CA. CLIENT

DOE/SANDI.

DATE AUGUST 1979 TAKE-OFF

PRICED

_ CALC. CHKD

APPROVED

SHEET 5 OF 5

[illegible]

ional

JOB NO. 133-046 PROJECT

LOCATION

CLIENT

DATE 4-18-79

TAKE-OFF JC

PRICED JC

CALC. CKD

APPROVED

SHEET

OF

ESG-79-30, VOL III

0-21

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
RECEIVER 34'φ x 49.2'									
248 MW-S.S. SECT. VIII.									
ABSORBER PANELS 6' x 49' (18)									
WITH 96 - 3/4" O.D. x .065 WALL TUBES									
S.S. T-304 TUBING 3/4" O.D. x .065	4800	L.F.	2.00	.04		9600	1920		
SCH. 40 PIPE 6"	40		43	10		1720	400		
90° ell 6"	3	EA	291	30		873	90		
TEE 6"	8		500	30		4000	240		
TEE 8"	1		733	40		733	40		
CONC. REG. 8x4	2		215	40		430	80		
PNEU. OPER. BUTTERFLY VALVES 6"	3		5000	300		15000	900		
3x3x1/4 L IRON 80'	400	LBS.	.60	.03		240	120		
3/4" O.D. TUBE WELDS	192	EA.		.15			288		
PENOS	96			.5			480		
WELD TUBE LENGTHS	4704	L.F.		.2			9408		
HEADER L ^s 6x6x3/8 12'	350	LBS.	.60	.03		210	110		
PYROMARK PAINT 600ft ²	4	GAL	50	15		200	60		
TUBE TO HEADER JIG (AVG./PANEL)	1	L.S.						1333	
MISC. MATERIAL	1	L.S.	500			500			
WELL DEVELOPMENT (AVG./PANEL)	1	L.S.						1000	
SCH. 40 S.S. BUTTWELDS 8"	2	EA.		120			240		
6"	38			100			3800		
B.W. CAPS 6"	6		94	30		1128	360		
3000# S.S. COUPLINGS 3/4"	192		26	10		6912	1920		
							2040	M.H.P. 310	
CODE				PER PANEL		41546	63426	2333	107305
5400	SODIUM COOLED RECEIVER PANELS				X 18				81931400

Rock

B

JOB NO. 133-046 PROJECT

LOCATION

CLIENT

DATE 5-3-79

TAKE-OFF: JK

PRICED 22

CALC. CHKD

APPROVED

 SWEET

OF

[illegible]

val

PROJECT

LOCATION

CLIENT

TAKE-OFF

PRICED 25

CALC. CHKD

APPROVED

SWEET

— of

[illegible]

JOB NO. 133-046 PROJECT _____ LOCATION _____ CLIENT _____DATE 4-18-79 TAKE-OFF JC PRICED JC CALC. CHKD _____ APPROVED _____ SHEET _____ OF _____

ESG-79-30, Vol III

0-24

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
EVAPORATOR - 50"φ x 95' (X1) 15,924 ft ² SURFACE AREA 1250 5/8 O.D. x .075 WALL 2 1/4 IN. / 1000 TUBES - SEET ON VIII DEV. I	1	EA			72 TON	329337.0	3500		
SUPERHEATER - 30" x 91' (X2) 4118 ft ² SURFACE AREA 269 3/4 O.D. x .122 WALL S.S TUBES	1	EA			22 TON	983150	1600		
REHEATER - 32"φ x 66' (X3) 3387 ft ² SURFACE AREA 166 1 1/2 O.D. x .107 WALL S.S TUBES	1	EA			24 TON	1081300	1600		
CRANE RENTAL	400	HRS			150 ⁰⁰ /HR			60000	
INSULATION	2757	ft ²			22 ⁰⁰ /ft ²			60654	
TRACE HEATER:	919	L.F			162 ⁰⁰ /L.F			148878	
CODE 5400	STEAM GENERATORS					5357720	6700	M. H. G. 22 ⁰⁰	
							21441	559532	

0-25

JOB NO. 133-046 PROJECT HyBRILLOCATION BARSTOW CLIENT DOEDATE 4-16-79 TAKE-OFF JC PRICED JC CALC. CHKD _____ APPROVED _____ SHEET _____ OF _____

ESG-79-30, Vol III

0-26

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
C.S. PIPE A-53 GR. B. .375 WALL 20"	500	L.F.	47	3.5		23500	17500		
C.S. STD BUTTWELD 90° ELL 20"	28	EA	733	11		20524	308		
1 BUTTWELDS 20"	88	EA	1	5.4			475		
S.S. T-304 PIPE .375 WALL 20"	600	L.F.	189	3.5		113400	21000		
90° ELL 20"	28	EA	3200	11		89600	308		
1 BUTTWELDS 20"	95	EA	1	21			1995		
GRUNWELL #45 HORIZ. HANGERS	33		1355	60		44715	1980		
#261 VERT.	40		50	3		2000	120		
#200 SNUBBERS	15		3000	40		45000	600		
C.S. CHECK VA. 20"	1		90K	100		90000	100		
C.S. BLOCK VA. PNEU. OPER. 20"	1		100K	212		200000	424		
PRODUCTIVITY 60% X D.L.							17463		
TRACE HEATERS 20"	2576	L.F.		160	1/16"		412160		
CODE	5400	RISED & DOWNCOMMER				625739	1282722	412160	
							465223	M.H.P. 32	

[illegible]

JOB NO. 133-046 PROJECT

LOCATION

CLIENT

DATE 4-19-79

TAKI-OFF JK

PRICED 25

__ CALC. CHKD

— APPROVED

— SHEET

OF

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
C.S A-53 GR. B Pipe	24"	500	LF	60	4.7		30000	2350°		
STD. C.S B.W 90° ELL	24	5	EA	1237	13.°		6185	65°		
BUTTWELOS	24	45	EA	✓	6.75			304°		
STD. S.S T-304 PIPE A-312	20	700	LF	189	3.5		132300	2450°		
	14	60		182	2.8		10920	168°		
	10	100		135	2.°		13500	200°		
	8	100	✓	74	1.5		7400	150°		
B.W 90° ELL	20	60	EA	3200	11.°		192000	660°		
	14	6		2000	7.5		12000	45°		
	10	10		1090	5.°		10900	50°		
	8	10		605	4.°		6050	40°		
FLKE PLURST DISK ASSEMBLY	10	3		2800	3°		8400	9°		
STD. S.S BUTTWELOS	20	166			21.°			3486°		
	14	20			17.9			358°		
	10	23			13.6			317°		
	8	20			12.°			240°		
S.S MIXING TEL	20	1		60K	200°		60000	200°		
S.S CONTROL VA.	20	2		100K	250°		200000	500°		
Block VA.	20	2		70K	512°	11	140000	224°		
CHECK VA.	20	1		90K	100°	1	90000	100°		
Block VA.	14	1		55K	55°	1-10'	55000	55°		
Block VA.	8	1		27K	30°		27000	30°		
S.S BLOCK VA.	24	3		108K	220°	1	324000	660°		
Block VA.	20	1		90K	100°	1	90000	100°		
CHECK VA.	20	1		90K	100°	1	90000	100°		
DRAW VA	20	1		120K	110°		120000	110°		
CODE										
5400	H.C. Z. PIERCE									
	M.H.C. 32 nd									
	415072									

ESG-79-30, Vol III

0-28

JOB NO. 133-046 PROJECT HyBRID

LOCATION

CLIENT

DATE 4-18-79

TAKE-OFF JK

PRICED 2c

CALC. CHKD

APPROVED

SWEET

Of

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
SPRING HANGERS & SUPPORTS		24	36	EA	1120	80°	40320	2880°		
		14	4		724	60°	2896	240°		
		10	10		477	60°	4770	600°		
		8	10		510	40°	10200	800°		
		20	40		1000	80°	40000	3200°		
TRACE HEATERS		24	1060	LF		160/LF		169600		
		20	2000					320000		
		14	200					32000		
		10	150					24000		
		8	150					24000		
CODE										
5400		HORIZ. PIPING								
		7720° N.H.C. 32°								
		98124 247040 560600								

ESG-79-30, Vol III

0-29

LOCATION

CLIENT

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SWEET

Of

[illegible]

ESG-79-30, Vol II

0-30

LOCATION

CLIENT

TAKE-OFF

PRICED 2c

CALC. CHKD

APPROVED

SWEET

OF

[illegible]

FSG-79-30. Vol III

0-31

DATE 5-3-79 TAKE-OFF JC PRICED JC CALC. CKD _____ APPROVED _____ SHEET _____ OF _____

[illegible]

una!

JOB NO. 133-046

PROJECT**LOCATION**

CLIENT

DATE 5-3-79

TAKE-OFF JK

PRICED 25

CALC. CHKD

APPROVED

SHEET

OF

[illegible]

JOB NO

PROJECT

LOCATION

CLIENT

DATE

5-3-79

TAKE-OFF

JC

PRICED

JC

CALC. CHKD

APPROVED

SHEET

OF

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT	MATERIAL	LABOR	SUB CONTRACT	TOTAL
"MECHANICAL"										
ESG-79-30, Vol 1 III	TEMPORARY CONSTRUCTION "L"									
	OFFICE TRAILER									17000
	TOILETS									9000
	FAB. SHELTER & WAREHOUSE									20000
0-34	RENTAL EQUIPMENT "Q"									
	CRANES & HOISTING EQUIPT.									92000
	PICKUP TRUCKS									28000
	FLATBED TRUCKS									20000
	WELDING MACHINES									30000
	PIPE MACHINES									3000
	GAS RIGS									4000
	TEST PUMPS SMALL TOOLS									10000
	SCAFFOLDING ALLOWANCE									10000
	JOB OVERHEAD									
N	SUPERINTENDENT									218000
A	ENGINEERS									167000
A	OFFICE-MANAGER GENERAL FOREMAN									175000
N	CLERKS WAREHOUSEMAN									125000
A	UNALLOCABLE LABOR @ 6% OF DEL X \$	2252	000							136000
N	CONSUMABLES @ 6% OF DEL X \$	2252	000							136000
CODE										
5400										
CONTRACTORS FIELD OVERHEAD										1200000

131

JOB NO.

PROJECT

HYBRID SOLAR T

LOCATION

CLIENT

DATE 5-15-79

TAKE-OFF NAMEAGHAN PRICED

CALC. CHKD

APPROVED

SHEET

1

OF 4

ESG-79-30, VOL III

0-35

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
					#		M.H.		
PRIMARY STAGE UP TO THE FIRST PLATFORM									
12" Ø 1" THK. SCH/120 168 L.F. @ 125.5¢/L.F.	168	L.F.	78.74	3.40	21084#	13228	571		
10" Ø .719 THK. SCH/100 414 L.F. @ 77.03¢/L.F.	414	L.F.	48.85	2.70	31890#	20223	1118		
6" Ø .502 THK. SCH/60 264 L.F. @ 36.39¢/L.F.	264	L.F.	21.82	1.10	9609#	5760	290		
GRATING 1/4" x 3/16"									
2620 S.F.	6020	SQ. FT.			419.5¢			26000	
DRAW PAN 3/16" STEEL PLATE @ 7.7¢/S.F. - 880 SQ. FT.	6776	#							
MAIN DRAW PAN: 3/16" ST. PLATE @ 7.7¢/S.F. - 2000 SQ. FT.	15400#								
SUPPORTS FOR DRAW PAN 680 FT. 3x3x3/16 @ 2.4¢/FT	7720#								
	24896#	#/lbs			\$1.25			31120	
						39211	M.H. 1979 @ 32¢		
							63328		
CODE									
5400						39211	63328	33720	136255

JOB NO.

PROJECT

HYBRID SOLAR PLA

LOCATION

CLIENT

DATE _____

5-15-79

TAKE-OFF 4' ANT GHRN!

PRICED

CALC. CHKD

APPROVED

— SHEET

2

6

4

[illegible]

PROJECT**LOCATION**

CLIENT

TAKE-OFF MANAGHANI PRICED

CALC. CHKD

APPROVED

SHEET 3 OF 4

[illegible]

JOB NO. _____

PROJECT

HYBRID SOLAR PLA

LOCATION

CLIENT

DATE _____

5-14-79

TAKE-OFF MAMAGHANI PRICED

PRICED

CALC. CHKD

- APPROVED

SWEET

4

10

4

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
CUTS									
SCH 1120 C.S. 12"	12	EA		1.5			18		
SCH 1100 C.S. 10"	54			1.0			54		
SCH 1170 6"	72			0.5			36		
WELDS									
SCH 1120 C.S. 12"	24	EA		13.15			316		
SCH 1100 C.S. 10"	108			7.4			799		
SCH 1170 C.S. 6"	144			5.32			766		
							1989		
INSULATION									
	7500	S.F.	3.34	.20		25200	1500		
MODEL									
	1	L.S.						20000	
						\$ 752.00	MM3489	\$ 20000	
CODE									
5400

DATE 5-3-79 TAKE-OFF _____ PRICED _____ CALC. CKCD _____ APPROVED _____ SHEET _____ OF _____

[illegible]

DATE 5-3-79 TAKE-OFF FIERER PRICED FIERER CALC. CHKD APPROVED SHEET 7 OF

[illegible]

ESG-79-30, Vol III

0-40

JOB NO.

PROJECT

DATE _____

5-3-79

TAKE-OFF

FIERER

PRICED

FIERER

CALC. CHKD

APPROVED

CLIENT

SHEET:

£

OF

[illegible]

1st Division
1st

JOB NO. _____ PROJECT _____ LOCATION _____ CLIENT _____

DATE 5-3-79 TAKE-OFF FIERZER PRICED FIERZER CALC. CHKD _____ APPROVED _____ SHEET 9 OF _____

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL		LABOR	SUB-CONTRACT	TOTAL
45' HIGH											
$20' \div 6 = 3.33 \text{ use } 3.5'$											
STEEL W 10K21											
50K2+6'x4' 6		15624									
L3K3K1/4 @ 4.9 (8K10S		4116									
MISC BRACING ETC		4260									
		24000	LBS	1						24000	
EXCAV											
(2K4K8K6) - 27 + MISC		15	CY	40 ⁰⁰						600	
CONCRETE		15	CY	80 ⁰⁰						1200	
REBAR		1500	LBS	0 ⁷⁵						1125	
FORM & MISC		1	LS							500

$3.5 \times 72 \div 4 \div 20 = 3 +$											
CODE											
5400										27500	

CONSTRUCTION COST ESTIMATE.

CLIENT DOE / SANDIA

DESCRIPTION 0.8 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

1ST COMMERCIAL PLANT

SUB ACCOUNT 5500

CONT. NO. ET-7B-C-03-2233

MADE BY W. WILCOX

PROJECT SOLAR CENTRAL

MASTER CONTROL SUBSYSTEM

APPROVED

RECEIVER HYBRID POWER SYSTEM

[illegible]

JOB

national

PROJECT

SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

LOCATION

BARSTOW, CA CLIENT

DOE/
SANDIA

DATE

AUGUST 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

1

OF

3

ESG-79-30, Vol III

0-45

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5500 MASTER CONTROL SUBSYSTEM *										
A	EXCAVATION AND CIVIL									
A1	CONTROL BUILDING FOUNDATION (SR)								1000	1000
B	CONCRETE									
B1	CONTROL BUILDING FOUNDATION (SR)						5000	5000		10000
D	BUILDINGS									
D1	CONTROL BUILDING (SR)	3750	SF	\$9	.5MH		34000	20000		54000
D11	CONTROL ROOM		INC							
D12	COMPUTER ROOM		INC							
	D BUILDINGS TOTAL									54000
E	EQUIPMENT & MACHINERY									
E1	COMPUTER HVAC (SR)	20	TON	CO					25000	25000
E2	EQUIPMENT ENCLOSURES						1689000	46088		1735088
	E & E1 TOTAL									1760088
G	ELECTRICAL									
G1	CONTROL BUILDING SUPPLY (SR)						1800	3000		4800
H	INSTRUMENTS									
H1	PLANT CONTROLS (SR)									
H2	COMPUTERS									
H3	SOFTWARE									
H4	DISPLAYS									
H5	BEAM CHARACTERIZATION						140100	5234		145334
	H INSTRUMENTS TOTAL									145334
CODE										
5500

JOB

national

PROJECT

SOLAR CENTRAL RECEIVING
HYBRID POWER SYSTEM

LOCATION BARSTON, CA CLIENT

DOE/
SANDIA

DATE AUGUST 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

2

OF

3

ESG-79-30, Vol III

0-46

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5500 MASTER CONTROL SUBSYSTEM *									
J PAINTING									
J1 CONTROL BUILDING (SR)								1500	1500
L TEMPORARY CONSTRUCTION FACILITIES (MDAC - SR)									-0-
M CONSTRUCTION SERVICES, SUPPLIES & EXPENSE (MDAC - SR)									-0-
N FIELD STAFF, SUBSISTENCE & EXPENSE (MDAC - SR)							10210		10210
P CRAFT BENEFITS, PAYROLL BURDENS & INSURANCES (MDAC - SR)							20451		20451
Q EQUIPMENT RENTAL (MDAC SR)									-0-
R ENGINEERING									-0-
R1 HARDWARE DESIGN									
R2 SOFTWARE DESIGN									
S MAJOR EQUIPMENT PROCUREMENT									-0-
T CONSTRUCTION MANAGEMENT (MDAC - SR)									60000
CODE									
5500									

FORM 702-D REV. 9-78

* MDAC UNLESS NOTED

JOA

PROJECT

SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

LOCATION BARSTOW, CA

CLIENT

DOE/
SANDIA

DATE AUGUST 1979

TAKE-OFF

PRICED

_ CALC. CHKD

APPROVED

SWEET

OF

3

[illegible]

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 0.8 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

1ST COMMERCIAL PLANT

CONT. NO. ET-7B-C-03-2233

SUB ACCOUNT 5500

MADE BY W. WILLCOX

PROJECT SOLAR CENTRAL

NON-SOLAR ENERGY SUB-SYSTEM APPROVED

RECEIVER HYBRID POWER SYSTEM

[illegible]

contract

SOLAR CENTRAL RECEIVER

PROJECT

HYBRID POWER SYSTEM

LOCATION

BARSTOW, CA

CLIENT

DOL / FANCIA

DATE

AUGUST 1979

TAKE-OFF

PRICED

CALC. CHECK

APPROVED

SHEET

1 OF 7

ESG-79-30, Vol III

0-49

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONTR.	MATERIAL		LABOR		SUB-CONTRACT		TOTAL	
5000 NON-SOLAR ENERGY SUBSYSTEM														
A	EXCAVATION & CIVIL													
A1	TRACK HOPPER BUILDING											35000		35000
A2	CRUSHER BUILDING											25000		25000
A3	FEED STORAGE											15000		15000
A4	LIVE STORAGE SILO													
A5	CONVEYORS A THRU H											95000		95000
A6	CONVEYOR B													
A7	CONVEYOR C													
A8	CONVEYOR D													
A9	CONVEYOR E													
A10	CONVEYOR F													
A11	TRANSFER BUILDING											5000		5000
A12	COAL SILOS											25000		25000
A13	PULVERIZERS (BFW)											1000		1000
A14	PRIMARY AIR FAN (BFW)											2000		2000
A15	SODIUM HEATER (BFW)											8000		8000
A16	GAS RECIRCULATION FAN (BFW)											1000		1000
A17	FORCED DRAFT FAN (BFW)											1000		1000
A18	AIR HEATER (BFW)											2000		2000
	A CIVIL TOTAL											53000		53000
CONCRETE														
FOUNDATIONS														
B1	TRACK HOPPER BUILDING - 1/2 TRENCH	1100	sq ft				212000		173000					385000
B2	CRUSHER BUILDING		sq ft				15000		15000					30000
B3	LIVE STORAGE SILO		sq ft				126000		104000					230000
B4	CONVEYORS (incl. CONVEYOR E TRENCH)		sq ft				135000		110000					245000
CODE														
5000														

Continued

10

PROJECT SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEMLOCATION EARSFORD, CA CLINDOE/
SANDIADATE AUGUST 1979 TAKE-OFF

PRICED

CALC. CHECK

APPROVED

SHEET

2

OF

7

ESG-79-30, Vol III

0-50

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-COIT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
1000 NON-SOLAR ENERGY SUBSYSTEM									
1 CONCRETE (cont.)									
14 CONVEYOR B									
15 CONVEYOR C									
16 CONVEYOR D									
17 CONVEYOR E									
18 CONVEYOR F									
19 TRANSFER BUILDING	60	CY				65200	55200		120400
20 COAL SILOS	160	CY				175000	145000		320000
21 PULVERIZERS (BFW)	30	CY				25000	20000		45000
22 PRIMARY AIR FAN (BFW)	20	CY				17000	13000		30000
23 SODIUM HEATER (BFW)	200	CY				160000	140000		300000
24 GAS RECIRCULATION FAN (BFW)	20	CY				17000	13000		30000
25 FORCED DRAFT FAN (BFW)	20	CY				17000	13000		30000
26 AIR HEATER (BFW)	100	CY				80000	70000		150000
B CONCRETE TOTAL						546600	448900		995500
C STRUCTURAL STEEL									
1 TRUCK HOPPER	90T					90000	150000		550000
2 CRUSHER	5T					5000	2000		7000
3 LIKE STORAGE SILO	115T					690000	460000		1150000
4 CONVEYORS A-F	100T					1000000	380000		1380000
5 COAL SILOS	160T					1500000	560000		2060000
6 SODIUM HEATER (BFW)	INCLUDED IN E 9								
7 AIR HEATER (BFW)	INCLUDED IN E 12								
C STRUCTURAL TOTAL						364000	157000		521000
1001									
5600									

FORM 702-10 (REV. 7-78)

SR (VALUES NOTED)

decentral

SOLAR CENTRAL RECEIVED

1

PROJECT HYBRID POWER SYSTEM

LOCATION BARSTON, CA

CLIENT

DATE / SANDIA

DATE AUGUST 1979

TAXES OFF

PRICED

CALC. CHKD

APPROVED

SHEET

4

OF

7

ESG-79-30, Vol III

0-52

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5600 NON-SOLAR ENERGY SUBSYSTEM										
E MACHINERY AND EQUIPMENT										
E1	TRUCK HOPPER						125000	29200		154200
E2	CRUSHER						25000	15000		40000
E3	LIVE STORAGE SILO						922000	253000		1155000
E4	DUST COLLECTORS						148000	88000		236000
E5	CONVEYORS						628000	156000		784000
E6	COAL SILOS						112000	27000		139000
E7	PULVERIZERS (B/W)	3	ea						425000	425000
E8	PRIMARY AIR FANS (B/W)	3	ea						637500	637500
E9	SODIUM HEATER (B/W)	1	ea						2187500	2187500
E10	GAS RECIRCULATION FAN (B/W)									
E11	FORCED DRAFT FAN (B/W)									
E12	AIR HEATER (B/W)								425000	425000
E13	COAL FEEDERS (B/W)									
E14	OIL IGNITORS (B/W)									
E15	OIL TANKS (1-25000 GAL 1-6000 GAL)								110000	110000
	TRANSFER						26000	11200		37200
E EQUIPMENT TOTAL							1966000	579000	21785000	23380000
CODE										
5600										

UNITED STATES ARMY

UNITED STATES ARMY

JDS

at contract
 Group

PROJECT

SOLAR CENTRAL RECEIVER
 HYBRID POWER SYSTEM

LOCATION BARSTON, CA CLIENT

DOE LANDIA

DATE

AUGUST 1979

TAKE-OFF

PRICED

CALC. CHD

APPROVED

SHEET

5

OF

1

ESG-79-30, Vol III

0-53

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONTR.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
1. NEW SOLAR ENERGY SUBSYSTEM #									
1. PIPING									
11 PRIMARY AIR (B/W)	INCLUDED			IN	EQ				
12 AIR/FUEL (B/W)									
13 GAS RECIRCULATION (B/W)									
14 FUEL GAS (FRO)(B/W)									
15 OIL IGNITOR (15" O.L.F. - 2")						27000	18000		45000
16 SODIUM PIPING (ESB)(B/W)	INCLUDED			IN	EQ				
F PIPING TOTAL						27000	18000		45000
G ELECTRICAL									
21 5% TRACK HOPPER SUPPLY									
22 10% CRUSHER SUPPLY									
23 2% LIFE STORAGE SUPPLY									
24 25% CONVEYORS SUPPLY									
25 6% CON. SILO SUPPLY									
26 1% FINELIZER SUPPLY									
27 10% PRIMARY AIR FAN SUPPLY									
28 1% GAS RECIRCULATION FAN SUPPLY									
29 15% FORCED DRAFT FAN SUPPLY									
30 1% AIR HEATER SUPPLY									
G ELECTRICAL TOTAL						216000	119000		425000
COMP									
56.00									

continued

PROJECT SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

LOCATION EASTON, VA CLIENT

DOE/
SANDIA

DATE AUGUST 1977

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

6

OF

7

ESG-79-30, Vol III

O-S-54

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONTR.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
6-00 NEW SOLAR SUBSYSTEM									
H INSTRUMENTS									
11 COAL SAMPLING				INCLUDED	IN E5				
12 COAL WEIGHING				INCLUDED	IN E5				
13 PRIMARY AIR (B/W)				INCLUDED	IN E6				
14 COMBUSTION MONITORING (B/W)				INCLUDED	IN E1				
15 FLUE GAS MONITORING (B/W)									
16 HEATER CONTROLS (B/W)									
17 AIR HEATER CONTROLS (B/W)									
18 COAL/AIR CONTROLS (B/W) (SR)									
H INSTRUMENTS TOTAL									- 0 -
J PAINTING									
21 COAL HANDLING EQUIPMENT								35000	35000
22 HEATER (B/W)				INCLUDED	IN E				
23 AIR HEATER (B/W) (SR)									
24 AIR LEVER/FLUE GAS DUCTING									
J PAINTING TOTAL								35000	35000
K INSULATION									
25 HEATER (B/W) (SR)									
26 PRIMARY AIR/FUEL/FLUE GAS				INCLUDED	IN E				
27 AIR HEATER (B/W)									
K INSULATION TOTAL									- 0 -
CODE									
5600									

FORM 20-100 (Rev. 11-76)

SR UNIVERS NOTED

PROJECT SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM LOCATION BARSTOW, CA CLIENT: DOE/EA/DM
 DATE AUGUST 1979 TAKE-OFF _____ PRICE _____ CALC. CHKD _____ APPROVED _____ SHEET 7 OF 7

ESG-79-30, Vol III

0-55

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
NON-SOLAR SUBSYSTEM									
PLATFORM CONSTRUCTION FACILITIES (B/W)(SA)			INCLUDED	IN	E				-0-
CONSTRUCTION SERVICES, SUPPLIES & EXPENSE (B/W)(SA)									-0-
FIELD STAFF, SUBSISTENCE & EXPENSE (B/W, SA)									-0-
CRAFT BENEFITS, PAYROLL BURDENS & INSURANCES (B/W, SA)									-0-
EQUIPMENT RENTAL									-0-
ENGINEERING (B/W, SA)									-0-
MAJOR EQUIPMENT PROCUREMENT (B/W, SA)									-0-
CONSTRUCTION MANAGEMENT (B/W, SA)							282000		282000
LABOR PRODUCTIVITY (B/W, SA)									-0-
CONTINGENCY (B/W, SA)									-0-
FEE									1415000
CODS									
5600	5600	TOTAL							29862000

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA DESCRIPTION 08 SOLAR MULTIPLE
LOCATION BARSTOW, CA. 1ST COMMERCIAL PLANT CONT. NO. ET-78-C-03-2233
SUB-ACCOUNT 5700 MADE BY W. WILLCOX
PROJECT SOLAR CENTRAL ENERGY STORAGE SUBSYS. APPROVED _____
RECEIVER HYBRID POWER SYSTEM

[illegible]

National

SOLAR CENTRAL RECEIVER

JOB NO.

PROJECT

HYBRID POWER SYSTEM

LOCATION BARSTOW, CA

CLIENT

DOE/SANDIA

DATE

AUGUST 1979

TAKE-OFF

PRICED

CALC. CHECK

APPROVED

SHEET

1 OF 3

ESG-79-30, Vol 1 III

0-57

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5700 ENERGY STORAGE SUBSYSTEM*										
A	EXCAVATION & CIVIL									
	EXCAVATE									
111	STEAM GEN. PUMP FOUNDATION									
112	LOW TEMP. SOD. TK. FOUNDATION (1.4 SM)									
113	HIGH TEMP. SOD. TK. FOUNDATION (1.4 SM)									
	TOTAL									- 0 -
B	CONCRETE									
B1	STEAM GEN. PUMP FOUNDATION									
B2	LOW TEMP. SOD. TK. FOUNDATION (1.4 SM)									
B3	HIGH TEMP. SOD. TK. FOUNDATION (1.4 SM)									
	TOTAL									- 0 -
C	STRUCTURAL STEEL IN ACCOUNT # 54000									
C1	STEAM GEN. PUMP									
C2	LOW TEMP. SOD. TK. (1.4 SM)						- 0 -			
C3	HIGH TEMP. SOD. TK. (1.4 SM)						- 0 -			
	TOTAL									- 0 -
D	BUILDINGS - NONE									
E	EQUIPMENT									
E1	STEAM GEN. PUMP									
E2	LOW TEMP. SOD. TK. (1.4 SM)						- 0 -	- 0 -		
E3	HIGH TEMP. SOD. TK. (1.4 SM)						- 0 -	- 0 -		
E4	LOW TEMP. BUFFER TK. (0.8 SM)						727482	270784		998266
E5	HIGH TEMP. BUFFER TK. (0.8 SM)									
CODE	EG SODIUM	127,500	LB	8.40			51000			
5700										1049266

national
up

JOB NO.

PROJECT

SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

LOCATION

BARSTOW, CA

CLIENT

DOE, SANDIA

DATE

AUGUST 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

2

OF 3

ESG-79-30, Vol III

0-58

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5700 ENERGY STORAGE SUBSYSTEM										
F	PIPING IN ACCOUNT # 59,00									
F1	SODIUM PIPING HIGH TEMP.									
F2	SODIUM PIPING LOW TEMP.									
F3	FITTINGS									
F4	VALVES									
F5	HANGERS AND SUPPORTS									
	TOTAL									- 0 -
G	ELECTRICAL									
G1	SWITCH GEAR									
G2	POWER WIRING									
G3	ELECTRICAL STRUCTURES									
	TOTAL									- 0 -
H	INSTRUMENTS IN ACCOUNT # 54,012									
H1	SENSORS AND CONTROL									
	TOTAL									- 0 -
J	PAINTING						- 0 -	- 0 -		
	TOTAL									- 0 -
K	INSULATION INCL. W/ COMPONENTS									
K1	SODIUM PIPING, VALVES & FITTINGS									
K2	LOW TEMP. SOD. TK. (1.4 SM)									
K3	HIGH TEMP. SOD. TK. (1.4 SM)									
K4	LOW TEMP. BUFFER TK. (0.8 SM)									
K5	HIGH TEMP. BUFFER TK. (0.8 SM)									
K6	STEAM GEN. PUMP									
	TOTAL									- 0 -
CODE										
5700

national

SOLAR CENTRAL RECEIVER

JOB NO.

PROJECT

HYBRID POWER SYSTEM

LOCATION

BARSTOW, CA

CLIENT

DOE/INDIA

DATE

AUGUST 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

3

OF

3

ESG-79-30, Vol III

0-59

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5700 ENERGY STORAGE SUBSYSTEM										
L	TEMPORARY CONSTRUCTION FACILITIES	IN ACCOUNT #5700								
M	CONSTR. SERVICES, SUPPLIES & EXPENSES									
N	FIELD, STAFF, SUBSISTENCE & EXPENSE									
P	CRAFT BENEFITS, PAYROLL BURDENS & INSURANCE									
Q	EQUIPMENT RENTAL									
R	ENGINEERING - PLANT DESIGN							63000		63000
S	AIRBOR EQUIPMENT PROCUREMENT									
T	CONSTRUCTION MANAGEMENT							31000		31000
U	LABOR PRODUCTIVITY INCL. w/ COMPONENT COST									
V	CONTINGENCY									
W	FEE									57000
5700 TOTAL										1700266

CODE

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 0.8 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

1ST COMMERCIAL PLANT

CONT. NO. ET-78-C-03-2233

PROJECT SOLAR CENTRAL

SUB ACCOUNT 5800
ELECTRIC POWER GENERATION
SUBSYSTEM

MADE BY W. WILCOX

APPROVED _____

[illegible]

SOLAR CENTRAL RECEIVER

PROJECT HYBRID POWER SYSTEM

LOCATION BARSTOW, CA CLIENT

Due Less:

DATE AUGUST 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SMITT

1 of 6

ESG-79-30, Vol III

0-61

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
GOOD ELECTRICAL POWER GENERATING SYSTEM										
A. PREPARATION & CIVIL										
1. EXCAVATE & BACKFILL										
11	TURBINE BAY (S-R)	1600	CY							
12	WATER BAY (S-R)	750	CY							
13	WATER TREATMENT (S-R)	500	CY							
14	COOLING TOWER BASIN (S-R)	400	CY							
15	STACK FOUNDATION (S-R)	6500	CY							
16	ASH HANDLING & STORAGE (SR)	6400	CY							
TOTAL		20250								71000
B. CONCRETE										
17	TURBINE FOUNDATION (S-R)	800	CY	160	12		128000	154000		
18	FIN. HTR. FOUNDATIONS (S-R)	150	CY	70	6		11000	14000		
19	WATER TREATMENT (S-R)	200	CY	70	15		14000	48000		
20	COOLING TOWER (S-R)	400	CY	75	20		30000	128000		
21	STACK (S-R)	5027	CY	75	5		377000	402000		
TOTAL		6477		75%	15%		562000	746000		1306000
C. STRUCTURAL STEEL										
INCL IN BUILDINGS "D"										
22	TURBINE SUPPORT (S-R)									
23	FIN. HEATERS (S-R)									
24	STACK SUPPORT STRUCTURE (S-R)									
D. BUILDINGS										
25	TURBINE BAY } 50 x 110 (S-R)						156000	100000		256000
26	WATER BAY } 50 x 110 (S-R)						87000	57000		144000
27	WATER TREATMENT 50 x 75 (S-R)						51000	36000		87000
TOTAL							297000	193000		490000
COST										5800
										1867000

JOB 1. PROJECT SOLAR CENTRAL RECEIVER HYBRID POWER SYSTEM LOCATION BARSTON, CA CLIENT DO

DATE AUGUST 1979 TAKE-OFF PRICED CALC. CHKD APPROVED SHEET 2 OF 6

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONF.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
580 ELECTRICAL POWER GEN. SUB SYSTEM									
E EQUIPMENT SR EXCEPT AS NOTED									
TURBINE GENERATOR (13,000 KW)	1					14,790.00	315,000		11,794,000
L.P. HEATERS	2					14,000.00	60,000		1,460,000
H.P. HEATERS	3					27,000.00	50,000		2,450,000
DEAERATOR	1					53,000.00	20,000		550,000
CONDENSER (84,000 SF) (56000 ⁴)	1					70,000.00	50,000		1,500,000
CONDENSATE STORAGE TANKS (100,000 GAL)	2							75,000	750,000
CONDENSATE PUMPS (13,000 GPM @ 400' TD)	2					18,000	30,000		210,000
BOILER FEED PUMPS (1750 GPM @ 540' TD)	2					70,000.00	30,000		730,000
CONDENSATE VAC PUMPS 50 HP	2					100,000	100,000		1,120,000
COOLING TOWER	1							830,000	830,000
DEMINERALIZER (POULTHING)	1					550,000	97,000		647,000
GLAND STEAM CONDENSER	1					35,000	20,000		370,000
WATER TREATMENT						720,000	80,000		800,000
LINE HANDLING ESG								896,000.00	896,000
SPRAY DRYER ESG									
BAG HOUSE ESG									
I.D. FANS 13 ¹ / ₂ W						INCLUDED IN 5600			
STACK								430,000	430,000
ASH HANDLING						950,000	635,000		1,585,000
TURBINE BOY CRANE (GANEY 200T)	1					225,000	80,000		233,000
CIRC WATER PUMPS (4,000 GPM @ 16' TD)	2					126,000	60,000		132,000
BLARING COOLING WATER SYST.						43,000	29,000		72,000
CONDENSED AIR SYSTEMS						761,000	170,000		431,000
CONDENSING TOWER MAKEUP PUMPS						80,000	20,000		100,000
OIL TANKS (#2 FUEL OIL) SEC 5600 115									
CODE									
						11,945,000	1,450,000	1,335,000	10,333,000

10295000 28,293,000

national
JOB NO. _____

PROJECT SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

LOCATION FARMINGTON, CA CLIENT _____

DOL/SANDIA

DATE AUGUST 1979 TAKE-OFF _____

PRICE _____

CALC. CHKD _____

APPROVED _____

SHEET 23 OF 6

ESG-79-30, Vol III

0-63

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONTR.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5000 ELECTRICAL POWER GENERATING SUBSYSTEM									
1 TURBINE GEN. (S-R)									
2 FEEDWATER HEATERS (S-R)									
3 CONDENSER (S-R)									
4 COOLING TOWER (S-R)									
5 WATER TREATMENT (S-R)									
6 CONDENSATE MAKEUP (S-R)									
7 SPRAY DRYER (ESG)									
8 FABRIC FILTER BAG HOUSE (ESG)									
9 LIME HANDLING (ESG)									
10 I.D. FANS (B&W)									
11 I.W. PUMPS (S-R)									
12 ASH HANDLING (S-R)									
13 STACK (S-R)									
14 PIPING						1897000	1266000		3165000
15 FEEDWATER (S-R)									
16 STEAM (S-R)									
17 WATER TREATMENT (S-R)									
18 COOLING WATER (S-R)									
19 LIME HANDLING (ESG)									
20 LIME GAS DUCTING (B&W) (ESG)									
21 FITTINGS (S-R)									
22 VALVES (S-R)									
23 HANGERS & SUPPORTS (S-R)									
CODE									
5000									3165000

INCLUDED IN E
INCLUDED IN 5000

10-9 110

PROJECT

SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

LOCATION

BARTON, CA

CLIENT

DOB/SANZ/A

DATE AUGUST 1979

TAK-OFF

PRICED

CALC. CHKD

APPROVED

SHEET 24 OF 6

ESG-79-30, VOL III

O-64

ITEM AND DESCRIPTION			QUANTITY	UNIT	MAT'L	LABOR	SUB CONT.	MATERIAL			LABOR			SUB-CONTRACT			TOTAL		
ELECTRICAL POWER GENERATING SYSTEM:																			
10	ELECTRICAL	8 1/2 TCHL						3095000	22		990000	22					1085000	22	
11	GILSON GEAR	(S-R)						1342000	22		142000	22					1482000	22	
12	PROTECTIVE EQUIP.	(S-R)						156000	22		104000	22					260000	22	
13	POWER WIRING	(S-P)						965000	22		645000	22					1605000	22	
14	ELECTRICAL STRUCTURES	(S-R)						156000	22		12000	22					208000	22	
15	STARTUP TRANSFORMER	(S-R)						134200	22		15000	22					149200	22	
16	AUXILIARY TRANSFORMER	(S-R)						134000	22		15000	22					149000	22	
17	ALUM TRANSFORMER	(S-R)						220000	22		22000	22					222000	22	
INSTRUMENTS																	50000	22	
18	STEAM FEEDWATER CONTROLS	(S-R)																	
19	WATER TREATMENT	(S-R)																	
20	STACK MONITORING	(S-R)																	
21	ANALYTICAL	(S-R)																	
PAINTING																	250000	22	
CODE																	4835000		
ES00																	8920000		

(A)

Schematic

SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

JOB NO.

PROJECT

LOCATION BARSTOW, CA

CLIENT

DOE/
JAN. A

DATE AUGUST 1979

TAKE-OFF

PRICED

CALC. CHECK

APPROVED

SHEET

A-5

OF 6

ESG-79-30, Vol 1 B1

0-65

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONTR.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5000 ELECTRICAL POWER GENERATING SUBSYSTEM									
1 INSULATION									520000
11 STEAM-TO-WATER PIPING (S-R)									
12 TURBINE-TO-WATER PIPING (S-R)									
13 BUILDINGS (S-R)									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									
32									
33									
34									
35									
36									
37									
38									
39									
40									
41									
42									
43									
44									
45									
46									
47									
48									
49									
50									
51									
52									
53									
54									
55									
56									
57									
58									
59									
60									
61									
62									
63									
64									
65									
66									
67									
68									
69									
70									
71									
72									
73									
74									
75									
76									
77									
78									
79									
80									
81									
82									
83									
84									
85									
86									
87									
88									
89									
90									
91									
92									
93									
94									
95									
96									
97									
98									
99									
100									
101									
102									
103									
104									
105									
106									
107									
108									
109									
110									
111									
112									
113									
114									
115									
116									
117									
118									
119									
120									
121									
122									
123									
124									
125									
126									
127									
128									
129									
130									
131									
132									
133									
134									
135									
136									
137									
138									
139									
140									
141									
142									
143									
144									
145									
146									
147									
148									
149									
150									
151									
152									
153									
154									
155									
156									
157									
158									
159									
160									
161									
162									
163									
164									
165									
166									
167									
168									
169									
170									
171									
172									
173									
174									
175									
176									
177									
178									
179									
180									
181									
182									
183									
184									
185									
186									
187									
188									
189									
190									
191									
192									
193									
194									
195									
196									
197									
198									
199									
200									
201									
202									
203									
204									
205									
206									
207									
208									
209									
210									
211									
212									
213									
214									
215									
216									
217									
218									
219									
220									
221									
222									
223									
224									
225									
226									
227									
228									
229									
230									
231									
232									
233									
234									
235									
236									
237									
238									
239									
240									
241									
242									

APPENDIX P

0.8 SOLAR MULTIPLE Nth PLANT COST DATA

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONSTRUCTION COST ESTIMATE.

CLIENT DOE / SANDIA

DESCRIPTION 0.8 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

NTH COMMERCIAL PLANT.

SUB-ACCOUNT 5100

CONT. NO. ET-7B-C-03-2233

MADE BY W. WILCOX

PROJECT SOLAR CENTRAL LAND AND SITE PREPARATION
RECEIVER HYBRID POWER SYSTEM

APPROVED

[illegible]

DATE AUGUST 1979 REVISION NO. _____ REVISION DATE _____ PAGE NO. 1 OF 8

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION O.B. SOLAR MULTIPLE

LOCATION BARSTOW, CA.

NTH COMMERCIAL PLANT.

SUB-ACCOUNT 5200

CONT. NO. ET-78-C-03-2233

MADE BY W. WILLCOX

PROJECT SOLAR CENTRAL

ADMINISTRATIVE AREAS

APPROVED _____

RECEIVER HYBRID POWER SYSTEM

A/C NO.	ITEM & DESCRIPTION	ESTIMATED COST \$ X 10 ³				
		MANHOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
	SUMMARY -					
A	Excavation & Civil			14		14
B	Concrete		38		47	86
C	Structural Steel					-0-
D	Buildings		120		180	300
E	Machinery & Equipment		145		1142	1287
F	Piping		15		23	38
G	Electrical		62		37	99
H	Instruments					-0-
J	Painting					8
K	Insulation					-0-
	DIRECT FIELD COSTS					1832
L	Temporary Construction Facilities		8		11	19
M	Construction Services, Supplies & Expense				50	50
N	Field Staff, Subsistence & Expense		46			46
P	Craft Benefits, Payroll Burdens & Insurances		34			34
Q	Equipment Rental					
	INDIRECT FIELD COSTS					147
	TOTAL FIELD COSTS					1981
R	Engineering Plant Design % of TFC					0
S	Major Equipment Procurement					0
I	Construction Management 3% of TFC					59
	TOTAL FIELD & ENGR. COSTS					2040
U	Labor Productivity					0
V	Contingency Construction Design					0
W	Fee 5% of (A thru V)					102
	ESG-79-30, Vol III					
	P-4					
	TOTAL CONSTRUCTION COST					2142

DATE AUGUST 1979 REVISION NO. _____

REVISION DATE _____

PAGE NO. 2 OF 8

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 0.8 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

NTH COMMERCIAL PLANT.

SUB ACCOUNT 5.300

CONT. NO. ET-7B-C-03-2233

MADE BY W. WILLCOX

PROJECT SOLAR CENTRAL

COLLECTOR SUBSYSTEM

APPROVED.

RECEIVER HYBRID POWER SYSTEM

A/C NO.	ITEM & DESCRIPTION	MANHOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
	SUMMARY-					
A	Excavation & Civil	34 x 10 ³	420			420
B	Concrete	89.2 x 10 ³	1103		2,515	3618
C	Structural Steel		INCLUDED IN E			
D	Buildings					-0-
E	Machinery & Equipment	34 x 10 ³	420		2,362	21,782
F	Piping					-0-
G	Electrical	15.3 x 10 ³	189		1,198	1,387
H	Instruments	800	10		101	111
J	Painting					0
K	Insulation					0
	DIRECT FIELD COSTS					27,599
L	Temporary Construction Facilities		57			57
M	Construction Services, Supplies & Expense		43			43
N	Field Staff, Subsistence & Expense		364			364
P	Craft Benefits, Payroll Burdens & Insurances		483			483
Q	Equipment Rental				743	743
	INDIRECT FIELD COSTS					1,611
	TOTAL FIELD COSTS					29,210
R	Engineering Plant Design					0
S	Major Equipment Procurement					34
T	Construction Management 3% of TFC					876
	TOTAL FIELD & ENGR. COSTS					29,914
U	Labor Productivity					703
V	Contingency Construction Design					
W	Fee 5% of (A thru V)					1,531
	TOTAL CONSTRUCTION COST					32,153

DATE AUGUST 1979 REVISION NO. _____

REVISION DATE

PAGE NO. 3 OF 8

JOB NO. _____ PROJECT THANK CENTRAL REGIONAL POWER PLANT LOCATION BALTIMORE, MD CLIENT DOE/EPRI

DATE AUG 1979 TAKE-OFF _____ PRICED _____ CALC. CHKD _____ APPROVED _____ SHEET 4 OF 6

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5300 COLLECTOR SUBSYSTEM									
H INSTRUMENTS									
HI SENSOR/CALIBRATION EQ						101000			
INSTALL, CALIBRATE	.8	HRS		1237			10449		
H INSTRUMENT TOTAL									111449
J PAINTING (HELIOSTATS SHIPPED TO SITE PREFINISHED)									
L TEMPORARY CONST. FACILITIES							57384		57384
M CONST. SERVICES, SUPPLIES, EXPENSE							43432		43432
N FIELD STAFF, SUBSISTANCE, EXPENSE							364256		364256
P CRAFT BENEFITS, PAYROLL BURDENS, INS.							482925		482925
Q EQUIPMENT RENTAL						742616			742616
R ENGINEERING	N/A								
S MAJOR EQUIPMENT PROCUREMENT									
INITIAL SPARES						34000			34000
T CONSTRUCTION MGMT.	N/A								
U LABOR PRODUCTIVITY							708463		708463
V CONTINGENCY	N/A								
W FEE	TBD								
CODE 5300									29752000

Rockwell International
Energy Syst.

SOLAR CENTRAL RECEIVER

JOB NO.

PROJECT

HYBRID POWER SYSTEM 0.8 MW PLANT

LOCATION

BAHAW, CA

CLIENT

DOE/SANDIA

DATE

AUG 12 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

3

OF

6

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5300 COLLECTOR SUBSYSTEM										
A	EXCAVATION AND CIVIL									
A1	HELIOSTAT FOUNDATIONS	34 K	HRS		12.37			420194		
	A CIVIL TOTAL									420194
B	CONCRETE									
B1	HELIOSTAT FOUNDATIONS						2515000			
		89.2 K	HRS		12.37			1103450		
	B CONCRETE TOTAL									3618450
C	STRUCTURAL STEEL (INCLUDED IN E1 & E2)									
E	MACHINERY & EQUIPMENT									
E1	REFLECTOR PANELS INCLUDING MIRROR BACKING STRUCTURE						8360950			
E2	DRIVE UNIT (PEDESTAL, DRIVE, SHORT MAIN BEAM ASSY, ELECTRONICS)						13001050			
	FIELD ASSY, C/O, ALIGNMENT	34 K	HRS		12.37			420194		
	E MACHINERY & EQUIPT. TOTAL						21362000			21782194
G	ELECTRICAL									
G1	ELECTRICAL DISTRIBUTION ASSEMBLY, INSTALL, C/O	15.3 K	HRS		12.37		1198000	189085		
	G ELECTRICAL TOTAL									1387085
CODE										
5300										

ESG-79-30, Vol III

P-7

CONSTRUCTION COST ESTIMATE.

CLIENT DOE / SANDIA

DESCRIPTION 0.8 SOLAR MULTIPLE
NTH COMMERCIAL PLANT.

LOCATION BARSTOW, CA.

SUB-ACCOUNT 5400

CONT. NO. ET-7B-C-03-2233

MADE BY W. WILLCOX

PROJECT SOLAR CENTRAL RECEIVER SUBSYSTEM
RECEIVER HYBRID POWER SYSTEM

APPROVED,

[illegible]

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 0.8 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

NTH COMMERCIAL PLANT.

CONT. NO. ET-7B-C-03-2233

SUB-ACCOUNT 5500

MADE BY W. WILLCOX

PROJECT SOLAR CENTRAL

WASH. R. CONTROL DIVISION

APPROVED

RECEIVER HYBRID POWER SYSTEM

[illegible]

DATE AUGUST 1979 REVISION NO. _____

REVISION DATE

PAGE NO. 5 OF 8

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 0.8 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

NTH COMMERCIAL PLANT.

5% ADJUT 5600

CONT. NO. ET-7B-C-03-2233

MADE BY W. WILLCOX

PROJECT SOLAR CENTRAL

NON-SOLAR SUBSYSTEM

APPROVED.

RECEIVER HYBRID POWER SYSTEM

[illegible]

CLIENT DOE / SANDIA

DESCRIPTION 0.8 SOLAR MULTIPLE

NTH COMMERCIAL PLANT.

LOCATION BARSTOW, CA.

SUB-ACCOUNT 5700

CONT. NO. ET-7B-C-03-2233

MADE BY W. WILLCOX

PROJECT SOLAR CENTRAL

ENERGY STORAGE SUBSYSTEM APPROVED

RECEIVER HYBRID POWER SYSTEM

[illegible]

CLIENT DOE / SANDIA DESCRIPTION 0.8 SOLAR MULTIPLE

NTH COMMERCIAL PLANT.

SUB. ACCOUNT 5800

CONT. NO. ET-78-C-03-2233

MADE BY W. WILCOX

PROJECT SOLAR CENTRAL ELECTRIC POWER
RECEIVER HYBRID POWER SYSTEM GENERATION SUBSYSTEM

APPROVED

[illegible]

APPENDIX Q

1.4 SOLAR MULTIPLE 1ST PLANT COST DATA

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA DESCRIPTION 1.4 SOLAR MULTIPLE
LOCATION BARSTOW, CA. 1ST COMMERCIAL PLANT CONT. NO. ET-78-C-03-2233
SUB ACCOUNT 5100 MADE BY W. WILLCOX
PROJECT SOLAR CENTRAL LAND AND SITE PREPARATION APPROVED _____
RECEIVER HYBRID POWER SYSTEM

A/C NO.	ITEM & DESCRIPTION	ESTIMATED COST \$ X 10 ³				TOTALS
		MANHOURS	LABOR	SUBCONTRACTS	MATERIALS	
	SUMMARY					
A	Excavation & Civil			3718		3,718
B	Concrete			126		126
C	Structural Steel					0
D	Buildings					0
E	Machinery & Equipment					0
F	Piping		21		32	53
G	Electrical		43		53	96
H	Instruments					0
J	Painting					0
K	Insulation					0
	DIRECT FIELD COSTS					3,713
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS		INCLUDED IN DIRECT			0
	TOTAL FIELD COSTS					3,713
R	Engineering Plant Design 6 % of TFC					240
S	Major Equipment Procurement					0
T	Construction Management 3% of TFC					119
	TOTAL FIELD & ENGR. COSTS					4,352
U	Labor Productivity					
V	Contingency Construction Design					
W	Fee 5% of (A thru V)					213
	ESG-79-30, Vol III					
	Q-3					
	TOTAL CONSTRUCTION COST					4,570

DATE AUGUST 1979 REVISION NO. _____ REVISION DATE _____ PAGE NO. 1 OF 8

JOB NO. 1725 PROJECT SOLAR CENTRAL ELECTRIC HYDRO POWER SYSTEM LOCATION PHOENIX, AZ CLIENT

DATE 8-13-79 TAKE-OFF PRICED RIE CALC. CHKD APPROVED SHEET 1 OF 3

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
C100 LAND AND GENERAL SITE PREPARATION									
A1 EXCAVATION AND CIVIL									
1.1 LAND (MDAC - SR)	765	AC						680850	680850
\$890 / AC									
A2 SITE CLEARING (MDAC - SR)	3,723.7	SY						557000	557000
@ 15 1/4									
A3 SITE GRADING (MDAC - SR)								683000	683000
33,515,000 SF X 1.0' ÷ 27 @ 55 1/4									
A4 SITE FENCING (MDAC)	26800	LF						215000	215000
@ 8 1/4 / LF									
A5 EVAPORATION POND, LINED	30	AC						1500000	1500000
\$50,000 / AC INCLUSIVE									
A6 GENERAL ROAD AND WALKWAY (SR)	2500	CY						52000	52000
EXCAVATION @ 2 1/2 / CY									
A CIVIL TOTAL									3717850
B CONCRETE + ASPHALT SIDEWALKS	7000	SE						6200	6200
@ 50 / SE									
C1 GENERAL ROAD + WALKWAY (SR)	10000	CY						120000	120000
@ 3 1/2 / CY									
B CONCRETE TOTAL									126200
C100									
PAGE TOTAL									3844050

ESG-79-30, Vol III Q-4

JOB NO. PROJECT SOLAR CENTRAL REGENERATOR H.P. 3 COMB. UNIT LOCATION BARSTON, CA CLIENT DOE, ANDREA

DATE AUGUST 1977 TAKE-OFF _____ PRICED _____ CALC. CHKD _____ APPROVED _____ SHEET 2 OF 3

[illegible]

[illegible]

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 1.4 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

1ST COMMERCIAL PLANT

SUB ACCOUNT 5200

CONT. NO. ET-78-G-03-2233

MADE BY W. WILLCOX

PROJECT SOLAR CENTRAL

ADMINISTRATIVE AREA

APPROVED _____

RECEIVER HYBRID POWER SYSTEM

A/C NO.	ITEM & DESCRIPTION	ESTIMATED COST \$ X 10 ³				TOTALS
		MANHOURS	LABOR	SUBCONTRACTS	MATERIALS	
	SUMMARY -					
A	Excavation & Civil			14		14
B	Concrete		38		47	86
C	Structural Steel					-0-
D	Buildings		120		180	300
E	Machinery & Equipment		145		1,232	1,377
F	Piping		15		23	38
G	Electrical		62		37	99
H	Instruments					-0-
J	Painting			8		8
K	Insulation					-0-
	DIRECT FIELD COSTS					1,322
L	Temporary Construction Facilities		8		11	19
M	Construction Services, Supplies & Expense				50	50
N	Field Staff, Subsistence & Expense		46			46
P	Craft Benefits, Payroll Burdens & Insurances		34			34
Q	Equipment Rental					-0-
	INDIRECT FIELD COSTS					14
	TOTAL FIELD COSTS					2,271
R	Engineering Plant Design 5% of TFC					104
S	Major Equipment Procurement					0
T	Construction Management 3% of TFC					-62
	TOTAL FIELD & ENGR. COSTS					2,237
U	Labor Productivity					
V	Contingency Construction Design					25
W	Fee 5% of (A thru V)					113
	ESG-79-30, Vol III					
	Q-7					
	TOTAL CONSTRUCTION COST					2,375

DATE AUGUST 1979 REVISION NO.

REVISION DATE

PAGE NO. 2 OF 8

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5200 ADMINISTRATIVE AREAS										
A	EXCAVATION AND CIVIL									
A1	ADMINISTRATION BUILDING FOUNDATION (SR)	12,700	CY		\$0.55/CY				7000	7000
A2	WAREHOUSE/MAINTENANCE BUILDING FOUNDATIONS (SR)	11,800	CY		\$0.55/CY				6500	6500
A3	GUARD HOUSE FOUNDATIONS (SR)	200	CY		\$0.55/CY				100	100
A CIVIL TOTAL										13600
B CONCRETE										
B1	ADMINISTRATION BUILDING FOUNDATION (SR)	300	CY	\$70/CY	6 MH CY		22000	18000		40000
B2	WAREHOUSE/MAINTENANCE BUILDING FOUNDATION (SR)	570	CY	\$35/CY	3 MH CY		20000	16000		36000
B3	GUARD HOUSE FOUNDATION (SR)	11	CY	\$70/CY	6 MH CY		800	700		1500
B4	MISCELLANEOUS (SR)	63	CY	\$70/CY	6 MH CY		4400	3600		8000
B CONCRETE TOTAL										85500
D BUILDINGS										
D1	ADMINISTRATION BUILDING (SR)	5000	SF	\$18/SF	12 MH SF		90000	60000		150000
D2	WAREHOUSE/MAINTENANCE BUILDING (SR)	15000	SF	\$5.80 SF	0.4 MH SF		87000	58000		145000
D3	GUARD HOUSE (SR)	400	SF	\$7.50 SF	0.5 MH SF		3000	2000		5000
D BUILDINGS TOTAL										300000
E MACHINERY & EQUIPMENT										
E1	TRANSPORTATION + LIFTING EQUIPMENT (SR)						520000	130000		650000
E2	COMMUNICATION EQUIPMENT (SR)						29000	7000		36000
CODE										
5200

Rockwell International
Energy Corp.

JOB NO.

PROJECT

SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

LOCATION BARSTOW, CA.

CLIENT

DOE /
SANDIA

DATE

AUGUST 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

2

OF

4

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5200 ADMINISTRATIVE AREAS									
E MACHINERY & EQUIPMENT (CONC.)									
E3 MISCELLANEOUS MAINTENANCE (SR)						32000	8000		40000
EQUIPMENT MDAC (HELIOSTAT MAINTENANCE EQPT.)						651000			651000
E MACHINERY & EQUIPMENT									
TOTAL						1232000	145000		1377000
F PIPING									
F1 ADMINISTRATION WATER AND									
UTILITY SUPPLY & SEWER (SR)						12000	8000		20000
F2 WAREHOUSE / MAINTENANCE WATER									
AND UTILITY SUPPLY & SEWER (SR)						10000	7000		17000
F3 GUARD HOUSE WATER AND									
UTILITY SUPPLY & SEWER (SR)						600	400		1000
F PIPING TOTAL						22600	15400		38000
G ELECTRICAL									
G1 ADMINISTRATION ELECTRICAL									
SUPPLY (SR)						16500	25500		42000
G2 WAREHOUSE / MAINTENANCE ELECTRICAL									
SUPPLY (SR)						19000	33000		52000
G3 GUARD HOUSE ELECTRICAL SUPPLY									
(SR)						1700	3400		5100
G ELECTRICAL TOTAL						37200	61900		99100
J PAINTING									
J1 ADMINISTRATION BUILDING								4000	4000
J2 WAREHOUSE / MAINTENANCE BUILDING								3500	3500
CODE									
5200

Rockwell International
Energy Corp.

JOB NO.

PROJECT

SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

LOCATION

BARSTOW, CA

CLIENT

DOE/
SANDIA

DATE

AUGUST, 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

3

OF

4

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5200 ADMINISTRATIVE AREAS									
J PAINTING (CONT)									
J3 GUARD HOUSE (SR)								200	200
J PAINTING TOTAL								7700	7700
L TEMPORARY CONSTRUCTION FACILITIES (SR)						11300	7700		19000
M CONSTRUCTION SERVICES, SUPPLIES & EXPENSE (SR)						50000			50000
N FIELD STAFF, SUBSISTENCE & EXPENSE (SR)							46000		46000
P CRAFT BENEFITS, PAYROLL BURDENS & INSURANCE (SR)							34000		34000
Q EQUIPMENT RENTAL (SR)							-0-		
R ENGINEERING (SR)									104000
T CONSTRUCTION MANAGEMENT (SR)									62000
U LABOR PRODUCTIVITY (SR)									
CODE									
5200									

R-1
SODIUM COOLED RECEIVER
15.3m (50.2 ft) HEIGHT
13.0m (42.6 ft) DIAMETER
1.5 MW/m² (0.976 x 10⁶ BTU/h-ft²) PEAK POWER DENSITY
0.0069 MP (g) (1.0 PSIG) ULLAGE PRESSURE
AUSTENITIC 33
ASME SECTION VIII-DIV 1
364 MW (1.24 x 10⁹ BTU/h), SOLAR POWER ABSORBED

T-3
HIGH TEMPERATURE SODIUM EXPANSION TANK
0.0069 MP (g) (1.0 PSIG) ULLAGE PRESSURE
49 m³ (13,000 GAL)
593 °C (1100 °F)
AUSTENITIC 33
ASME SECTION VIII - DIV 1

H-1
FOSSIL FIRED SODIUM HEATER
240 MWt (8.9 x 10⁸ BTU/h)
593 °C (1100 °F)
2.07 MP (300 PSIA)
AUSTENITIC 33
ASME SECTION VIII-DIV 1

P-1
RECEIVER PUMP
242 m (795 ft) TDH
1.17 m³/s (18,600 GPM)
NPSH 12.2 (40 ft)
3.01 MW (4200 HP)
288 °C (550 °F)
CARBON STEEL
ASME SECTION VIII, DIV 1

T-1
LOW TEMPERATURE SODIUM TANK
8700 m³ (2.3 x 10⁶ GAL) CAPACITY
288 °C (550 °F)
0.0069 MP (g) (1.0 PSIG) ULLAGE PRESSURE
MILD STEEL
ASME SECTION VIII, DIV 1

Continued
on next
page

T-2
HIGH TEMPERATURE SODIUM TANK
9460 m³ (2.5 x 10⁶ GAL)
593°C (1100°F)
0.0069 MPa (1.25 PSIG) ULLAGE PRESSURE
AUSTENITIC SS
ASME SECTION VIII, DIV. 1

P-2
STEAM GENERATOR PUMP
76 M (250 FT) TDH
0.95 m³/sec (5,000 GPM)
UPSH 9.1 M (30 FT)
0.56 MW (750 HP)
593°C (1100°F)
1.5-3.7 M (5-12 FT)
AUSTENITIC SS
ASME SECTION VIII-DIV.1

X-1
EVAPORATOR
HEIGHT 29 m (95 ft)
SHELL DIAMETER 1.27 m (50 in)
346°C (656°F) SATURATED STEAM OUT
13.79 MPa (2000 PSIA) STEAM
146.0 MW (2.5 x 10⁶ BTU/h)
2-1/4 Cr-1 Mo
ASME-SECTION VIII, DIV. 1

X-2
SUPERHEATER
HEIGHT 27.7 m (91 ft)
SHELL DIAMETER 0.76 m (30 in)
538°C (1000°F) STEAM OUT
13.4 MPa (1950 PSIG) STEAM
74.0 MW (2.5 x 10⁶ BTU/h)
AUSTENITIC SS
ASME-SECTION VIII-DIV. 1

X-3
REHEATER
HEIGHT 20.1 m (66 ft)
SHELL DIAMETER 0.81 m (32 in)
538°C (1000°F) STEAM OUT
2.07 MPa (300 PSIG) STEAM
40.0 MW (1.16 x 10⁶ BTU/h)
AUSTENITIC SS
ASME-SECTION VIII-DIV. 1

LEGEND			
SYMBOL	UNIT	DESCRIPTION	
F	S	2.7 MPa (400 PSI)	
C	B	0.84 MPa (125 PSI)	
D	H	304 SS	
H	K	CARBON STEEL	
K	T	POWER PIPING CODE ANSI B31.1	
T	T	ASME B & PV CODE SECT. VIII	
		AMERICAN PETROLEUM INST. STD.	
		TBD	

- NOTES ON THIS DRAWING:
1. PIPES, VESSELS & EQUIPMENT CONTAINING SODIUM ARE HEAT TRACED.
 2. SODIUM DENSITY;
287°C (550°F) - 821 kg/m³ (51.1 LB/FT³)
593°C (1100°F) - 809 kg/m³ (50.5 LB/FT³)
 3. STEAM SYSTEM INSTRUMENTATION NOT SHOWN.
 4. FOR LEGEND & SYMBOLS REFER TO STANDARD DWG. NP 773-0001.
 5. UNLESS OTHERWISE SPECIFIED, REFER TO VALUES GIVEN IN THE DESIGN DATA SHEETS - APPENDIX "A"

Continued from preceding page

MASTER 8-16-79
SM-1.40
100 MWe

R-1
SODIUM COOLED RECEIVER
16.0 m (52.5 ft) HEIGHT
16.0 m (52.5 ft) DIAMETER
1.5 MW/m² (2.4 x 10⁵ BTU/h-ft²) PEAK POWER DENSITY
0.0069 MP(g) (1.0 PSIG) ULLAGE PRESSURE
AUSTENITIC SS
ASME SECTION VIII - DIV. 1
364 MW (1.24 x 10⁶ BTU/h) SOLAR POWER ABSORBED

T-5
HIGH TEMPERATURE SODIUM EXPANSION TANK
0.0069 MP(g) (1.0 PSIG) ULLAGE PRESSURE
49 m³ (13,000 GAL)
593 °C (1100 °F)
AUSTENITIC SS
ASME SECTION VIII - DIV. 1

H-1
FOSSIL FIRED SODIUM HEATER
240 MW (6.9 x 10⁵ BTU/h)
593 °C (1100 °F)
2.07 MP (300 PSIA)
AUSTENITIC SS
ASME SECTION VIII - DIV. 1

P-1
RECEIVER PUMP
242 m (795 ft) TDH
417 m³/h (18,000 GPM)
NPSH 12.2 (40 ft)
3.12 MW (4200 HP)
283 °C (550 °F)
CARBON STEEL
ASME SECTION VIII, DIV. 1

T-1
LOW TEMPERATURE SODIUM TANK
8700 m³ (2.3 x 10⁶ GAL) CAPACITY
288 °C (550 °F)
0.0069 MP(g) (1.0 PSIG) ULLAGE PRESSURE
MILD STEEL
ASME SECTION VIII, DIV. 1

Continued
on next
page

Continued on next page

Rockwell International
Energy

JOB NO. _____ PROJECT SOLAR CENTRAL RECEIVER LOCATION BARSTOW, CA. CLIENT DOE / SANDIA
HYBRID POWER SYSTEM

DATE AUGUST 1979 TAKE-OFF _____ PRICED _____ CALC. CHKD _____ APPROVED _____ SHEET 4 OF 4

ESG-79-30, Vol III

Q-19

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5200 ADMINISTRATIVE AREAS										
V	CONTINGENCY (SR)									25000
W	FEE (SR)									25000
	(ESG)									112,000
5200 TOTALS							1580000	634000	172000	237,4900

CONSTRUCTION COST ESTIMATE.

CLIENT DOE / SANDIA

DESCRIPTION 1.4 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

1ST COMMERCIAL PLANT

SUB-ACCOUNT 5300

CONT. NO. ET-7B-C-03-2233

MADE BY W. WILCOX

PROJECT SOLAR CENTRAL COLLECTION SUBSYSTEM

APPROVED _____

RECEIVER HYBRID POWER SYSTEM.

[illegible]

DATE AUGUST 1979 REVISION NO.

REVISION DATE

PAGE NO. 3 OF 8

Rockwell International
Energy Sys. Div.

SOLAR CELL - 1.2.2.552.1000.

JOB NO. _____ PROJECT _____

LOCATION BARSTON, N.J. CLIENT DELTA INDIA

DATE AUGUST 1979 TAKE-OFF _____ PRICED _____ CALC. CHKD _____ APPROVED _____ SHEET 8 OF 10

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5300 COLLECTOR SUBSYSTEM										
A	EXCAVATION AND CIVIL									
AI	HELIOSTAT FOUNDATIONS	69 K	HRS		12.37			852820		
	A CIVIL TOTAL									852820
B CONCRETE										
BI	HELIOSTAT FOUNDATIONS						5070000			
		1798 K	HRS		12.37			2224294		
	B CONCRETE TOTAL									7294294
C STRUCTURAL STEEL (INCLUDED IN E1 & E2)										
E MACHINERY & EQUIPMENT										
E1	REFLECTOR PANELS INCLUDING MIRROR BACKING STRUCTURE						18030650			
E2	DRIVE UNIT (PEDESTAL, DRIVE, SHORT MAIN BEAM ASSY, ELECTRONICS)						77460350			
	FIELD ASSY, C/O, ALIGNMENT	68.9 K	HRS		12.37		45491000	852820		
	E MACHINERY & EQUIPT. TOTAL									46343820
G ELECTRICAL										
GI	ELECTRICAL DISTRIBUTION						25830000			
	ASSEMBLE, INSTALL, C/O	36.1 K	HRS		12.37			364638		
	G ELECTRICAL TOTAL									2967638
CODE										
5300										

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5300 COLLECTOR SUBSYSTEM									
H INSTRUMENTS									
HI SENSOR/CALIBRATION EQ						109000			
INSTALL, CALIBRATE	1.4K	HRS		12.37			16918		
H INSTRUMENT TOTAL									125918
J PAINTING (HELIOSTATS SHIPPED TO SITE PREFINISHED)									
L TEMPORARY CONST. FACILITIES							115564		115564
M CONST. SERVICES, SUPPLIES, EXPENSE							87466		87466
N FIELD STAFF, SUBSISTANCE, EXPENSE							718538		718538
P CRAFT BENEFITS, PAYROLL BURDENS, INS.							972550		972550
Q EQUIPMENT RENTAL						1495533			1495533
R ENGINEERING									
S MAJOR EQUIPMENT PROCUREMENT									
INITIAL SPARES						59000			59000
T CONSTRUCTION MGMT.									
U LABOR PRODUCTIVITY							1425861		1425861
V CONTINGENCY		N/A							
W FEE									3123000
CODE									
5300									65581000

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 1.4 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

1ST COMMERCIAL PLANT

SUE ACCOUNT 5400

CONT. NO. ET-78-C-03-2233

MADE BY W. WILCOX

PROJECT SOLAR CENTRAL RECEIVER SUBSYSTEM
RECEIVER HYBRID POWER SYSTEM

APPROVED.

A/C NO.	ITEM & DESCRIPTION	ESTIMATED COST \$ X 10 ³				TOTALS
		MANHOURS	LABOR	SUBCONTRACTS	MATERIALS	
	SUMMARY-					
A	Excavation & Civil			20		20
B	Concrete		446	1,309	412	2,167
C	Structural Steel		414	252	503	1,169
D	Buildings			535		535
E	Machinery & Equipment		2,404	1,000	8,039	11,503
F	Piping		4,230	1,000	7,420	13,020
G	Electrical			46	31	77
H	Instruments			204	191	395
J	Painting					0
K	Insulation					
	DIRECT FIELD COSTS					21,503
L	Temporary Construction Facilities		29	127	70	176
M	Construction Services, Supplies & Expense		116		321	497
N	Field Staff, Subsistence & Expense		1,069			1,069
P	Craft Benefits, Payroll Burdens & Insurances		80			80
Q	Equipment Rental			197		197
	INDIRECT FIELD COSTS					2,027
	TOTAL FIELD COSTS					31,430
R	Engineering Plant Design 5% of TFC		1,572	312		1,884
S	Major Equipment Procurement			19		19
T	Construction Management 3% of TFC		943			943
	TOTAL FIELD & ENGR. COSTS					34,776
U	Labor Productivity					0
V	Contingency Construction Design					348
W	Fee 5% of (A thru V)					1,836
	TOTAL CONSTRUCTION COST					36,460

DATE AUGUST 1979 REVISION NO. REVISION DATE

PAGE NO. 4 OF 8

Ro International
Energy & Group

SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

JOB NO. _____

PROJECT _____

LOCATION BARSTON, CA

CLIENT DOE / SANDIA

DATE AUGUST 1979

TAKE-OFF _____

PRICED _____

CALC. CHKD _____

APPROVED _____

SHEET 1 OF 5

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5400 RECEIVER SUBSYSTEM *									
A EXCAVATION & CIVIL				INCLUDED IN					
EXCAVATE				SEINFELT					
A1 REC. PUMP FOUNDATION				UNLESS NOTED				20000	20000
A2 STEAM GENERATOR FOUNDATIONS									
A3 DRUG VALVE									
A4 TOWER FOUNDATION (S-R)									
A5 DRAIN TANK									
CIVIL TOTAL									20000
B CONCRETE									
B1 REC. PUMP FOUNDATION	50	CY		125				7500	7500
B2 STEAM GENERATOR FOUNDATIONS	385	CY		125				48000	48000
B3 DRUG VALVE	8	CY		125				1000	1000
B4 TOWER FOUNDATION						412000	446000	1252000	2110000
B5 DRAIN TANK									-0-
CONCRETE TOTAL									2166500
C STRUCTURAL STEEL				INCLUDED W/ CONCRETE					
C1 RECEIVER SUPPORT				UNLESS NOTED					
C2 STEAM GENERATORS & STEAM DRUM									
C3 TOWER STRUCTURE									
C4 ABSORBER ATTACHMENTS						410200	387500	176500	974200
C5 PLATFORMS, CATWALKS, LADDERS, ETC.						94000	26000		120000
C6 SODIUM/WATER REACTION RELIEF								75000	75000
C7 PURIFICATION SYSTEM									
C8 DRAIN TANK									-0-
STEEL TOTAL									1169200
D BUILDINGS									
CODE									
5400	STYLISH GLIMMER BLDG.	15000	CF		1.00			135000	535000
PAGE TOTAL									3890700

Ro
Energy, International
a Group

JOB NO. PROJECT SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

LOCATION KANSAS CITY, MO CLIENT DOW CHEMICAL

DATE AUGUST 1979 TAKE-OFF PRICED CALC. CHKD APPROVED SHEET 2 OF 5

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL		LABOR	SUB-CONTRACT	TOTAL	
5400 RECEIVER SUBSYSTEM												
E	EQUIPMENT TOTAL										11502570	
E1	ABSORBER UNIT	24	ea	44.00	95.00	2404	1061760	2146288		59616	3269664	
E2	EXPANSION TANK	1	ea			100					-0-	
E3	RECEIVER PUMP	1	ea				242480	71200			314160	
E4	RECEIVER COOLANT-SODIUM	612334	lb	0.40			247854				247854	
E5	EVAPORATOR	1	ea				3457785	11200			3468985	
E6	SUPERHEATER	1	ea				1012789	5120			1017918	
E7	REHEATER	1	ea				1156669	5120			1161789	
E8	STEAM DRUM	1	ea							200000	200000	
E9	CRANES	2	ea				600000	160000	400000		1160000	
E10	TOWER ELEVATOR (S-R)	1	ea							400000	400000	
E11	COLD TRAP				INCLUDED IN F1							
E12	SODIUM/WATER REACTION RELIEF EQUIP.						259000	3200			262200	
E13	DRAIN TANK										-0-	
E14	TOWER (S-R)						INCLUDED IN TOWER ELEVATOR					
F	PIPING											
F1	SODIUM PIPING-HORIZONTAL *						6211700	1471700	811250		8574650	
F2	RISER						1081850	2441450	523940		4052240	
F3	DOWNCOMER				INCLUDED IN F2							
F4	FITTINGS											
F5	VALVES											
F6	MANUAL											
F7	CONTROL											
F8	ANTI-SIPHON											
F9	HANGERS & SUPPORTS						126000	317000			443000	
F10	MIXING TEE											
* INCLUDE: 1/2" 3000' 3/4" 3000' 1" 3000'												
CODE	PIPING TOTAL										13069890	
5400											24572460	

SOLAR CENTRAL RECEIVER HYBRID POWER SYSTEM

LOCATION BARSTON, CA CLIENT

DOE/
SANDIA

JOB NO.

PROJECT

DATE AUGUST 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

of 5

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5400 RECEIVER SUBSYSTEM										
G	ELECTRICAL				INCLUDED IN					
G1	SWITCH GEAR				5800 g UNLESS					
G2	POWER WIRING				NUTS					
G3	ELECTRICAL STRUCTURES									
G4	TOWER						31000	46000		77000
H	INSTRUMENTS									
H1	RECEIVER SENSORS & CONTROLS								66350.0	66350.0
H2	RECEIVER PUMP SENSORS & CONTROLS									
H3	STEAM GENERATOR " "									
H4	PURIFICATION SYSTEM " "									
H5	SODIUM/WATER REACTION RELIEF " "									
H6	BEAM CHARACTERIZATION SYST (MDAC)						191400	6661		198061
	TOTAL									861561
J	PAINTING				INCLUDED IN TOWER					
J1					& STRUCTURAL STEEL					
					ESTIMATE					
CODE										
5400		PAGE TOTAL								
		938561

Ro
Energy & Group International

JOB NO.

PROJECT

SOLAR CENTRAL PLANT 115
HYBRID POWER SYSTEM

LOCATION

FLORIDA

CLIENT

SKILL

DATE

1/12/77

1977

TAKE-OFF

PRICED

CALC. CKCD

APPROVED

SHEET

4

OF

5

ESG-79-30. Vol 111

0-27

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5400 RECEIVER SUBSYSTEM									
K INSULATION									
K1 SODIUM PIPING, FITTINGS & VALVES									
K2 RECEIVER PUMP									
K3 STEAM GENERATORS & STEAM DRUM									
K4 ABSORBER UNIT									
K5 EXPANSION TANK									
K6 TOWER (S-R)									
L TEMPORARY CONSTRUCTION FACILITIES									176400
L1 ALL EXCEPT TOWER (ESG)								127400	127400
L2 TOWER (S-R)						20000	29000		49000
M CONSTRUCTION SERVICES, SUPPLIES & EXPENSES									497400
M1 ALL EXCEPT TOWER (ESG)						365400			365400
M2 TOWER (S-R)						16000	116000		132000
N FIELD, STAFF, SUBSISTENCE & EXPENSE									1069000
N1 ALL EXCEPT TOWER (ESG)							950000		950000
N2 TOWER (S-R)							119000		119000
P CRAFT BENEFITS, PAYROLL BURDENS & INSURANCE									
P1 ALL EXCEPT TOWER (ESG)									
P2 TOWER (S-R)							88000		88000
Q EQUIPMENT RENTAL									
Q1 ALL EXCEPT TOWER (ESG)								197000	197000
Q2 TOWER (S-R)									-0-
CODE									
5400									
PAGE TOTAL									2027800

International
Energy Group

JOB NO.

PROJECT

SOLAR CENTRAL RECEIVER
HYBRID SOLAR SYSTEM

LOCATION

BARTON, VA

CLIENT

DOE/
SANDIA

DATE

AUGUST 1977

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

5

OF

5

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5400 RECEIVER SUBSYSTEM									
R ENGINEERING - PLANT DESIGN									1883500
R1 ALL EXCEPT TOWER (ESG)									
R2 PLANT STARTUP AND CHECKOUT (ESG)							1571500		1571500
R3 TOWER (S-R)							312000		312000
S MAJOR EQUIPMENT PROCUREMENT									19000
S1 ALL EXCEPT TOWER (ESG)								-0-	
S2 TOWER (S-R)								19000	
T CONSTRUCTION MANAGEMENT									
T1 ALL EXCEPT TOWER (ESG)						943000			943000
T2 TOWER (S-R)									
U LABOR PRODUCTIVITY									
U1 ALL EXCEPT TOWER (ESG)									
U2 TOWER (S-R)									
V CONTINGENCY									
V1 ALL EXCEPT TOWER (ESG)									
V2 TOWER (S-R)									348000
W FEE									1836200
W1 ALL EXCEPT TOWER (ESG)								105000	
W2 TOWER (S-R)									
5400 TOTAL									36460000

CONSTRUCTION COST ESTIMATE.

CLIENT DOE / SANDIA

DESCRIPTION 1.4 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

1ST COMMERCIAL PLANT

SUB ACCOUNT 5500

CONT. NO. ET-7B-C-03-2233

MADE BY W. WILCOX

PROJECT SOLAR CENTRAL

MASTER CONTROL SUBSYSTEM

APPROVED

RECEIVER HYBRID POWER SYSTEM

[illegible]

5500 - MASTER CONTROL SUBSYSTEM

This subaccount was cancelled. The summary sheet is from the ACR Plant which has the identical system. There are no back-up sheets for this account given here.

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 1.4 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

1ST COMMERCIAL PLANT

SUB ACCOUNT 5600

CONT. NO. ET-78-C-03-2233

MADE BY W. WILLCOX

PROJECT SOLAR CENTRAL NON-SOLAR SUBSYSTEM
RECEIVER HYBRID POWER SYSTEM

APPROVED _____

A/C NO.	ITEM & DESCRIPTION	ESTIMATED COST $\$ \times 10^3$				TOTALS
		MANHOURS	LABOR	SUBCONTRACTS	MATERIALS	
	SUMMARY -					
A	Excavation & Civil			53		53
B	Concrete		449		547	996
C	Structural Steel		157		364	521
D	Buildings		704		1256	1760
E	Machinery & Equipment		579	21,785	1,966	24,330
F	Piping		18		27	45
G	Electrical		149		276	425
H	Instruments		INCLUDED IN E			0
J	Painting			35		35
K	Insulation		INCLUDED IN E			0
	DIRECT FIELD COSTS					28,165
L	Temporary Construction Facilities		INCLUDED IN DIRECT COSTS			
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					0
	TOTAL FIELD COSTS					28,165
R	Engineering Plant Design					0
S	Major Equipment Procurement					0
T	Construction Management 1 % of TFC					282
	TOTAL FIELD & ENGR. COSTS					28,447
U	Labor Productivity					
V	Contingency Construction Design					
W	Fee 5% of (A thru V)					1,415
	ESG-79-30, Vol III					
	Q-31					
	ESG-79-30, Vol III					
	Q-31					
	TOTAL CONSTRUCTION COST					29,862

5600 - NON SOLAR SYSTEM

The cost is the same as that given for the 0.8 SM plant. There are no back-up sheets for this account in this section.

PROJECT : SOLAR CENTRAL

SUB ACCOUNT 5700

MADE BY W. WILCOX

APPROVED _____

[illegible]

Ro International
Energy Group

JOB NO. _____

PROJECT _____

SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM

LOCATION BARSTOWN, CA

CLIENT DOE, SANDIA

DATE AUGUST 1979

TAKE-OFF _____

PRICED _____

CALC. CHKD _____

APPROVED _____

SHEET _____

OF 3

ESG-79-30, Vol III

0-34

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5700 ENERGY STORAGE SUBSYSTEM*										
A	EXCAVATION & CIVIL									
	EXCAVATE									
A1	STEAM GEN. PUMP FOUNDATION			INCLUDED IN						
A2	LOW TEMP. SOD. TK. FOUNDATION (1.4 SM)			CONCRETE UNLESS						
A3	HIGH TEMP. SOD. TK. FOUNDATION (1.4 SM)			NOTED						
B CONCRETE										
B1	STEAM GEN. PUMP FOUNDATION	40	CY		125				5000	5000
B2	LOW TEMP. SOD. TK. FOUNDATION (1.4 SM)	1000	CY		125				125000	125000
B3	HIGH TEMP. SOD. TK. FOUNDATION (1.4 SM)	1200	CY		125				150000	150000
	TOTAL									280000
C STRUCTURAL STEEL				INCLUDED IN CONCRETE						
C1	STEAM GEN. PUMP									
C2	LOW TEMP. SOD. TK. (1.4 SM)									
C3	HIGH TEMP. SOD. TK. (1.4 SM)									
D BUILDINGS - NONE										
E EQUIPMENT TOTAL										12896266
E1	STEAM GEN. PUMP	1	ea						219000	219000
E2	LOW TEMP. SOD. TK. (1.4 SM)	1	ea	}			4791000			4791000
E3	HIGH TEMP. SOD. TK. (1.4 SM)	1	ea							
E4	LOW TEMP. BUFFER TK.	1	ea	}			727482	270784		998266
E5	HIGH TEMP. BUFFER TK.	1	ea							
CODE	E6 SODIUM	17.2x10 ⁶	lb	0.40						6888000
5700	PAGE TOTAL									13176266

Ro
Energy and Group
International

JOB NO.

PROJECT

SOLAR CENTRAL DESULFUR
HYBRID POWER SYSTEM

LOCATION

BILTON FL

CLIENT

DOL /
SARLIA

DATE

AUGUST 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

2

OF

3

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5700 ENERGY STORAGE SUBSYSTEM										
F	PIPING					INCLUDED	IN 5400 F			
F1	SODIUM PIPING HIGH TEMP.									-0-
F2	SODIUM PIPING LOW TEMP.									
F3	FITTINGS									
F4	VALVES									
F5	HANGERS AND SUPPORTS									
G	ELECTRICAL									-0-
G1	SWITCH GEAR									
G2	POWER WIRING									
G3	ELECTRICAL STRUCTURES									
H	INSTRUMENTS					INCLUDED	IN 5400 H			-0-
H1	SENSORS AND CONTROL									
J	PAINTING									
K	INSULATION					INCLUDED	IN E			-0-
K1	SODIUM PIPING, VALVES & FITTINGS									
K2	LOW TEMP. SOD. TK. (1.4 SM)									
K3	HIGH TEMP. SOD. TK. (1.4 SM)									
K4	LOW TEMP. BUFFER TK. (0.8 SM)									
K5	HIGH TEMP. BUFFER TK. (0.8 SM)									
K6	STEAM GEN. PUMP									
CODE										
5700										

Ro

Ro international

Energy

as Group

JOB NO.**PROJECT**

SOLAR CENTRAL RESEARCH
HYDRO POWER SYSTEM

LOCATION PALESTINE, A

CLIENT DOE / SANCIA

DATE _____

AUGUST 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

— SWEET

•

On

3

[illegible]

CLIENT DOE / SANDIA DESCRIPTION 1.4 SOLAR MULTIPLE

LOCATION BARSTOW, CA. 1st COMMERCIAL PLANT

PROJECT : SOLAR CENTRAL ELECTRIC
SUBSYSTEM

DESCRIPTION 1.4 SOLAR MULTIPLE

1ST COMMERCIAL PLANT

SUB-ACCOUNT 5800

ELECTRIC SUBSYSTEM

CONT. NO. ET-7B-C-03-2233

MADE BY W. WILCOX

APPROVED.

[illegible]

DATE AUGUST 1979 REVISION NO. REVISION DATE PAGE NO. 5 OF 8

5800 - Electric Power Generation Subsystem

The cost is the same as for the 0.8 SM Plant. There are no back-up sheets given here.

1.4 SOLAR MULTIPLE Nth PLANT COST DATA

APPENDIX R

1.4 SOLAR MULTIPLE Nth PLANT COST DATA

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA DESCRIPTION 1.4 SOLAR MULTIPLE
 LOCATION BARSTOW, CA. NTH COMMERCIAL PLANT CONT. NO. ET-79-G-03-2233
 SUB ACCOUNT 5100 MADE BY _____
 PROJECT SOLAR CENTRAL LAND AND SITE PREPARATION APPROVED W. WILLCOX
RECEIVER HYBRID POWER SYSTEM

A/C NO.	ITEM & DESCRIPTION	ESTIMATED COST \$ x 10 ³			
		MANHOURS	LABOR	SUBCONTRACTS	TOTALS
	SUMMARY -				
A	Excavation & Civil			3719	3719
B	Concrete			126	126
C	Structural Steel				0
D	Buildings				0
E	Machinery & Equipment				0
F	Piping		21		53
G	Electrical		43		96
H	Instruments				0
J	Painting				0
K	Insulation				0
	DIRECT FIELD COSTS				3993
L	Temporary Construction Facilities				
M	Construction Services, Supplies & Expense				
N	Field Staff, Subsistence & Expense				
P	Craft Benefits, Payroll Burdens & Insurances				
Q	Equipment Rental				
	INDIRECT FIELD COSTS		INCLUDED IN DIRECT		0
	TOTAL FIELD COSTS				3993
R	Engineering Plant Design				0
S	Major Equipment Procurement				0
T	Construction Management 3% of TFC				120
	TOTAL FIELD & ENGR. COSTS				4113
U	Labor Productivity				0
V	Contingency Construction Design				0
W	Fee 5% of (A thru V)				206
	ESG-79-30, Vol III				
	R-3				
	TOTAL CONSTRUCTION COST				4319

CONSTRUCTION COST ESTIMATE.

CLIENT DOE / SANDIA

DESCRIPTION 1.9 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

NTH COMMERCIAL PLANT.

SUB ACCOUNT 5.300

CONT. NO. ET-7B-C-03-2233

MADE BY

APPROVED W. WILCOX

PROJECT SOLAR CENTRAL

COLLECTOR SUBSYSTEM

[illegible]

5300A CENTRAL RECEIVER

JOB NO. _____ PROJECT PHOTO POWER SYSTEM LOCATION BARSTOW, CA CLIENT DOE/SPANIA

DATE AUGUST 1979 TAKE-OFF _____ PRICED _____ CALC. CHKD _____ APPROVED _____ SHEET 3 OF 6

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5300 COLLECTOR SUBSYSTEM									
A EXCAVATION AND CIVIL									
AI HELIOSTAT FOUNDATIONS	54.1 K	HRS		12.37			668830		
A CIVIL TOTAL									668830
B CONCRETE									
BI HELIOSTAT FOUNDATIONS						4002000			
	142. K	HRS		12.37			1755864		
B CONCRETE TOTAL									5757864
C STRUCTURAL STEEL (INCLUDED IN E1 & E2)									---
E MACHINERY & EQUIPMENT									
E1 REFLECTOR PANELS INCLUDING MIRROR BACKING STRUCTURE						3304100			
E2 DRIVE UNIT (PEDESTAL, DRIVE, SHORT MAIN BEAM ASSY, ELECTRONICS)						20691900			
FIELD ASSY, C/O, ALIGNMENT	54.2 K	HRS		12.37			668830		
E MACHINERY & EQUIPT. TOTAL									34664830
G ELECTRICAL									
GI ELECTRICAL DISTRIBUTION ASSEMBLY, INSTALL, C/O	24.3 K	HRS		12.37		1906000	301043		
G ELECTRICAL TOTAL									2207043
CODE									
5300									

ESG-79-30, Vol III

R-5

SOLAR CENTRAL RECEIVER

JOB NO. _____ PROJECT HYBRID POWER SYSTEM LOCATION BARSTOW, CA CLIENT DOE, ANDIA
 DATE AUGUST 1979 TAKE-OFF _____ PRICED _____ CALC. CHKD _____ APPROVED _____ SHEET 4 OF 6

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5300 COLLECTOR SUBSYSTEM									
H INSTRUMENTS									
HI SENSOR/CALIBRATION EQ						101000			
INSTALL, CALIBRATE	1.4K	HRS		12.37			112918		
H INSTRUMENT TOTAL									117918
J PAINTING (HELIOSTATS SHIPPED TO SITE PREFINISHED)									
L TEMPORARY CONST. FACILITIES							91344		91344
M CONST. SERVICES, SUPPLIES, EXPENSE							69135		69135
N FIELD STAFF, SUBSISTANCE, EXPENSE							580171		580171
P CRAFT BENEFITS, PAYROLL BURDENS, INS.							768721		768721
Q EQUIPMENT RENTAL						1182096			1182096
R ENGINEERING	N/A								
S MAJOR EQUIPMENT PROCUREMENT									
INITIAL SPARES						59000			59000
T CONSTRUCTION MGMT.							1383000		1383000
U LABOR PRODUCTIVITY							1127050		1127050
V CONTINGENCY	N/A								
W FEE	TBD								2434000
CODE									
5300									51111000

CLIENT DOE / SANDIADESCRIPTION 1.4 SOLAR MULTIPLELOCATION BARSTOW, CA.NTH COMMERCIAL PLANTSUB ACCOUNT 5400CONT. NO. ET-78-C-03-2233PROJECT SOLAR CENTRALRECEIVER SUBSYSTEM

MADE BY

APPROVED W. WILLCOXRECEIVER HYBRID POWER SYSTEM

A/C NO.	ITEM & DESCRIPTION	ESTIMATED COST \$ X 10 ³				
		MANHOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
	SUMMARY-					
A	Excavation & Civil			20		20
B	Concrete		389	1,309	412	2,110
C	Structural Steel		414	252	503	1,169
D	Buildings			535		535
E	Machinery & Equipment		1,807	797	6,043	8,647
F	Piping		4,230	1,420	7,420	13,070
G	Electrical		46	31		77
H	Instruments			702		702
J	Painting			0		
K	Insulation					
	DIRECT FIELD COSTS			INCLUDED		26,330
L	Temporary Construction Facilities				99	99
M	Construction Services, Supplies & Expense				132	132
N	Field Staff, Subsistence & Expense		970			970
P	Craft Benefits, Payroll Burdens & Insurances		88			88
Q	Equipment Rental			197		197
	INDIRECT FIELD COSTS					1,456
	TOTAL FIELD COSTS					27,766
R	Engineering Plant Design 6% of TFC					0
S	Major Equipment Procurement					0
T	Construction Management 3% of TFC					833
	TOTAL FIELD & ENGR. COSTS					28,599
U	Labor Productivity					0
V	Contingency Construction Design					0
W	Fee 5% of (A thru V)					1,430
	ESG-79-30, Vol III					
	R-7					
	TOTAL CONSTRUCTION COST					30,029

DATE AUGUST 1979 REVISION NO. _____

REVISION DATE _____

PAGE NO. _____

4 OF 8

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 1.4 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

NTH COMMERCIAL PLANT

CONT. NO. ET-78-C-03-2233

SUB ACCOUNT 5500

MADE BY _____

PROJECT SOLAR CENTRAL

MASTER CONTROL SUBSYSTEM

APPROVED W. WILLCOX

RECEIVER HYBRID POWER SYSTEM

A/C NO.	ITEM & DESCRIPTION	ESTIMATED COST \$ X 10 ³				TOTALS
		MANHOURS	LABOR	SUBCONTRACTS	MATERIALS	
	SUMMARY -					
A	Excavation & Civil			1		1
B	Concrete		5		5	10
C	Structural Steel					0
D	Buildings		20		34	54
E	Machinery & Equipment		34		938	972
F	Piping					0
G	Electrical		3		2	5
H	Instruments		1		140	141
J	Painting			2		2
K	Insulation					
	DIRECT FIELD COSTS					1,185
L	Temporary Construction Facilities					0
M	Construction Services, Supplies & Expense					0
N	Field Staff, Subsistence & Expense		7			7
P	Craft Benefits, Payroll Burdens & Insurances		14			14
Q	Equipment Rental					0
	INDIRECT FIELD COSTS					21
	TOTAL FIELD COSTS					1,206
R	Engineering Plant Design					0
S	Major Equipment Procurement					0
T	Construction Management 3% of TFC					36
	TOTAL FIELD & ENGR. COSTS					1,242
U	Labor Productivity					13
V	Contingency Construction Design					
W	Fee 5% of (A thru V)					63
	ESG-79-30, Vol III					
	R-8					
	TOTAL CONSTRUCTION COST					1,315

CLIENT DOE / SANDIA

DESCRIPTION 1.4 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

NTH COMMERCIAL PLANT

SUB ACCOUNT 5600

CONT. NO. ET-72-C-03-2233

MADE BY

PROJECT SOLAR CENTRAL NON-SOLAR SUBSYSTEM

APPROVED W. WILLCOX

RECEIVER HYBRID POWER SYSTEM

[illegible]

DATE AUGUST 1979 REVISION NO. REVISION DATE PAGE NO. 6 OF 8

CONSTRUCTION COST ESTIMATE.

CLIENT DOE / SANDIA

DESCRIPTION 1.4 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

NTH COMMERCIAL PLANT

SUB ACCOUNT 5700

CONT. NO. ET-7R-C-03-2233

MADE BY.

PROJECT SOLAR CENTRAL ENERGY STORAGE SUBSYSTEM
RECEIVER HYBRID POWER SYSTEM.

APPROVED W. WILCOX

[illegible]

CONSTRUCTION COST ESTIMATE.

CLIENT DOE / SANDIA

DESCRIPTION 1.9 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

NTH COMMERCIAL PLANT

CONT. NO. ET-78-C-03-223:

PROJECT SOLAR CENTRAL

SUB ACCOUNT 5300
ELECTRIC POWER GENERATION
SUBSYSTEM

MADE BY

APPROVED W. WILCOX

[illegible]

APPENDIX S

1.44 SOLAR MULTIPLE PREFERRED COMMERCIAL PLANT COST DATA

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA DESCRIPTION 1.94 SOLAR MULTIPLE
LOCATION BARSTOW, CA. NTH PREFERRED COMMERCIAL PLANT CONT. NO. ET-7R-G-03-2233
SUB ACCOUNT 5100 MADE BY W. WILLCOX
PROJECT SOLAR CENTRAL LAND AND SITE PREPARATION APPROVED _____
RECEIVER HYBRID POWER SYSTEM

A/C NO.	ITEM & DESCRIPTION	MANHOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
	SUMMARY-					
A	Excavation & Civil			14,838		14,838
B	Concrete			187		187
C	Structural Steel					
D	Buildings					
E	Machinery & Equipment					
F	Piping		42		68	106
G	Electrical		86		106	192
H	Instruments					
J	Painting					
K	Insulation					
	DIRECT FIELD COSTS					15,323
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					- 0 -
	TOTAL FIELD COSTS					15,323
R	Engineering Plant Design 6% of TFC					919
S	Major Equipment Procurement					
T	Construction Management 3% of TFC					460
	TOTAL FIELD & ENGR. COSTS					16,702
U	Labor Productivity					
V	Contingency Construction Design					
W	Fee 5% of (A thru V)					835
	ESG-79-30, Vol III					
	S-3					
	TOTAL CONSTRUCTION COST					17,537

Ro
international
Engrs. & Group

SOLAR CENTRAL RECEIVER

JOB NO.

PROJECT

HYBRID POWER SYSTEM - PCP

LOCATION

BARETOW

CLIENT

DOE / SANDIA

DATE AUGUST 1977

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

1 OF 3

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5100 LAND AND GENERAL SITE PREPARATION										
A	EXCAVATION AND CIVIL									
A1	LAND (MDAC - SR) \$840 / ACRE	3080	AC						2741200	2741200
A2	SITE CLEARING (MDAC - SR) \$0.15 / SY	147810	SY						2212200	2212200
A3	SITE GRADING (MDAC - SR) \$9.55 / CIVIL YARD	49700	CY						2733000	2733000
A4	SITE FENCING (MDAC) \$8.00 / LF	80875	LF						647000	647000
A5	GENERAL ROAD AND WALKWAY 18,500 LF X 2.0' X 1.5' X 2.0' WIDE @ 27	27,500	CY						55000	55000
A6	EVAPORATION POND \$50,000 / ACRE INCLUSIVE	129	AC						6450000	6450000
A CIVIL TOTAL										14838400
B	CONCRETE + ASPHALT SIDEWALKS \$0.88 / SF 4300 LF X 5 FT WIDE	21000	SF						18900	18900
B1	GENERAL ROAD + PARKING (SR) \$3.00 / SY 12000 SY 24000 SF + ROADS 40000 SF	56000	SY						168000	168000
B CONCRETE TOTAL										186900
CODE										
5100										
PAGE TOTAL										15025300

Ro
International
a Group

SOLAR CENTRAL RECEIVER

JOB NO.

PROJECT

HYBRID POWER SYSTEM, PCP

LOCATION

BARSTON, CA

CLIENT

DOE SANDIA

DATE

AUGUST 1977

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

2

OF 3

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5100	LAND AND GENERAL SITE PREP.									
F	PIPING									
	E 10/12"	10560	LF				64000	42000		106000
F1	SITE WATER SUPPLY (SR)									
	F PIPING TOTAL									106000
G	ELECTRICAL									
G1	SITE UTILITY ELECTRICAL SUPPLY (SR)						106000	86000		192000
	G ELECTRICAL TOTAL									192000
L	TEMPORARY CONSTRUCTION FAC.									
	(MDAC - SR)									
M	CONSTRUCTION SERVICES, SUPPLIES & EXPENSE									
	(MDAC - SR)									
N	FIELD STAFF, SUBSISTANCE & EXPENSE									
	(MDAC - SR)									
P	CRAFT BENEFITS, PAYROLL BURDENS & INSURANCES									
	(MDAC - SR)									
Q	EQUIPMENT RENTAL (MDAC - SR)									
R	ENGINEERING (MDAC - SR)								919000	919000
	CODE									
5100	PAGE TOTAL									1217000

Rc
EngineeringInternational
Group

JOB NO.

PROJECT

SOLAR CENTRAL RECEIVER
HYBRID POWER SYSTEM - PCDLOCATION BARETOW, CA CLIENTDOE/
SANDIA

DATE

AUGUST 1979

TAKE-OFF

PRICED

CALC. CHKD

APPROVED

SHEET

3

OF 3

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5100 LAND & GENERAL SITE PREPARATION									
T CONSTRUCTION MANAGEMENT (MDAC-SR)								460000	460000
U LABOR PRODUCTIVITY (MDAC-SR)									
V CONTINGENCY (MDAC-SR)									
W FEE (MDAC-SR)									835000
5100 TOTAL									17537300

CODE

5100

5100 TOTAL

500

DESCRIPTION

5200

ADMINISTRATIVE TREFS

CONT. NO.

PROJECT

OPTIMUM COM'L PLANT

MADE BY

APPROVED

430 MWe, 5 HRS. STORAGE, COAL FIRED

ESG-79-30, Vol III

5-7

TOTAL CONSTRUCTION COST

5445

DATE _____ REVISION NO. _____ REVISION DATE _____ PAGE NO. 2 of 8

PAGE NO.

$$\frac{2}{3} \varepsilon$$

CONSTRUCTION COST ESTIMATE

CLIENT DOE / SANDIA

DESCRIPTION 1.94 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

NTH PREFERRED COMMERCIAL PLANT

CONT. NO. ET-78-C-03-2233

SUB-ACCOUNT 5300

MADE BY W. WILL COX

PROJECT SOLAR CENTRAL

COLLECTOR SUBSYSTEM

APPROVED

RECEIVER HYBRID POWER SYSTEM

A/C NO.	ITEM & DESCRIPTION	MANHOURS	LABOR	SUBCONTRACTS	MATERIALS	TOTALS
	SUMMARY -					
A	Excavation & Civil	242,700	3002			3,002
B	Concrete	637,100	7881		17,960	25,841
C	Structural Steel	INCLUDED IN E				
D	Buildings					-0-
E	Machinery & Equipment	242,700	3002		152,555	155,557
F	Piping					-0-
G	Electrical	109,200	1351		7,204	8,555
H	Instruments	6,100	75		200	275
J	Painting	INCLUDED IN E				-0-
K	Insulation					-0-
	DIRECT FIELD COSTS					193,230
L	Temporary Construction Facilities		410			410
M	Construction Services, Supplies & Expense		312			312
N	Field Staff, Subsistence & Expense		2,609			2,609
P	Craft Benefits, Payroll Burdens & Insurances		3,462			3,462
Q	Equipment Rental		5,323			5,323
	INDIRECT FIELD COSTS					12,116
	TOTAL FIELD COSTS					205,346
R	Engineering Plant Design					-0-
S	Major Equipment Procurement INITIAL SPARES					115
T	Construction Management					-0-
	TOTAL FIELD & ENGR. COSTS					205,461
U	Labor Productivity		5018			5018
V	Contingency Construction Design					
W	Fee 5% of (A thru V)					10,524
	ESG-79-30, Vol III					
	S-8					
	TOTAL CONSTRUCTION COST					221,003

SOLAR CENTRAL RECEIVER

JOB NO.

PROJECT

HYBRID POWER SYSTEM - PCP

LOCATION

BARSTOW, CA

CLIENT

DOE/ARNDT

DATE

AUGUST

TAKS-OFF

PRICED

CALC. CHKO

APPROVED

SHEET

1 OF 2

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5300 COLLECTOR SUBSYSTEM										
A	EXCAVATION AND CIVIL									
AI	HELIOSTAT FOUNDATIONS	242.7K	HRS		12.37			3002000		
	A CIVIL TOTAL									3002000
B	CONCRETE									
BI	HELIOSTAT FOUNDATIONS						17960000			
		637.1K	HRS		12.37			7881000		
	B CONCRETE TOTAL									25841000
C	STRUCTURAL STEEL (INCLUDED IN E1 & E2)									
E	MACHINERY & EQUIPMENT									
EI	REFLECTOR PANELS INCLUDING MIRROR BACKING STRUCTURE						59704000			
E2	DRIVE UNIT (PEDESTAL, DRIVE, SHORT MAIN BEAM ASSY, ELECTRONICS)						92851000			
	FIELD ASSY, C/O, ALIGNMENT	242.7K	HRS		12.37			3002000		
	E MACHINERY & EQUIPT. TOTAL									155557000
G	ELECTRICAL									
GI	ELECTRICAL DISTRIBUTION						8555000			
	ASSEMBLE, INSTALL, C/O	109.2K	HRS		12.37			1351000		
	G ELECTRICAL TOTAL									9906000
CODE										
5300										

ESG-79-30, Vol I III

S-9

ESG-79-30, Vol III
S-10

ITEM AND DESCRIPTION		QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5300 COLLECTOR SUBSYSTEM										
H	INSTRUMENTS									
HI	SENSOR/CALIBRATION EQ						200000			
	INSTALL, CALIBRATE	6.1 K	HRS		12.37			75000		
	H INSTRUMENT TOTAL									275000
J	PAINTING (HELIOSTATS SHIPPED TO SITE PREFINISHED)									---
L	TEMPORARY CONST. FACILITIES							410000		410000
M	CONST. SERVICES, SUPPLIES, EXPENSE							312000		312000
N	FIELD STAFF, SUBSISTANCE, EXPENSE							2609000		2609000
P	CRAFT BENEFITS, PAYROLL BURDENS, INS.							3462000		3462000
Q	EQUIPMENT RENTAL							5323000		5323000
R	ENGINEERING									---
S	MAJOR EQUIPMENT PROCUREMENT									
	INITIAL SPARES						115000			115000
T	CONSTRUCTION MGMT.									---
U	LABOR PRODUCTIVITY							5018000		5018000
V	CONTINGENCY									---
W	FEE									---
										TBD
CODE										
5300										211830000

" 0000 "

DESCRIPTION

5400

RECEIVER SUBSYSTEM

MADE BY _____

APPROVED

PROJECT OPTIMUM Soil Plant

430 MW, 5 HRS STORAGE, COAL FIRED

ESG-79-30, Vol III

S-11

DATE _____

REVISION NO.

REVISION DATE

PAGE NO.

478

CONSTRUCTION COST ESTIMATE.

CLIENT DOE / SANDIA

DESCRIPTION 1.94 SOLAR MULTIPLE

LOCATION BARSTOW, CA.

Nth PREFERRED COMMERCIAL PLANT

CONT. NO. ET-7B-G-03-2233

SUB-ACCOUNT 55.00

MADE BY W. WILCOX

PROJECT SOLAR CENTRAL

MASTER CONTROL SUBSYSTEM

APPROVED.

[illegible]

JOB NO. _____ PROJECT 60676-Nth LOCATION _____ CLIENT _____

DATE _____ TAKE-OFF _____ PRICED _____ CALC. CHECK _____ APPROVED _____ SHEET _____ OF _____

ITEM AND DESCRIPTION	QUANTITY	UNIT	MAT'L	LABOR	SUB-CONT.	MATERIAL	LABOR	SUB-CONTRACT	TOTAL
5500 MASTER CONTROL SUBSYSTEM									
E EQUIPMENT & MACHINERY									
E2 EQUIPMENT & ENCLOSURES						1290000			
FIELD INSTALLATION	2.7 K	HRS		12.31			33000		
E EQUIP. & MACH. TOTAL									1323000
H INSTRUMENTS									
H2 COMPUTERS									
H3 SOFTWARE									
H4 DISPLAYS									
H5 BEAM CHARACTERIZATION						276000			
INSTALLATION	.09 K	HRS		12.31			1000		
H INSTRUMENTS TOTAL									277000
L TEMPORARY CONST. FACILITIES									
M CONST. SERVICES, SUPPLIES, EXPENSE									
N FIELD STAFF, SUBSISTENCE, EXPENSE							7000		7600
P CRAFT BENEFITS, PAYROLL BURDENS, INSUR.							13000		13000
Q EQUIPMENT RENTAL									
R ENGINEERING									
S MAJOR EQUIP. PROCUREMENT									
T CONSTRUCTION MGMT.									
U LABOR PRODUCTIVITY							5000		
V CONTINGENCY									
W FEE									
	TBD								
CODE									
5500									1620000

ESG-79-30, Vol III

S-13

\$ 000.5600

DESCRIPTION 2600

NON-SOLAR ENERGY

SUBSYSTEM

MADE BY _____

APPROVED _____

430 MWE, 5 HRS. STORAGE, COAL FIRED

ESG-79-30, Vol III

S-14

TOTAL CONSTRUCTION COST

83.765

DATE _____ REVISION NO. _____ REVISION DATE _____ PAGE NO. 6 of 8

PAGE NO. 6 of 8

CONSTRUCTION COST ESTIMATE

CLIENT _____ DESCRIPTION 57.00
LOCATION _____ ENERGY STORAGE SUBSYSTEM
PROJECT OPTIMUM COMI PLANT CONT. NO. _____
430 MWC, 5 HRS. STORAGE, COAL FIRED MADE BY _____
APPROVED _____

A/C NO.	ITEM & DESCRIPTION	ESTIMATED COST				TOTALS
		MANHOURS	LABOR	SUBCONTRACTS	MATERIALS	
	SUMMARY -					
A	Excavation & Civil					
B	Concrete					
C	Structural Steel					
D	Boilings <u>SODIUM @ 41¢/lb (5 hrs storage)</u>					49060
E	Machinery & Equipment					532
F	Piping					1215
G	Electrical					635
H	Instruments					
J	Painting <u>STORAGE TANKS</u>					15360
K	Insulation					
	DIRECT FIELD COSTS					67,002
L	Temporary Construction Facilities					
M	Construction Services, Supplies & Expense					
N	Field Staff, Subsistence & Expense					
P	Craft Benefits, Payroll Burdens & Insurances					
Q	Equipment Rental					
	INDIRECT FIELD COSTS					
	TOTAL FIELD COSTS					67,002
R	Engineering Plant Design 10% of TFC					
	R&D					
S	Major Equipment Procurement 10% of Pump					
T	Construction Management 3% of (TFC + R + S)					2010
	TOTAL FIELD & ENGR. COSTS					69,012
U	Labor Productivity See pg. 5/5					
V	Contingency Construction See pg. 5/5					
	Design See pg. 5/5					
W	Fee <u>5.7%</u> of (A thru V)					3451
	ESG-79-30, Vol III					
	S-15					
	TOTAL CONSTRUCTION COST					72,463

DATE _____ REVISION NO. _____ REVISION DATE _____ PAGE NO. 7 of 8

5800

DESCRIPTION

EPES

MADE BY_

OPTIMUM COM'L PLANT

APPROVED

430 MWE, 5 HRS STORAGE, COAL FIRED

S-16

REVISION NO.

REVISION DATE

PAGE NO.

8/18

APPENDIX T

1.4 SOLAR MULTIPLE OPERATION AND MAINTENANCE COST DATA

ESG-79-30, Vol III

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

OPERATIONS & MAINTENANCE COSTS

SOLAR HYBRID 112 MWe SM = 1.4

		(\$000)			1979 DOLLARS		
		1ST YEAR	2 - 15 Yrs		16 - 30 Yrs		
OM-100	OPERATIONS						
OM-110	OPERATING PERSONNEL	1175		1175			1175
OM-111	EPGS	1050		1050			1050
OM-112	COLLECTOR EQUIP	1050		1050			1050
OM-113	RECEIVER EQUIP						
OM-114	THERMAL STORAGE						
OM-115	NON-SOLAR ENERGY						
OM-120	OPERATING CONSUMABLES	125		125			125
OM-121	EPGS						
OM-122	COLLECTOR EQUIP	125		125			125
OM-123	RECEIVER EQUIP						
OM-124	THERMAL STORAGE						
OM-125	NON-SOLAR ENERGY						

COSTS NOT ESCALATED

	1st YEAR	2 - 15 Yrs	16 - 30 Yrs
OM-200 MAINTENANCE MATERIALS	727	1057	1447
OM-210 SPARE PARTS	307	422	607
OM-211 EPGS	150	175	210
OM-212 COLLECTOR EQUIP	37	37	37
OM-213 RECEIVER EQUIP	40	80	100
OM-214 THERMAL STORAGE	20	30	50
OM-215 NON-SOLAR ENERGY	60	100	210
OM-220 MATERIALS FOR REPAIRS	330	545	750
OM-221 EPGS	150	225	300
OM-222 COLLECTOR EQUIP	40	40	40
OM-223 RECEIVER EQUIP	30	60	80
OM-224 THERMAL STORAGE	10	20	30
OM-225 NON-SOLAR ENERGY	100	200	300
OM-230 OTHER	90	90	90
MASTER CONTROL	57	57	57
BEAM CHARACTERIZATION	33	33	33

	1ST YEAR	2 - 15 YRS	16 - 30 YRS
<u>OM-300</u> MAINTENANCE LABOR	1110	1140	1210
OM-310 SCHEDULED MAINTENANCE	690	710	780
OM-311 EPGS	190	210	280
OM-312 COLLECTOR EQUIP	300	300	300
OM-313 RECEIVER EQUIP			
OM-314 THERMAL STORAGE			
OM-315 NON-SOLAR ENERGY	200	200	200
OM-320 CORRECTIVE MAINTENANCE	420	430	430
OM-321 EPGS	90	80	60
OM-322 COLLECTOR EQUIP	230	230	230
OM-323 RECEIVER EQUIP			
OM-324 THERMAL STORAGE			
OM-325 NON-SOLAR ENERGY	100	120	140
GRAND TOTAL	3012	3372	3832

Operations and Maintenance Material Cost Estimate 13521 Heliostats - Nth Site

OM122 Operating Consumables - Collector Equipment

<u>Part Description</u>	<u>Expected Failures per Year per Plant</u>	<u>1st Year Cost per Unit</u>	<u>Subtotal</u>	<u>Learning Curve Factor Years 1-10</u>	<u>G&A</u>	<u>Overhead</u>	<u>Total</u>
Packaging, trans- portation	2422.52	\$4.47	\$ 10,826.94		1.0	1.0	\$ 10,826.94
Consumables	N/A	8.45	114,230.41		1.0	1.0	114,230.41
			\$125,057.35	TOTAL FOR OM122			\$125,057.35

NOTES:

- ° Packaging and transportation, here, is for spares and repair parts, only. Packaging includes cardbaord containers, pallets, wooden skids, as needed. Transportation costs are based on common carrier rates.
- ° Consumables, include washing solution, delonized rinse water, fuel for washing trucks and other vehicles, and lubricant for drives. Cost indicated is per heliostat.

Operations and Maintenance Material Cost Estimate

13521 Heliostats - Nth Site

OM212 Spare Parts - Collector Equipment

<u>Part Description</u>	<u>Expected Failures per Year per Plant</u>	<u>1st Year Cost per Unit</u>	<u>Subtotal</u>	<u>Learning Curve Factor Years 1-10</u>	<u>G&A</u>	<u>Overhead</u>	<u>Total</u>
Reflective Surface	53.33	\$ 46.77	\$ 2,494.35	1.0	1.0	1.0	\$ 2,494.35
Azimuth	131.42	20.83	2,736.92	1.0	1.0	1.0	2,736.92
Jack Screw	121.69	13.39	1,629.16	1.0	1.0	1.0	1,629.16
Jack Screw	6.00	13.39	80.35	1.0	1.0	1.0	80.35
Azimuth Motor	504.30	3.88	1,958.68	1.0	1.0	1.0	1,958.68
Trking Motor	505.79	2.94	1,485.07	1.0	1.0	1.0	1,485.07
Stowage Motor	25.11	2.94	73.72	1.0	1.0	1.0	73.72
Transformer	1.01	1,704.09	1,844.15	1.0	1.0	1.0	1,844.15
Branch Cir. Bkr.	2.02	75.20	151.98	1.0	1.0	1.0	151.98
Cir. Bkr/Holder	44.62	50.30	2,243.95	1.0	1.0	1.0	2,243.95
Data Dist. Int.	9.77	544.02	5,333.27	1.0	1.0	1.0	5,333.27
Cntrl/Sig. Eq.	956.21	6.71	6,414.60	1.0	1.0	1.0	6,414.60
			<u>\$26,446.20</u>				
				TOTAL FOR OM212			\$26,446.20

NOTES:

- ° Failure rates are provided by reliability engineer.
- ° First year cost per unit is the average unit cost for the first year.
- ° Cost represents only that portion of the item that actually failed, with factors applied for refix and efficiency.
- ° Learning Curve Factor does not apply because these are first year costs.
- ° G&A and Overhead are covered in the labor rates.

Operations and Maintenance Material Cost Estimate

13521 Heliostats - Nth Site

OM222 Materials for Repairs - Collector Equipment

Part Description	Expected Failures per Year per Plant	1st Year Cost per Unit	Subtotal	Learning Curve Factor Years 1-10	G&A	Overhead	Total
Mirror Back Struct.	13.52	\$ 8.61	\$ 116.50	1.0	1.0	1.0	\$ 116.50
Azimuth	131.42	39.61	5,205.15	1.0	1.0	1.0	5,205.15
Jack Screw	121.69	25.46	3,099.13	1.0	1.0	1.0	3,099.13
Jack Screw	6.00	25.46	152.80	1.0	1.0	1.0	152.80
Azimuth Motor	504.30	7.39	3,725.78	1.0	1.0	1.0	3,725.78
Trking Motor	505.79	5.58	2,824.83	1.0	1.0	1.0	2,824.83
Stowage Motor	25.11	5.58	140.23	1.0	1.0	1.0	140.23
Feeder Cable	.03	330.21	9.91	1.0	1.0	1.0	9.91
Transformer	1.00	511.48	511.48	1.0	1.0	1.0	511.48
Dist. Panel	2.11	79.82	168.41	1.0	1.0	1.0	168.41
Branch Cir. Cable	4.97	6.52	32.38	1.0	1.0	1.0	32.38
Wire	27.04	1.10	29.78	1.0	1.0	1.0	29.78
Cntrl/Sig. Eq.	956.21	12.75	12,196.31	1.0	1.0	1.0	12,196.31
Helio Supp. Struct.	13.52	3.23	43.60	1.0	1.0	1.0	43.60
			<u>\$28,256.29</u>				
				TOTAL FOR OM222			\$28,256.29

NOTES:

- ° Failure rates are provided by reliability engineer.
- ° First year cost per unit is the average unit cost for the first year.
- ° Cost represents only that portion of the item that actually failed, with factors applied for refix and efficiency.
- ° Learning Curve Factor does not apply because these are first year costs.
- ° G&A and Overhead are covered in the labor rates.

Operations and Maintenance Labor Cost Estimate 13521 Heliostats-NTH Site

OM230. Other

<u>Description</u>	<u>Expected Failures Per Yr. Per Plant</u>	<u>1st Year Cost Per Unit</u>	<u>Subtotal</u>	<u>G&A</u>	<u>Overhead</u>	<u>Total</u>
Plant Master Control (Yearly service contract)	N/A	N/A	\$56,700.00	1.0	1.0	\$ 56,700.00
Beam Char. Subsystem (Yearly service contract)	N/A	N/A	<u>32,926.82</u> \$89,626.82	1.0	1.0	<u>32,926.82</u> \$ 89,526.82

ESG-79-30, Vol 1 III

T-9

NOTES:

- Beam Char. Subsystem service contract includes the Beam Char. components in 3 areas; i.e., Master Control, Heliostat Field, and Receiver.

Operations and Maintenance Labor Cost Estimate 13521 Heliostat NTH Site

OM312 Scheduled Maintenance - Collector Equipment

<u>Description</u>	<u>Hours Per Year</u>	<u>Unit Cost</u>	<u>Subtotal</u>	<u>G&A</u>	<u>Overhead</u>	<u>Total</u>
Washing Labor	4556.04	16.20	\$ 73807.79	1.0	1.0	\$ 73807.79
Corrosion Control	1271.89	16.20	<u>20604.67</u>	1.0	1.0	<u>20604.67</u>
			<u>\$ 94412.46</u>			<u>\$ 94412.46</u>

NOTES:

- . Washing labor includes truck drivers for wash and rinse trucks
- . Unit cost is labor cost per hour which includes G&A and overhead.

Operations and Maintenance Labor .st Estimate 13521 Heliostats - Nth Site

OM322 Corrective Maintenance - Collector Equipment

<u>Part Description</u>	<u>Hours Per Year</u>	<u>Unit Cost</u>	<u>Subtotal</u>	<u>G&A</u>	<u>Overhead</u>	<u>Total</u>
Reflective Surface	588.76	\$16.20	\$9,537.98	1.0	1.0	\$ 9,537.98
Mirror Back Struct	89.56	16.32	1,461.57	1.0	1.0	1,461.57
Azimuth	6475.62	16.24	105,164.10	1.0	1.0	105,164.10
Jack Screw	1642.86	16.24	26,680.02	1.0	1.0	26,680.02
Jack Screw	58.30	16.24	946.72	1.0	1.0	946.72
Azimuth Motor	5377.40	16.24	87,329.06	1.0	1.0	87,329.06
Trking Motor	5838.91	16.24	94,823.94	1.0	1.0	94,823.94
Stowage Motor	289.86	16.24	4,797.33	1.0	1.0	4,797.33
Feeder Cable	.52	16.32	8.54	1.0	1.0	8.54
Transformer	30.01	16.24	487.42	1.0	1.0	487.42
Dish Panel	14.92	16.32	243.54	1.0	1.0	243.54
Branch Cir Bkr	32.27	16.24	524.09	1.0	1.0	524.09
Branch Cir. Breaker	44.59	16.32	727.63	1.0	1.0	727.63
Wire	242.97	16.32	3,965.28	1.0	1.0	3,965.28
Cir Bkr/Holder	713.62	16.24	11,589.16	1.0	1.0	11,589.16
Data Dist Int.	120.67	16.24	1,959.62	1.0	1.0	1,959.62
Cntrl/Sig Eq	10990.39	16.24	178,483.93	1.0	1.0	178,483.93
Helio Suppl Struct	59.70	16.32	974.37	1.0	1.0	974.37
Corrective Maintenance	9.01	16.20	<u>146.03</u>	1.0	1.0	<u>146.03</u>
			\$ 529,760.33	TOTAL FOR OM322		\$529,760.33

ESG-79-30, Vol 111
T-11

OM 322

NOTES:

- . Hours per year are based on estimates to remove and replace the failed item, repair in place, or bench repair.
- . Unit cost is the labor rate per hour. Labor rate varies, depending on the location of the repair: on the field or back at a central point.
- . G&A and overhead are included in the overhead rate.

ESG-79-30, Vol III

T-12

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

FOSSIL -FIRED
SODIUM HEATER

NUMBER

PREPARED BY

W. F. CLANCEY (B&W)

APPROVED BY

WBS NO.

PAGE 1 of 10

DATE 8/15/79

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		<u>DESIGN CHARACTERISTICS</u>					
	A.0	GENERAL ARRANGEMENT					Parallel operation with Solar subsystem
		Number of Heaters		1			
		Fuel		Pulverized coal			
		Coolant		Sodium			
	A.1	Size					
		Plan	M (ft)	9.1X11.0 (30X35)			
		Height	M (ft)	48.2 (158)			Grade level to top of support steel
	A.2	Heat Transfer Surface Area					
		Low-Temperature convection	M ² (ft ²)	5650 (60800)			
		High-Temperature convection	M ² (ft ²)	2480 (26700)			
		Radiant	M ² (ft ²)	850 (9120)			Effective at full load
				690 (7460)			Effective at 20 percent load

Attachment - Item 7

ESG 10247 ESG

ESG-79-30, Vol III
T-13

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

FOSSIL-FIRED
SODIUM HEATER

NUMBER

PREPARED BY

W. F. CLANCEY (B&W)

APPROVED BY

WBS NO.

PAGE 2 of 10

DATE 8/15/79

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	A.3	Tube Size (OD/Wall) Low-Temperature convection High-Temperature convection Furnace	MM (in) MM (in) MM (in)	63.5/4.2 (2.5/0.155) 63.5/4.2 (2.5/0.155) 31.8/3.8 (1.25/0.148)			
	A.4	Tube Length Low-Temperature convection High-Temperature convection	M (ft) M (ft)	160 (530) 120 (400)			
	A.5	Number of Tubes Low-Temperature convection High-Temperature convection Furnace		104 176 892			
	A.6	Tube Material Low-Temperature convection High-Temperature convection Furnace		carbon steel stainless steel 2 1/4 Cr-1 Mo			Type 304

ESG-79-30, Vol III
I-14

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
FOSSIL-FIRED
SODIUM HEATER

NUMBER

PREPARED BY

APPROVED BY

W. F. CLANCEY (B&W)

WBS NO.

PAGE 3 of 10

DATE 8/15/79

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	A.7	Header and Downcomer Material Inlet Between L.T. conv. and furnace tubes Between furnace and H.T. conv. tubes Outlet		carbon steel carbon steel 2 1/4 Cr-1 Mo stainless steel			Type 304
	A.8	Total Weight Dry Operating	kg (lb) kg (lb)	566900 (1250000) 687100 (1515000)			
	A.9	Furnace Internal Volume	M ³ (ft ³)	3540 (125000)			
	A.10	Sodium Volume	M ³ (ft ³)	142 (5000)			
	A.11	Structural Design Code Pressure vessel Piping					ASME Section VIII, Division 1 ANSI B31.1

ESG-79-30, Vol III
T-15

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

FOSSIL -FIRED
SODIUM HEATER

NUMBER

PREPARED BY

W. F. CLANCEY (B&W)

APPROVED BY

WBS NO.

PAGE 4 of 10

DATE 8/15/79

NEW REV	NO.	ITEM	DESIGN POINT		TEN- SATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	A.12	Fuel Handling Equipment Method Pulverizer type Number of pulverizers		B&W EL-76 3			Direct feed from pulverizers to burners/one pulverizer for each row of burners Ball and race
	A.13	Combustion Equipment Burner Type Number of burners Burner arrangement		B&W dual register 9			Selected for NO _x control Opposed-wall firing with 3 rows of burners and 3 burners per row.
	A.14	NO _x Emission Limits	1b/10 ⁶ Btu	0.5			

ESG-79-30, Vol III
T-16

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
FOSSIL-FIRED
SODIUM HEATER

NUMBER

PREPARED BY

APPROVED BY

W. F. CLANCEY (B&W)

WBS NO.

PAGE 5 of 10

DATE 8/15/79

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		<u>OPERATING CHARACTERISTICS</u>					
	B.0	Fuel		pulverized coal			As defined by Salt River Project
	B.1	Fuel Analysis (ultimate)					
		Moisture	Wt %	14.5			
		Carbon		55.8			
		Hydrogen		4.2			
		Oxygen		11.5			
		Nitrogen		0.9			
		Sulfur		0.6			
		Ash		12.5			
		Chlorine		0.03			
	B.2	Fuel Heating Value (As Fired)	j/kg (Btu /lb)	23.3×10^6 (10000)			
	B.3	Fuel Feed Rate	kg/hr (lb/hr)	47200 (104000)			
	B.4	Thermal Rating					
		Full load	MW _t	265			
		20 percent load	MW _t	53			

ESG-79-30, Vol III
T-17

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

FOSSIL-FIRED
SODIUM HEATER

NUMBER

PREPARED BY

W. F. CLANCEY (B&W)

APPROVED BY

WBS NO.

PAGE 6 of 10

DATE 8/15/79

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	B.5	Operating Load Range	%	20-100			
	B.6	Load Change Response					20 to 100% in 3 to 5 minutes (approximately)
	B.7	Flue Gas Temperature (Full Load)					
		Exiting radiant section	°C (°F)	1199 (2190)			
		Exiting H.T. conv. section	°C (°F)	788 (1450)			
		Exiting L.T. conv. section	°C (°F)	371 (700)			
		Exiting air heater	°C (°F)	149 (300)			
		Flue Gas Temperature (20 percent load)					
		Exiting radiant section	°C (°F)	721 (1330)			
		Exiting H.T. conv. section	°C (°F)	614 (1138)			
		Exiting L.T. conv. section	°C (°F)	313 (595)			
		Exiting air heater	°C (°F)	149 (300)			

Based on 50 percent flue
gas recirculation

ESG-79-30, Vol. III
T-18

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

FOSSIL-FIRED
SODIUM HEATER

NUMBER

PREPARED BY

W. F. CLANCEY (B&W)

APPROVED BY

WBS NO.

PAGE 7 of 10

DATE 8/15/79

REV REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	B.8	Air Temperature (Full Load)					
		Ambient	°C (°F)	28 (83)			
		Exiting air heater	°C (°F)	260 (500)			
		Air Temperature (20 Percent Load)					
		Ambient	°C (°F)	28 (83)			
		Exiting air heater	°C (°F)	204 (400)			
	B.9	Sodium Temperature (Full Load)					
		Inlet	°C (°F)	288 (550)			
		Exiting L.T. conv. section	°C (°F)	359 (678)			
		Exiting radiant section	°C (°F)	517 (963)			
		Exiting H.T. conv. section	°C (°F)	593 (1100)			
		Sodium Temperature (20 percent load)					
		Inlet	°C (°F)	288 (550)			
		Exiting L.T. conv. section	°C (°F)	402 (755)			
		Exiting radiant section	°C (°F)	553 (1028)			
		Exiting H.T. conv. section	°C (°F)	593 (1100)			
							Based on 50 percent flue gas recirculation

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

FOSSIL-FIRED
SODIUM HEATER

NUMBER

PREPARED BY

W. F. CLANCEY (B&W)

APPROVED BY

WBS NO.

PAGE 8 of 10

DATE 8/15/79

NEW REV	NO.	ITEM	DESIGN POINT		TEM- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	B.10	Sodium Flow Rate					
		Full Load	kg/hr (lb/hr)	2.45×10^6 (5.40 $\times 10^6$)			
		20 percent load	kg/hr (lb/hr)	0.49×10^6 (1.08 $\times 10^6$)			
	B.11	Sodium Velocity(Full Load)					
		Low-Temperature convection tubes	m/sec (ft/sec)	1.8 (6)			
		Furnace tubes	m/sec (ft/sec)	2.1 (7)			
		High-Temperature convection tubes	m/sec (ft/sec)	3.0 (10)			
	B.12	Sodium Pressure Drop					
		Full load	MN/m ² (psi)	0.483 (70)			
		20 percent load	MN/m ² (psi)	0.021 (3)			
	B.13	Flue Gas Flow Rate					
		Full load	kg/hr (lb/hr)	0.45×10^6 (1.0 $\times 10^6$)			
	B.14	Heat Absorption (Full load)					
		Low-Temperature convection	MW _t	62			
		Radiant	MW _t	137			
		High-Temperature convection	MW _t	66			

ESG-79-30, Vol III
T-20

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

FOSSIL-FIRED
SODIUM HEATER

NUMBER

PREPARED BY

W. F. CLANCEY (B&W)

APPROVED BY

WBS NO.

PAGE 9 of 10

DATE 8/15/79

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		Heat Absorption (20 percent load)					
		Low-temperature convection	MW _t	20			
		Radiant	MW _t	26			
		High-temperature convection	MW _t	7			
	8.15	Heat Losses (Full Load)	%				
		Unburned fuel		0.5			
		Radiation		0.2			
		Latent heat (moisture in fuel)		5.4			
		Sensible heat (flue gas)		5.3			
		Unaccounted		1.5			
		Total losses		12.9			
		Efficiency		87.1			
		Heat Losses (20 percent load)					
		Unburned fuel		0.5			
		Radiation		1.2			
		Latent heat (moisture in fuel)		5.4			
		Sensible heat (flue gas)		8.0			
		Unaccounted		1.5			
		Total losses		16.6			
		Efficiency		83.4			

ESG-79-30, Vol III
I-21

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE
FOSSIL-FIRED
SODIUM HEATER

NUMBER

PREPARED BY

W. F. CLANCEY (B&W)

APPROVED BY

WBS NO.

PAGE 10 of 10

DATE 8/15/79

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
	B.16	Auxiliary Power Requirements (Full Load) Coal Feeders and pulverizers Primary air fans Forced-draft fan Induced-draft fan Auxiliary Power Requirements (20 Percent Load) Coal feeders and pulverizers Primary air fans Forced-draft fan Induced-draft fan Gas recirculation fan	KW _e	2650			Gas recirculation required only during part load operation
			KW _e	1350			

ESG-79-30, Vol III
T-22

Enclosure II

Data Lists

Collector Subsystem

A. Design characteristics

1. Field geometry and size, m (ft)
2. Field layout
3. Field oversizing to allow for dirt on mirrors, reliability, etc.
4. Beam pointing accuracy and error budget versus environmental effects, m_r , 1σ
5. Heliostat beam quality and error budget versus environmental effects, m_r , 1σ
6. Heliostat Geometry and Size, m (ft)
7. Number of Heliostats

B. Operating Characteristics

1. Power required for track, slew, and emergency shutdown, MW_e
2. Heliostat operating modes
3. Control system characteristics
4. Operation and survival versus environmental conditions

Receiver Subsystem

A. Design characteristics

1. Receiver height, width, and depth or diameter, m (ft)
2. Area of aperture and/or working ^{Projected} surface, m^2 (ft^2). (For heat pipe receiver provide exposed pipe area and panel area separately)
3. Absorber tube/~~heat pipe~~ OD/ID/wall, mm (in)
4. Absorber tube/~~heat pipe~~ length, m (ft)
5. Number of panels; number of tubes or heat pipes per panel

6. Panel materials, total mass of panels, mass per panel (excluding headers and heat pipes), kg (lb)
7. Heat pipe material, total mass of heat pipes, mass per pipe, kg (lb) (if applicable)
8. Header material, total mass of headers, mass per header, kg (lb)
9. Insulation material, total mass of insulation, kg (lb)
10. Structure material, total mass of structure, kg (lb)
11. Support material, total mass of receiver support, kg (lb)
12. Piping material, total mass of receiver piping (excluding riser/downcomer), kg (lb)
13. Valve material, number and mass of receiver valves (receiver proper only), kg (lb)
14. Pump material, number and mass of receiver pumps (receiver proper only), kg (lb) *Wyle*
15. Total mass of other miscellaneous items in receiver proper (items should be identified and listed), kg (lb)
16. Total dry mass on top of tower (sum of items 6-15 above), kg (lb)
- 17. Total mass of receiver working fluid (excluding riser/downcomer), kg (lb)
18. Receiver operational seismic load (vertical and horizontal at tower top), g's *Steven Rogers*
19. Receiver survival seismic load (vertical and horizontal at tower top), g's
20. Section of ASME code receiver is designed to meet *Section VIII + addenda*
21. Composition and optical characteristics, including absorptivity and emissivity of receiver surface coatings *Pyromark*
22. Receiver pressure drop correlations *equations*
23. Receiver heat transfer correlations (for power into receiver working fluid)
24. Receiver heat transfer correlations (for receiver losses)
25. Tower construction (concrete or steel); height to top of tower, m (ft)
26. Riser/downcomer material, OD/ID/wall, mm (in)

27. Riser/downcomer total lengths, m (ft)
28. Mass of riser/downcomer, kg (lb)
29. Riser/downcomer insulation material, thickness, mm (in)
30. Mass of Riser/downcomer insulation, kg (lb)
31. Total mass of other miscellaneous items in tower (items should be identified and listed), kg (lb)
32. Horizontal piping material, OD/ID/wall, mm (in) (items 32 to 40 should be further identified according to equipment dependent on module size only and equipment dependent on the number of modules only)
33. Horizontal piping total lengths, m (ft)
34. Mass of horizontal piping, kg (lb)
35. Horizontal piping insulation material, thickness, mm (in)
36. Mass of horizontal piping insulation, kg (lb)
37. Valve material, size of valves (ground level only), mm (in)
38. Number and mass of valves (ground level only), kg (lb)
39. Pump material, number and mass of receiver pumps (ground level only), kg (lb)
40. Pump characteristics for all receiver subsystem pumps
 - type (centrifugal, etc)
 - speed and operating range (single, etc)
 - head, m (ft)
 - NPSH, m (ft)
 - operating temperature, °C (°F)
 - power, KW_e (HP)
 - capacity, m^3/s (GPM)
41. Steam generator heat exchanger characteristics (provide for each service)
 - service (boiler, superheater, etc)
 - number required

type (straight finned tube and shell, U tube and shell, etc)

orientation (horizontal or vertical)

number of tube passes

number of shell passes

tube side fluid

shell side fluid

tube material

shell material

number of tubes

tube OD/ID/wall, mm (in)

tube layout and pitch dimension, mm (in)

baffle type and spacing, mm (in)

unit size, m (ft)

mass per unit, kg (lb)

active external surface area per unit, m^2 (ft^2) (include finned area separately if applicable)

inactive external surface area per unit, m^2 (ft^2) (if applicable)

LMTD for each unit, $^{\circ}C$ ($^{\circ}F$)

pinch point ΔT for each unit, $^{\circ}C$ ($^{\circ}F$)

B. Operating Characteristics

1. Receiver Incident Power (provide total and per panel values)

@ maximum insolation, MW_t

@ design insolation, MW_t

@ minimum operating condition, MW_t

2. Receiver Absorbed Power (provide total and per panel values)

@ maximum insolation, MW_t

@ design insolation, MW_t

- @ minimum operating condition, MW_t
3. Flux Maps (design point is minimum requirement)
 4. Peak Flux Absorbed (indicate applicable panels)
 maximum, MW_t/m^2
 design point, MW_t/m^2
 5. Average Flux Absorbed
 maximum, MW_t/m^2
 design point, MW_t/m^2
 minimum operating condition, MW_t/m^2
 6. Receiver Working Fluid Operating Temperatures (in/out), °C (°F)
 7. Receiver Working Fluid Operating Pressures (in/out) MPa (PSI)
 8. Receiver Working Fluid Flow Rates (provide total and per panel values)
 maximum, kg/hr (lb/hr)
 design, kg/hr (lb/hr)
 minimum operating condition, kg/hr (lb/hr)
 9. Receiver Working Fluid Velocities (provide per panel values)
 maximum, m/sec (ft/sec)
 design, m/sec (ft/sec)
 minimum operating condition, m/sec (ft/sec)
 10. Receiver losses (% of incident power)
 - @ maximum power, MW_t . Indicate design point wind speed at receiver elevation, m/sec (MPH)
 - reflection, %
 - reradiation, %
 - natural convection, %
 - forced convection, %
 - @ design power, MW_t (specify same wind speed as above)

- reflection, %
- reradiation, %
- natural convection, %
- forced convection, %
- ⑥ minimum operating power, MW_t (specify same wind speed as above)
 - reflection, %
 - reradiation, %
 - natural convection, %
 - forced convection, %
- 11. Peak metal temperatures in receiver (also indicate location), $^{\circ}C$ ($^{\circ}F$)
- 12. Peak working stress in receiver (also indicate location), MPa (PSI)
- 13. Fatigue life, number of cycles and equivalent years of operation
- 14. Receiver heat transfer coefficients, $W/m^2-^{\circ}C$ (BTU/hr-ft $^2-^{\circ}F$)
 - ⑥ maximum absorbed power
 - tube wall
 - receiver working fluid (air, salt or sodium)
 - heat pipe working fluid (if applicable)
 - overall
 - ⑥ design absorbed power
 - tube wall
 - receiver working fluid
 - heat pipe working fluid (if applicable)
 - overall
 - ⑥ minimum operating condition absorbed power
 - tube wall
 - receiver working fluid

heat pipe working fluid (if applicable)

overall

15. Receiver ramp rate, % of maximum absorbed power per minute
16. Steam generator heat exchanger (HX) discharge rate (provide total and value for each heat exchanger unit)
 - maximum, MW_t
 - design, MW_t
 - minimum, MW_t
17. Working Fluid Operating temperatures for each HX unit (in/out), °C (°F)
18. Water/steam Operating temperatures for each HX unit (in/out), °C (°F)
19. Working fluid operating pressures for each HX unit (in/out), MPa (PSI)
20. Water/steam operating pressures for each HX unit (in/out, MPa (PSI)
21. Working fluid flow rates (provide total and value for each heat exchanger unit)
 - maximum, kg/hr (lb/hr)
 - design, kg/hr (lb/hr)
 - minimum, kg/hr (lb/hr)
22. Water/steam flow rates (provide total and value for each heat exchanger unit)
 - maximum, kg/hr (lb/hr)
 - design, kg/hr (lb/hr)
 - minimum, kg/hr (lb/hr)
23. Steam generator heat transfer coefficients, $W/m^2-^{\circ}C$ (BTU/hr-ft²-°F) (provide for each unit)
 - ① design power
 - tube side
 - tube fouling
 - tube wall

shell fouling

shell side

overall

@ maximum power

same as above (if available)

@ minimum power

same as above (if available)

Storage Subsystem (if applicable)

A. Design characteristics

1. Storage media (include specific heat, viscosity, and density over the operating temperature range)
2. Storage media mass, kg (lb)
3. Tank characteristics (provide for each tank type)

Number of storage tanks

Tank geometry and dimensions, m (ft)

Tank volume, m^3 (ft) (total and value per tank)

Tank material

Tank design temperature, °C (°F)

Tank mass, kg (lb) (total and value per tank)

Tank surface area (total and value per tank)

top, m^2 (ft²)

side, m^2 (ft²)

bottom, m^2 (ft²)

total (single tank), m^2 (ft²)

Tank insulation material (specify internal and/or external)

Insulation thickness, m (in)

Insulation mass, kg (lb) (total and value per tank)

4. Piping, material, OD/ID/wall, mm (in)
5. Piping total lengths, m (ft)
6. Mass of piping, kg (lb)
7. Piping insulation material, thickness, mm (in)
8. Mass of piping insulation, kg (lb)
9. Pump material, number and mass of storage pumps (ground level only), kg (lb)
10. Pump characteristics for all storage subsystem pumps
 - type (centrifugal, etc)
 - speed and operating range (single, etc)
 - head, m (ft)
 - NPSH, m (ft)
 - operating temperature, °C (°F)
 - power, KW_e (HP)
 - capacity, m³/s (GPM)

B. Operating characteristics

1. Extractable capacity, MWH_t (BTU)
2. Charging rate
 - maximum, MW_t
 - design, MW_t
 - minimum, MW_t
3. Discharging rate
 - maximum, MW_t
 - design, MW_t
 - minimum, MW_t
4. Duration
 - @ maximum discharge rate, hrs

- @ design discharge rate, hrs
- @ minimum discharge rate, hrs
- 5. Storage media operating temperatures (hot/cold), °C (°F)
- 6. Storage tank operating pressures (provide for both hot and cold tanks if applicable)
 - for fully charged storage
 - @ top, MPa (PSI)
 - @ bottom, MPa (PSI)
 - for fully discharged storage
 - @ top, MPa (PSI)
 - @ bottom, MPa (PSI)
- 7. Heat loss rate
 - for fully charged storage, MW_t
 - for fully discharged storage, MW_t
- 8. Storage ramp rate, % of maximum discharge power per minute

Electrical Power Generation Subsystem

A. Design characteristics

- 1. Turbine generator type and nameplate rating, MW
- 2. Turbine inlet conditions
 - temperature, °C (°F)
 - pressure, MPa (PSI)
 - flow rate
 - maximum, kg/hr (lb/hr)
 - design, kg/hr (lb/hr)
 - minimum, kg/hr (lb/hr)
- 3. Turbine reheat conditions (if applicable)
 - temperature, °C (°F)

pressure, MPa (PSI)

flowrate

maximum, kg/hr (lb/hr)

design, kg/hr (lb/hr)

minimum, kg/hr (lb/hr)

4. Number and location of feedwater heating extractions
5. Condenser type and configuration
6. Feedwater pump stages
7. Auxiliary steam supply
8. Sealing Steam Requirements
9. Turbine startup (cold, warm, and hot start) and shutdown characteristics
10. Non-solar energy source design interface (parallel, in-line, fluid heated, etc. - provide size, materials, weights, etc. similar to those requested for the receiver under items 1-15, Receiver Subsystem, Section A, Design Characteristics). Itemize all heat transfer surface areas as well as the furnace volume and surface areas.
11. Non-solar emission level limits, lb per million BTU (provide for fuel selected)
 - NO_x
 - SO_x
 - Particulates

B. Operational characteristics

1. Using the definitions provided and design point temperatures provide the data listed below for the following three modes: receiver operation (insolation = 950 watts/m²), storage operation (insolation=0), non-solar operation (insolation = 0 and storage capacity = 0)

Gross turbine cycle efficiency = $\frac{\text{generator output}}{\text{heat input to turbine}}$

Net turbine cycle efficiency = $\frac{\text{generator output} - \text{all auxiliary loads}}{\text{heat input to turbine}}$

Include in this tabulated data:

Gross turbine cycle efficiency

Net turbine cycle efficiency

Fraction of turbine cycle heat input supplied by solar

Gross cycle heat rate, kJ/kW-hr (BTU/kW-hr)

Net cycle heat rate, kJ/kW-hr (BTU/kW-hr)

Turbine exhaust pressure, mm (in)

Feedwater temperature, °C (°F)

Flowrate to turbine, kg/hr (lb/hr)

Table of auxiliary loads (provide for each mode of operation indicated above)

2. Non-solar energy fuel(s)
3. Fuel characteristics (provide fuel analysis % by weight)
4. Fuel heating value (as fired), J/kg (BTU/lb)
5. Fuel burning rate, kg/hr (lb/hr)
6. Non-solar discharge rate
 - maximum, MW_t
 - design, MW_t
 - minimum, MW_t
7. Combustor/Heater gas operating temperatures (in/out)
 - maximum, °C (°F)
 - design, °C (°F)
 - minimum, °C (°F)

8. Working fluid operating temperatures (in/out,
(also provide for reheat if applicable)
maximum, °C (°F)
design, °C (°F)
minimum, °C (°F)
9. Working fluid operating pressures (in/out)
(also provide for reheat if applicable)
maximum, °C (°F)
design, °C (°F)
minimum, °C (°F)
10. Working fluid flow rates (also provide for reheat if applicable)
maximum, kg/hr (lb/hr)
design, kg/hr (lb/hr)
minimum, kg/hr (lb/hr)
11. Non-solar heat losses (provide fuel heating value and other pertinent factors used as a basis for calculations)
- ① maximum power
 - radiation, %
 - dry gas, %
 - hydrogen and moisture in fuel, %
 - moisture in air, %
 - unburned combustible, %
 - other, %
 - ② design power
 - provide same quantities as above
 - ③ minimum power
 - provide same quantities as above
12. Non-solar startup and shutdown characteristics

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

NON-SOLAR SUBSYSTEM
STEDEC DEFINITIONS

NUMBER

PREPARED BY

APPROVED BY

PAGE 21/4

WBS NO.

DATE

NEW
REV

NO.

ITEM

DESIGN POINT

UNIT

VALUE

TEN-
TATIVE

FIRM

REFERENCES AND REMARKS

NOTE: AS FAR AS PRACTICAL THESE DEFINITIONS ARE SIMILAR TO
THOSE GIVEN IN "STEDEC - SOLAR THERMAL ELECTRIC ANNUAL ENERGY
CALCULATOR DOCUMENTATION" by J. B. Woodward & G. S. Miller
(SAND 77-8278, Jan. 1978).

3.2.1.3 NON SOLAR SUBSYSTEM

3. NON-SOLAR PROPORTIONAL EFFICIENCY, E_r

$$P_{wf}(t) = E_r(\dot{W}H - L_s) - L_v R_s$$

$$E_r = \frac{P_{wf} + L_v R_s}{\dot{W}H - L_s}$$

where: $\dot{W}$ = flow rate of fuel

H = Higher heating value of the fuel

L_v = Non-SOLAR SUBTRACTIVE LOSS PARAMETER
(See item b. of this paragraph)

L_s = STACK LOSS

P_{wf} = Power to the working fluid.

R_s = Name plate Rating of the HEATER

See
Monthly
Reports
to June
for type copy

Type
following
pgs.
on
Blank
Design
Data
Sheets

ESG-79-30, Vol III

T-36

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

NON-SOLAR SUBSYSTEM
SIEALC DEFINITIONS

NUMBER

PREPARED BY

APPROVED BY

WBS NO.

PAGE 22 / 4

DATE 8/8/79

NEW REV	NO.	ITEM	DESIGN POINT		TEN- TATIVE	FIRM	REFERENCES AND REMARKS
			UNIT	VALUE			
		3-2-1-3 - continued					
		b. NON-SOLAR SUBRACTIVE loss parameter, L_p (MW)					
		$L_p = \frac{\text{AVERAGE THERMAL POWER LOSS FROM HEATER SURFACES}}{\text{NAME PLATE RATING OF THE HEATER (R}_S\text{)}}$					
		To be given as a function of all combinations of the following					
		wind speeds, W (m/s) and temperatures, T (°C)					
		$T(°C) = -20, 0, 20, 40, \& 60$					
		$W(m/s) = 0, 3, 7, 11, 16$					
		c. NON-SOLAR SIZE, R_S (MW)					
		$R_S = \text{Name plate rating of the heater (MW)}$					
		d. NON-SOLAR heat capacity term, H_p (non-dimensional)					
		$H_p = \frac{(\text{sum of products of sodium \& heater masses and specific heats})(T_0 - T_S)}{(\text{heater name plate rating})(\text{time required for a cold start up})}$					
		$T_0 = \text{operating temperature}$					
		$T_S = \text{standby temperature}$

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

NON-SOLAR SUBSYSTEM
STEADY DEFINITIONS

NUMBER

PREPARED BY

APPROVED BY

PAGE 23/24

WBS NO.

DATE 8/8/79

NEW
REV

NO.

ITEM

DESIGN POINT

UNIT

VALUE

TEN-
TATIVE

FIRM

REFERENCES AND REMARKS

3.2.1.3 - continued

e. NON SOLAR COOLDOWN PARAMETER, α_r (h^{-1})

$$T = T_0 e^{-\alpha_r t_h}$$

$$\text{and } \alpha_r = -\frac{(\ln T/T_0)}{t_h}$$

t_h = time (h) to cool from
temperature T_0 ($^{\circ}C$)
to temperature T ($^{\circ}C$)

T_0 = Operating Temperature ($^{\circ}C$)

f. TIME REQUIRED FOR A COLD START, T_{CS} (h)

T_{CS} = time from standby to power
operation

ESG-79-30, Vol III

T-38

Rockwell International
Energy Systems Group

DESIGN DATA SHEET

TITLE

NON-SOLAR SUBSYSTEM
STEADY DEFINITIONS

NUMBER

PREPARED BY

APPROVED BY

WBS NO.

PAGE 24/28

DATE 8/8/79

NEW
REV

NO.

ITEM

DESIGN POINT

UNIT

VALUE

TEN-
TATIVE

FIRM

REFERENCES AND REMARKS

3.2.1.3 - continued

9. TIME BETWEEN THE INITIATION OF TURBINE SYNCHRONIZATION
WITH NON-SOLAR POWER & COMPLETION ($t_3 - t_2$), (h)

11. NON-SOLAR MINIMUM POWER REQUIREMENTS,
% OF NON-SOLAR POWER (%)

THIS IS THE MINIMUM FIRING RATE
EXPRESSED AS A FRACTION OF HEATER
NAME PLATE RATING.

12. AUXILIARY POWER REQUIREMENTS (MWE PER MWT
OF NON-SOLAR POWER)

THIS IS THE ELECTRIC ENERGY REQUIRED TO OPERATE
THE HEATER EQUIPMENT EXPRESSED AS A % OF
THE NAME PLATE RATING OF THE HEATER.

ESG-79-30, Vol III

T-39

STEACEC* DEFINITIONS FOR NONSOLAR SUBSYSTEM

3.2.1.3

A. NONSOLAR PROPORTIONAL EFFICIENCY, ϵ_R .

$$P_{WF(T)} = \epsilon_R (WH - L_S) - L_R R_S$$

$$\epsilon_R = \frac{P_{WF} + L_R R_S}{WH - L_S}$$

WHERE:

W = FLOW RATE OF FUEL

H = HIGH HEATING VALUE OF THE FUEL

L_R = NONSOLAR SUBTRACTIVE LOSS PARAMETER
(SEE ITEM B OF THIS PARAGRAPH)

L_S = STACK LOSS

P_{WF} = POWER TO THE WORKING FLUID

R_S = NAMEPLATE RATING OF THE HEATER

*STEAEAC - SOLAR THERMAL ELECTRIC ANNUAL ENERGY CALCULATOR
DOCUMENTATION BY J. B. WOODARD AND G. J. MILLER
(SAND 77-8278, JANUARY 1978)

Rockwell International
Energy Systems Group

STEAEK DEFINITIONS FOR NONSOLAR SUBSYSTEM

3.2.1.3 - CONTINUED

B. NONSOLAR SUBTRACTIVE LOSS PARAMETER, L_R (MW)

$$L_R = \frac{\text{AVERAGE THERMAL POWER LOSS FROM HEATER SURFACES}}{\text{NAMEPLATE RATING OF THE HEATER (R}_S\text{)}}$$

TO BE GIVEN AS A FUNCTION OF ALL COMBINATIONS OF THE FOLLOWING WIND SPEEDS, W(M/s) AND TEMPERATURE, T(°C)

T(°C) = -20, 0, 20, 40, AND 60

W(M/s) = 0, 3, 7, 11, 16

C. NONSOLAR SIZE, R_S (MW)

D. NONSOLAR HEAT CAPACITY TERM, H_R (NONDIMENSIONAL)

$$H_R = \frac{(\text{SUM OF PRODUCTS OF SODIUM AND HEATER MASSES AND SPECIFIC HEATS})}{(\text{HEATER NAMEPLATE RATING})(\text{TIME REQUIRED FOR A COLD STARTUP})} \times (T_0 - T_S)$$

T_0 = OPERATING TEMPERATURE

T_S = STANDBY TEMPERATURE

Rockwell International
Energy Systems Group

3.2.1.3 - CONTINUED

E. NONSOLAR COOLDOWN PARAMETER, $R(H^{-1})$

$$T = T_0 e^{-\alpha_R T_N}$$

$$\text{AND } \alpha_R = \frac{HR T/T_0}{T_H}$$

T_H = TIME (H) TO COOL FROM

TEMPERATURE T_0 ($^{\circ}\text{C}$)

TO TEMPERATURE T ($^{\circ}\text{C}$)

T_0 = OPERATING TEMPERATURE ($^{\circ}\text{C}$)

F. TIME REQUIRED FOR A COLD START, T_{CS} (H)

T_{CS} = TIME FROM STANDBY TO POWER OPERATION

ESG-79-30, Vol III
T-42

Rockwell International
Energy Systems Group

KLP:822

KLP:822